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EDITED BY
Isabel García-Rodeja Gayoso
Joaquín Díaz de Bustamante
Ute Harms
María Pilar Jiménez Aleixandre

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ISABEL GARCÍA-RODEJA GAYOSO
JOAQUÍN DÍAZ DE BUSTAMANTE
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MARÍA PILAR JIMÉNEZ ALEIXANDRE

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PREFACE

This volume includes a selection of the contributions presented in the III Conference of European Researchers in Didactic of Biology (ERIDOB), held in Santiago de Compostela from September 27th through October 1st, 2000. The conference was organised by the Department of Didáctica das Ciencias Experimentais of the University of Santiago.

ERIDOB intends to provide a forum for reflection and exchange among researchers in didactic of biology in the European context. It was born in Kiel, Germany, in November 1996, where the first conference took place and continued in the second conference held in Göteborg, Sweden, in 1998. The need for such a forum, providing the opportunity of building networks, common projects and, in summary, a community of scholars involved in research on biology learning and biology teaching, is a commonplace about biology educators. Clearly, although there are many concerns and research issues shared with other science education colleagues, there are particular topics and problems which deserve a place devoted to them. All sciences have experienced great changes in the last decades of the XX century, but perhaps biology research has experienced the most dramatic ones; the question of how these changes reach the school, and the public, is of great interest. The connections among science and society are surfacing, for instance in papers related to teaching biotechnology and genetics.

The contributions are grouped in four sections, devoted to learning biology, teaching biology, reasoning and environmental education, although many papers deal with several strands at a time. Learning biology includes nine contributions, three of them (Bandiera & di Macco, Bayrhuber & Schletter and Camino et al) about broad cross-topic issues, four (Baalmann & Kattmann, Hammelev, Knippels et al, and Wallin et al) about different aspects of learning genetics and / or evolution and two (Muñoz & Puigcerver and Reiss & Tunniclife) on understanding about biological systems. Some of these topics are connected with the second section, Teaching biology, which includes seven contributions, three of them about models (Boulter & Buckley, Gándara et al and Selles et al), three about teaching ecology and biodiversity in different contexts (Hammann & Bayrhuber, Helldén and

Magro et al) and one (Prechtl et al) about computer-based environments. The second section, Reasoning, is an emerging strand in educational research and includes seven contributions, three of them about students' argumentation (Díaz & Jiménez, Höβle & Bayrhuber and Simonneaux), two about classroom discourse (Pereiro & Jiménez and Sóñora et al), one about instructional strategies (Colucci et al) and one about written discourse (Tamayo & Sanmartí). The fourth section, Environmental Education, could be broader, taking into account that several contributions in the previous sections deal also with it; it includes four contributions, which report about gender differences in environmental knowledge (Bögeholz), connections among environmental and health education (Brinkman), comparison between turkish abd german teachers (Erten et al) and environmental behaviour (Lude).

All of the contributions represent research coming from seven European countries as well as from across the Atlantic (Brasil). Santiago de Compostela is proud to provide the environment for the exchange and contribute with its ancient role as a meeting point for different European cultures and thinking.

The conference was possible, first because of the scholars participating in it, but we want to thank also the scientific committee which selected the papers and suggested ways to improve them, to Adela Vázquez and Christine Francis who worked alongside the editors in the organisation, and to the sponsors, Xunta de Galicia–Secretaría Xeral de Investigación, Universidade de Santiago de Compostela–Vicerrectorado de Investigación and the Faculty of Education of the USC.

Santiago de Compostela, september 2001

I. García-Rodeja, J. Díaz, U. Harms and M. P. Jiménez

Section One: LEARNING BIOLOGY

Proceedings of the III Conference of European Researchers in Didactic of Biology. September 27th- October1st 2000. Santiago de Compostela (Spain), pp.13-25

TOWARDS A BETTER UNDERSTANDING OF GENETICS AND EVOLUTION – RESEARCH IN STUDENTS' CONCEPTIONS LEADS TO A RE-ARRANGEMENT OF TEACHING BIOLOGY

Wilfried Baalmann & Ulrich Kattmann
Carl von Ossietzky University of Oldenburg, Germany

1 Instructional problems

Is genetical knowledge a prerequisite for understanding evolution? Or does an evolutionary frame provide a better understanding of genetic phenomena? The difficulties in understanding genetics and evolution are documented by several investigations (e. g. Clough & Wood-Robinson, 1985; Stewart, 1988; Jiménez Aleixandre, 1992; Venvil, 1996; Bishop & Anderson, 1990; Lewis & Wood-Robinson, 2000; Knippels, Waarlo & Boersma 2000). Furthermore there is no evidence that genetics may help the students to learn evolution more easily. Students hardly make use of what they learned in genetic lessons when they study topics of evolution. On the other side especially Mendelian genetics lead to a more formal and thus static understanding of hereditary rules.

These observations raise the question, how the conceptions in the two domains of genetics and evolution are interconnected in the mental framework of the students. Recent studies in cognitive psychology back the approach by which students' conceptions can be treated as implicit theories. In general implicit theories are consistent and coherent, but limited in extent and thus possibly incongruous with those of other topics. Therefore implicit theories are domain specific (cf. Hirschfeld & Gelman, 1994).

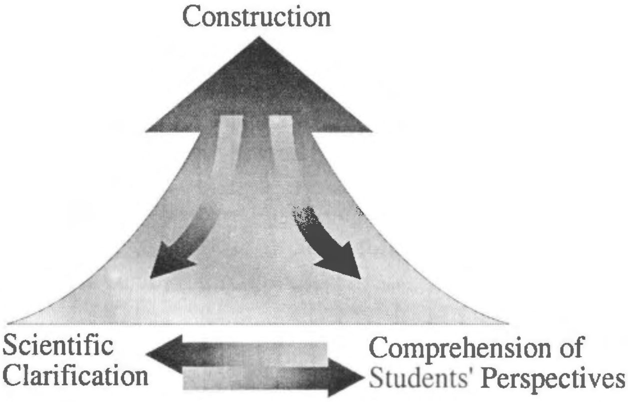
In our research concerning students' conceptions we tried to answer the questions (among others) what sort of conceptions the students develop and use in genetical contexts and how these conceptions are related to those developed in evolutionary contexts. The results should lead to a better understanding of students' difficulties and consequently to a more adequate arrangement of genetics and evolution in the course of biology instruction.

2 Research model and methods – Educational Reconstruction

2.1 Components of research

In the model of Educational Reconstruction students' conceptions are related to scientific conceptions systematically. Within this approach research in different fields of biology education is recently carried out. The intimate interplay between clarification of science subject matter structure and investigation of students' perspectives is the kernel of the model (cf. Kattmann, Duit & Gropengießer, 1998; Kattmann et al., 1997). Investigations of students' perspectives should comprise issues of possible instruction of the science content in question. Therefore a third component is explicitly integrated into the model, namely "construction of instruction". The dynamic interrelations between the issues mentioned are shown in figure 1.

Figure 1. Educational Reconstruction: Triplet of components



The **scientific clarification** contains the analysis of scientific content in order to detect the basic qualitative ideas and their relationships.
This contribution concerns itself mainly with the **empirical investigations of students' conceptions.** These are conducted to answer at least some of the following questions:

- How are the scientific concepts represented in students' perspectives?
- Which conceptions, i.e., theories, principles, notions and concepts, are used by the students?
- Which perspectives do students have about science itself?
- How do alternative conceptions of students correspond with scientific conceptions?

Students' conceptions and alternative framework in everyday life are accepted here above all as a necessary starting point to and even an aid for learning and not as an obstruction of scientific thought that should be removed.
The **construction instruction** is based on the feedback from scientific clarification and investigations of students' conceptions.

The most interesting questions in the reconstruction of science teaching are:

- Which opportunities are opened by certain elements of students' conceptions or perspectives?
- In which way do clarified scientific conceptions promote or constrain learning?
- Which conceptions of students correspond with scientific conceptions in such a way that they can be used for a more adequate and fruitful learning? (see section 5.)

2.2 Methods employed

Methodologically many previous studies in students' conceptions are unsatisfactory in some aspects: Most investigations are based on written explanation tests and multiple choice questionnaires. Using this method, students' conceptions are difficult to interpret, because a similar understanding of ideas of both the student and the investigator is assumed. Furthermore, investigators often seem to be more interested in deviations from scientific statements than in understanding the real meaning of students' conceptions.

To avoid those inadequacies, qualitative methods are available. We are looking for statements about the structure and quality of conceptions and not about quantities in which certain conceptions exist in a population. In accordance with this aim the decision was made to use problem centred interviews (cf. Mayring, 1990; Gallagher, 1991). We decided to conduct our investigations outsides the classroom and apart from influences of the school environment. Thereby we eliminated the instructional bias which can lead to statements of the students that do not represent their understanding but only reflect their expectations of what the teacher will accept as a good answer. Conducting the interviews in a non-school environment (e. g. a café) the students articulated ideas we had never heard within the classroom.

Each interview takes about 1 hour of time and is characterised by a number of features:

- The interviews are semi-structured, i. e. there is a rough guideline but not a sequence of defined questions. The use of all interventions is flexibly oriented on the actions and reactions of the interview partner;
- the interview partner is asked to answer freely and open-mindedly. No answer or reaction of the interview partner is regarded to be wrong (or right), but is supposed to be a valid articulation of her or his personal perspective;
- the interventions of the interviewer are problem-centred. The talk of the interview circles about these problems. Central topics will be touched several times during one interview.

The preparation and interpretation of the interviews follow the method of the "qualitative content analysis", which was adapted for educational research (cf. Gropengießer, 1997).
As elements of the students' conceptions we mainly identify notions and principles. Notions are elements of conceptions which describe significant topics. Principles are formulated as conceptions that cut across several notions which have components in common. As they are characterised by their explanatory character, we regard them as elements of implicit theories.
In the following presentation some edited statements are cited with the purpose of illustrating our results (the numbers in brackets give the numbers of the lines of the transcript). Please note that the original language of students' utterances is German. The translation into the English version may be a matter of interpretation. Furthermore one should be aware that the statements are particulate examples only and that the formulated notions and principles do not derive solely from the cited utterances but from of the whole interview by the process of interpretation which is described above.

3 Results

3.1 Genetic processes as a transfer of gifts and goods

3.1.1 The transfer of trait bearing particles

Within the investigations in genetics (cf. Frerichs, 1999) the investigated conceptions refer to the terms heredity, gene, character, hereditary disease, genetic load and eugenics. The interviews were conducted with 10 students (grade 8 to 12) of German Grammar Schools. The students with grade 8 to 10 hadn't got any instruction in genetics before the interviews were conducted whereas the students with grade 11 to 12 had been introduced to Mendelian genetics as well as to genetics on a molecular basis.
As to the material basis of heredity the notion of »trait bearing particles« is characteristic of most of the students:

> *»Transfer of trait bearing particles«: The characters are passed on from the parents to the offspring by little particles.*

The postulated small particles or genes have the qualities of the characters themselves. The students don't draw a clear distinction between the genotype and the phenotype.

3.1.2 The perpetuation of traits and genes

Part of the interventions in the interviews in the field of genetics was a picture of a black and a white gorilla. The reactions of the interview partners refer apparently to the transfer of trait bearing particles:

> This is my conception of the origin of the white gorilla: Genes can be passed on ahead of a generation. I can, for example, inherit my

> grandfather's eyes. I assume that the parents of the gorilla were no albinos. But perhaps his great-grandfather was an albino, and so his genes were handed down to him. So he came to his white fur.
> (Alan, 15 years, grade 9, 285 - 295)

The reason of the uncommon trait is explained through the pre-existence of the gene. In this perspective it is reasonable that a trait that appears in one generation had to have existed at least in one of the forerunning generations.
The interview partner Allan clearly expresses the conception that traits and genes are more or less immutable. Thus a constant basis of heredity is postulated:

> Heredity also occurs in animals. At a friend of mine the rabbits got young ones. Because the mother is black and the father is white, there can be at most a white rabbit with black spots. There were no real deviations. If there had been a red one among them, there would have been something wrong.
> If a child has brown hair and the parents don't, this can be the case because the grandparents or one of the grandparents has this hair colour. That is a hidden trait. If the parents have brown eyes, they have perhaps the hidden trait for blue eyes which cannot be seen. This comes from their parents.

The underlying notions can be formulated as follows:

> *»Transmission of pre-existing genes«: If an uncommon trait appears in an individual the corresponding gene was present in a former generation.*
> *»Hidden transmission«: Traits can be externally invisible in an organism and be handed on to the next generation as hidden traits. They can then become manifest in later* generations.
> *»Constant hereditary characters«: Under natural conditions genes and traits will not mutate.*

These notions demonstrate that the predominant perspective in the genetical context is the transfer merely of unchanged hereditary features. The notions formulated here are therefore referable to the following principle:

> *»Perpetuation of traits and genes«: The heredity of traits can be explained by the transfer of unchanged features (traits or genes) from one generation to the other.*

3.2 Evolution as a purposeful process

3.2.1 Adaptive acting

The study on evolution (Baalmann, 1998) focused on students' perspectives of the processes. The concepts in question were particularly "natural selection", "adaptation", "variability", "struggle for existence" and "survival of the fittest". In this study 10 students of grade 11 to 13 of several German Grammar Schools (Gymnasium) were interviewed. Statements and explanations of the students predominantly referred to the concept of "adaptation".

> When it gets colder, for instance at an ice-age, the animal's body realises somehow that it has to economise its energy and warmth, and then it happens automatically, that it produces more fur over the years. (Gisela, 18 years, grade 11, 31 - 36)

The statements of most of the students share the idea that organisms "realise" something about their situation and special needs. The students describe this process as "seeing", "insight" or "knowledge" of the organisms. This perspective can be formulated as the notion:

> *»Adaptive recognition«: Organisms realise - consciously or not - that they have to change under given conditions of living, in order to get adapted.*

This conception could be found repeatedly in most interviews. We do not consider the coincidence as insignificant or accidental, but suppose it relies on a general conception which as a mental construction is easily available by the students and therefore is looked upon as an element of the implicit theory of adaptation of these students.

3.2.2 Intentional transmutation of genes

The conception of »adaptive recognition« results almost necessarily in the difficulty for the students to explain how cognition can produce changes of the phenotype and consequently the genotype. The students do see this problem, but they cannot solve it. Yet, they suppose that for a permanent change of species these changes have to occur and must be heritable. During the interviews some of the students developed similar explanations of how the »adaptive recognition« gets into the genes.

An impressive example is the comment of interview partner Gerd on the photo of the black and the albinotic Gorilla. His reaction is quite different to those expressed by the students in the context of genetics:

> Somehow nature, or rather, the ape must have discovered about itself: black is good, and white is bad for me. And therefore I think there must be a cognition process at work; for somehow this information has to pass into the genes (somehow, somewhere it must have entered the genes, must have settled there). And by that it is a (unconscious) cognition process, which gets firmly branded and migrates into the genes. ... There are very many white apes there who find out: We all get eaten (they are an easy prey). Somehow the information enters their heads: White is no good for us. The apes look around and see: Everything around us is dark, so we must also become dark, so as not to stand out so much. An unconscious information takes place, which somehow passes into the genes, and the next generation will be black.

> I have tried all the time cleverly to scale around or to leave out how the unconscious information passes into the genes. There is a small gap, because it is difficult. (Gerd, 19 years, grade 12, 538 - 547, 553 - 564, 566 - 571)

Gerd apparently is aware of the difficulty in his conception of transmutation, but he is convinced that the mutation has to be the consequence of the insight that adaptation is necessary. His conception of the causes of evolutionary change are the direct outflow of the principle of "adaptive recognition". The process of mutation is therefore looked upon as to be analogous to cognition (and learning):

> *»Cognition-like mutation«: The recognition of the adaptation needed passes into and is fixed in the genetic material.*

The evolutionary change by intention is also predominant in the conceptions of other students, but the genetical change is not caused by recognition but by some physiological reaction of the body:

> Somehow this genetic material had to change in the peppered moth if the whole phenotype changes. That means that somehow the body makes the genetic material change, and in the next generation it is somehow different. And that goes on and on.
> If this chemical stuff is always there, the bacteria develop something that makes the genetic information change. The genetic information changes because the stuff is always there and the bacteria notice that they will die if they do not learn to defend themselves. (Gisela, 18 years, grade 11, 40 - 44, 501 - 507, 605 - 619)

This can be formulated as the notion:

> *»Experience-induced mutation«: When organisms realise the necessity of change, the body induces an adaptive change within the genetic material.*

Common to both notions is the opinion that the transmutation of organisms is caused by an intentional alteration of the genetic material. The notions are referable to the principle:

> *»Intentional transmutation«: The genetic material is altered by the organism or the body with the intent of adaptation.*

4 Synopsis of students' conceptions

The principles concerning genetical change are domain-specific: In the domain of evolution the principle of »intentional transmutation« determines the thinking to a great deal; in the domain of genetics it is the principle of »perpetuation of traits and genes«. In the field of genetics hardly any idea of genetic change is expressed. On the contrary, genes are merely understood as constant entities, while mutations are interpreted as exceptional and harmful accidents.

During the interviews in the field of evolution the students detected a link between adaptation and genetics by themselves and some of them

articulated the difficulties clearly. All of them passed through a genetics course. Nevertheless none of them had any genetically based idea how the change of the phenotype may depend on a change of the genotype. It is obvious that the concept of mutation is strongly affected by the evolutionary context instead: The genetical concepts are reinterpreted by the students to support the intentional conceptions of adaptation.
In both of the domains the alternative conceptions seem to be deep-rooted in the mental framework of the students by every day experience: The intentional acting for a goal to be reached is experienced essentially in early childhood and corresponds to the personal experience of the students, who themselves act as purposeful subjects. The transfer of goods is known from "giving and getting" gifts and goods and probably from heirlooms got from the grandparents. A characteristic of passing heirlooms through the generations is that they are thought to be the same, nearly unchangeable and so are genes and traits (in students' perspectives). Thus these every day conceptions, which are familiar to the students, serve to explain the abstract and invisible processes of evolutionary change and heredity.
The imprinting power of every day experience may be responsible for the resistance of students' preconceptions towards a conceptual change to scientific perspectives, which is reported by many recent investigations.

5 A new chance for conceptual change

To regard one's own conceptions as unsatisfactory is pointed out by Posner et al. (1982, 14) as the first condition for a conceptual change. Consequently many educators suggest a confrontation of the every day conceptions with the scientific ones. Although students' conceptions are no longer treated as misconceptions, nevertheless this approach aims at devaluation of the preconceptions by demonstrating the plausibility and fruitfulness of the scientific conceptions (cf. Driver, 1989; Hashweh, 1996). Some educators are aware of the possibility of using preconceptions not only as a starting point but as a basis of further learning, which refers to those elements which fit into the scientific framework (cf. Scott, Asoko & Driver, 1992; Duit 1994). Within the model of Educational Reconstruction this approach is strengthened by the results of scientific clarification, which in many cases reveal congruities and correspondences between scientific and students' conceptions that had not been imagined before. Sometimes students' perspective have their own right even in the light of scientific findings and theories. The range of valuable usage may be even larger in every day conceptions than in the scientific versions.
By mutual and contrasting comparison of students' notions and scientific ones we were able to describe five types of treatment for conceptual change:

- similarities and congruities as links of understanding;
- contrasting of incompatibilities;
- circumventing incompatibilities by avoiding scientifically inadequate conceptions through the instructional path before the scientific conception is learnt;
- arranging the conceptions into a more extensive range of context;
- mutual reinterpretation of scientific and students' conceptions (for details see Baalmann, Frerichs & Illner, 1998).

The identification of domain specific principles leads us to another chance for conceptual change:

- contrasting domain-specific elements of students' conceptions.

In this treatment students' conceptions are not confronted with the scientific ones but with differing conceptions of their own (see table 1).

Table 1: Corresponding conceptions

evolution	**genetics**
students' conceptions	
»adaptive recognition«	»transfer of trait bearing particles«
»cognition-like mutation«	»transmission of pre-existing genes«
»experience-induced mutations«	»constant hereditary characters«
»INTENTIONAL TRANSMUTATION«	»PERPETUATION OF GENES«
scientifically adequate conceptions	
adaptation by selection genetic diversity	transfer of genes mutation

Scientifically clarified conceptions are only the background of the area where the conflicting conceptions are brought together.
The arising cognitive conflict between the domain specific conceptions is the precondition for choosing and modifying one's own conceptions. It is supposed that it is easier to choose between conceptions one is familiar with than to develop or assimilate entirely new or strange ones. As a consequence of our findings we propose that the teaching of genetics and evolution should not be taught one after another but in an integrated manner. It is the task of biology instruction to combine the topics in order to bring the principles and notions of the two domains in touch with one another. Thereby students can be encouraged to combine and reflect their conceptions on both domains consequently and reach an adequate understanding of genetic transfer and evolutionary change. Accordingly the most promising way of bringing the domains together is to teach genetics in the context of evolution.

As one example of combining genetics and evolution the first draft of a unit on the "peppered moth" is given in table 2.

Table 2: Draft of an instructional unit

Teaching Genetics in the Context of Evolution
The Case of the Peppered Moth
Proposed sequence of lessons (grade 10)
1.1 History: When the dark moth appeared
1.2 Reasons for becoming dark
Expression of conceptions and development of hypotheses by the students
1.3 The concepts of genes and mutation
Production of melanin
Regulation of melanin production by a catalysing enzyme
The relation between genes and enzymes
1.4 The heredity of light and dark
Crossing light and dark moths: Mendelian rules
Dominant and recessive traits
1.5 Causes of becoming dark
Reflection of the conceptions articulated and comparison with the scientific explanations learnt
2.1 History: When the number of dark moths increased
Rarity of the dark form before 1900 in spite of genetical dominance
Phenomenon of industrial melanism in the peppered moth
2.2 Reasons for becoming frequent
Expression of conceptions and development of hypotheses by the students
2.3 Selection
Scientific observations and simulation game
2.4 Variation within a species
Frequencies of light and dark moths in different populations
2.5 Causes of becoming frequent
Reflection of the conceptions articulated and comparison with the scientific explanations learnt. Evaluation of the learning process

Compared with the traditional sequence, the major changes connected with this approach concern the genetic understanding of the mutation to the dark form and the combination of Mendelian genetics of the traits "light" and "dark" with the concepts of population and variability. Thus, on the one hand genetics is explicitly present in teaching the evolutionary process of "becoming dark". On the other hand the schematism of Mendelian genetics is avoided and evolution is present in the beginnings of understanding genetics, where it was completely absent before.

In co-operation with teachers this teaching unit will be developed further and evaluated in school. A draft version was taught in one class in a grammar school (cf. Baalmann & Kattmann, 2000). The results of this pilot study are encouraging. Especially the effects of the phases 1.2/2.2 and 1.5/2.5 in which the conceptions of the students are articulated and reflected, give insight into the learning processes which took place during the instruction. In phase 1.2 the notions of *»pre-existing genes«* (or traits) and *»hidden transfer«* were predominant. In phase 2.2 with only few exceptions the notion of *»adaptive recognition«* frequently articulated in previous studies was absent. Probably as an effect of the genetic knowledge learnt, the students expressed nearly with one accord that a high mutation rate was directly (but not intentionally) induced by the environmental change. Accordingly the argumentation was not teleological but causal. This may be a way to circumvent the notion «adaptive recognition». Nevertheless we feel that – for sustainable learning – the contradictory domain specific conceptions of the students need to be confronted. But to avoid it in the first place opens up the chance that the students will reflect these notions after the concept of selection is learnt. On this learning path the concept of selection can serve as a scientific anchor against teleological and intentional irritations.

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"THROUGH THE WINDPIPE AND INTESTINE DOWN INTO THE STOMACH ...": ATTITUDE AND COMPETENCE OF PROSPECTIVE PRIMARY SCHOOL TEACHERS

Milena Bandiera & Valentina di Macco
"Roma Tre" University

Abstract
This investigation regards one of the laboratory activities carried out by students enrolled in the degree programme in primary school teaching, which specifically concern the level of their scientific literacy – correlated with that of visual literacy – at the beginning of the University studies. Three tasks in the relative labsheets challenge the use (understanding and production) of graphic language: both virtual and actual comparison of drawings with real objects, virtual comparison between represented objects, autonomous elaboration of anatomical sections as they can be derived from three dimensional models and perspective images in the textbooks. The future teachers show that they have at their disposal very few pieces of scientific knowledge, display scarce training in reasoning about them; and, as far as the use of iconographic language is concerned, they neither require nor perceive the correspondence between a drawn image and the real object it represents.

1 Institutional and academical context

In 1998 Italian Universities, for the first time, dealt with primary school initial teacher training. Up until then these teachers went directly from a specific secondary school preparatory Institute (Istituto Magistrale) to professional engagement.

Now a four-year degree is required first. Therefore, in the academic years 1998/99 and 1999/2000, in the classrooms of "Roma Tre" University nearly 400 students coming from the Istituto Magistrale as well as those coming from the psycho-pedagogical stream of the lyceum met, having in common their total, generalised inexperience in science. Moreover, their choice of University studies was, more than anything, child-oriented and specifically science-independent, if not exclusive.

Primary school teachers who, in any case, will assume a field preference in their professional activity, may however find themselves in the position of teaching all subjects. For this reason, a course limited to only 60 classrooms hours and 20 in the laboratory has been designed in the service of science literacy. In this time the students are expected to acquire an adequate working knowledge in Biology, Chemistry, Geology and Physics. It is absurd to imagine, however, in such a short period, even time enough to introduce each one of those subjects.

This being the situation and having been entrusted with the planning of scientific education, we judged not only opportune but necessary the design of adequate methods and strategies for study, for thorough knowledge acquisition (guided by the teacher and autonomous), for labwork (as a way of cognitive interaction with natural objects and events)[1], and the adoption of ad hoc teaching methodologies with two main aims: to help students assume (or, at least, experience) an experimental attitude and to explore their actual level of competence in the fields of study and the most diffuse mechanisms for knowledge organisation and learning.

We referred to a basic constructivistic theoretical frame while we were choosing some necessary features of the teaching and research project, and to the awareness that the teaching of science (style and subjects) in primary school influences children's interest and, presumably, achievement in science (Craig & Ayres, 1988). The devised activities testify to the conviction that basic knowledge in science has something to do with the understanding of evidence (Gott & Duggan, 1996) and, preliminarily, with the focusing, the recognition, the singling out, of elementary and every-day natural objects and events. Consistently preferred were those content-transcendent goals which have, for some time, been the object of consideration in the fields bordering on science and cognitive psychology: reflective thought (Dewey, 1933), identification of tactics and strategies of science (Conant, 1947), capabilities, meaning *how to observe, how to figure, how to measure, how to orient things in space, how to describe, how to classify objects and events, how to infer, and how to make conceptual models* (Gagné, 1963), open-mindedness (Moore, 1982), learning *about* scientific knowledge (Duschl, 1990), the creation of *epistemic distance* between prospective students and science (Norris, 1997).

In practise, amusing problems and quizzes were introduced into the lessons in order to stimulate discussion between teacher and (some) students, and after the lessons home readings assigned accompanied by a printed guide. A problematic approach to labwork was adopted with the help of labsheets in order to encourage peer interaction and minimise intervention on the part of the teacher.

Given that educational prevailed over informative objectives, assessment was carried out mainly by focusing on the words the students used and the way they reasoned

a) when they were engaged in paraphrasing scientific texts,
b) when they talked about natural phenomena,

c) when they described and explained materials, methods and results concerning labwork.

This approach, in principle, would allow exploration both of the efficacy of the training and of the students' competence. The present analysis is limited to one of the fifteen "labworks", which concerns the reading and production of figures.

2 Scientific knowledge from and into figures

Whoever studies Biology should wonder, along with Alice "... what is the use of a book without pictures ...?" (Carrol, 1865) The endowment of Biology textbooks with figures not only influences their attractiveness, but enhances learning (Reid, 1990 a and 1990b), given that the students have so-called "visual literacy" (Goldsmith, 1984 and Kress & van Leeuwen, 1990) or "graphical literacy" (Fry, 1981). From an educational point of view an appropriate fruition of the, also necessary, figures requires the fulfilling of some basic conditions: in the textbook, the adoption of an adequate iconographic language to communicate relevant and meaningful information (Kearsey & Turner, 1999) and the presence of systematic and convenient links between pictures and written text (Harrison, 1980, Wright, 1981); the teachers, on the other hand, must concern themselves with students' gradual and careful training in interpreting (Bluth, 1981).

Reading and interpretation of the representations in Biology figures encounter inherent problems such as the three-dimensional structure of the objects depicted, the selection of details with reference to a particular context, the uniqueness (emblematicness or representativeness) of the depicted shapes (Constable, Campbell and Brown, 1988). But they also come up against more general learning obstacles, considering that part of assumed information comes through the senses from the object before us (null or poor information if we are disinterested or unmotivated), another part (and perhaps the larger part) always comes out of the mind (rational thinking, imagination or prejudice). This is the reason why the neglect in science classrooms of visual-spatial thinking has been considered as a major obstacle to scientific creativity and communication. (Mathewson, 1998)

According to J.H. Mathewson (1998) visual-spatial thinking includes vision – using the eyes to identify, locate, and think about objects and ourselves in the world, and imagery – the formation, inspection, transformation, and maintenance of image in the "mind's eye" in the absence of a visual stimulus. This definition has been the inspiration for one of the laboratory activities proposed to the prospective teachers, which at the same time tests and exercises their capacity to glean information from the representation of an object in section and to

communicate their knowledge by means of the representation of an object in section.
The choice of presenting precisely this activity takes into account the important role with respect to learning which, in primary school where these students are destined to teach one day, is played by the figures.

3 Research design and methodology

The labwork

Students were asked to engage collaboratively: from four to seven students were seated around a table were they found some pieces of fruit (apples, aubergines, bananas, cucumbers, kiwis, lemons, oranges, pears, peppers, tomatoes, zucchini) knives and dishes. Each student received three sheets: an instruction sheet (see appendix), a sheet for making drawings and inserting the information required (to be completed individually and handed in at the end of the task), and a sheet with two figures: a sagittal section of the human head and a typical anatomical model of the human trunk. During two and a half hours of work the students were encouraged to discuss the task amongst themselves while the teachers restricted themselves to supplying procedural information only, as well as on the labsheet text. Having completed the activity, the students had to hand in the sheet with the drawings and answers and to keep the sheets with instructions and figures in order to be able to repeat the task, while filling in eventual methodological and content-related gaps.

The survey

The objectives of this specific investigation, which dictated the labwork set-up and the investigation itself, were the definition of the level of mastery of the iconographic language of prospective primary school teachers, the identification of their problems with regard to reading and production by means of such a language, and the assessment of their content specific knowledge (elements of vegetable and human anatomy) as students enrolled in a degree programme in primary school teaching (Corso di laurea in Scienze della formazione primaria). To this end, an analysis was made of the three sections on the labsheets handed in by one hundred students: the fruit section (comprehension of the task, production using iconographic language, content-knowledge), the head section (reading of iconographic language, content knowledge), the trunk section (production using iconographic language, content knowledge). Students – different from the completers of labsheets – were interviewed with the aim of validating interpretation of ambiguities in drawings and answers, and providing further insights into their visual literacy.

4 Results

Sections of fruits

The collected data are presented in table 1. Ninety-six out of one hundred students who dealt with the task chose fruit varieties that they were used to handling, while they ignored "vegetable" fruits (except for a few who chose tomatoes).

They substantially drew verisimilar shapes: oranges and lemons (and tomatoes) are recognisable, pomes and bananas are nearly recognisable; representations of kiwis seems to be more problematic. One drawing out of three does not respect the correspondence between cross-wise and length-wise sections. Details identified by the drawers themselves as being present both in the fruit and in the drawing are more numerous than details verified as absent in drawings. More than one hundred details have to be considered as irrelevant (e.g. "the number of seeds actually seen in *our* fruit", "the shape", "the identification of both peel and pulp") and some definitions as incomprehensible (e.g. "typology and arrangement of *veins*", "seeds around the *nucleus*", "the *inner* stem").

Table 1. Analysis of one hundred labsheets (two hundred sections of fruits), taking into account meaningful features from the point of view of graphic, observational and botanical competence. Absolute frequencies are presented. (**o**: orange, **l**: lemon, **a**: apple, **p**: pear, **b**: banana, **k**: kiwi, **t**: tomato)

fruits	esperidia			pomes						tot
	o	**l**		**a**	**p**		**b**	**k**	**t**	
labsheets	6	27	33	24	8	32	9	22	4	100
correct sections	12	54	66	46	16	62	16	41	8	193
coherence between the two sections	6	26	32	17	4	21	0	11	3	67
correct shape	6	27	33	21	4	25	4	8	4	74
"corresponding" details identified	37	109	145	100	30	130	43	80	19	417
"missing" details identified	23	81	104	70	36	106	39	65	18	332
irrelevant details	10	21	31	18	21	39	26	9	0	105
incomprehensible details	1	1	2	1	0	1	3	0	7	10
botanical words	6	19	25	29	8	37	0	19	7	88
relevant details in sections: stem	3	25	28	18	4	22	7	9	4	70
corolla				19	4	23	4	5	4	
seeds	2	14	16	24	8	32		20	4	
exact symmetry				5	0	5	0		4	

From the disciplinary point of view, language seems to be nearer to the familiar than to the scientific: e.g. "apple core" (it. *torsolo*), "halo around the seeds", "difference between zones in the fruit". The 88 so-called botanical words include "seeds" (no. 56) and "stem" (it. *picciolo*, no. 20) and totally exclude, even if commonly used in school language, words like "organ", "tissue", "flower" or "ovary". Other, less familiar, words and expressions (e.g. "vascular bundles", "mesocarp" or "pollen tube") which are undoubtedly taught at school, are absent, and obviously their appearance was not expected. Structural symmetry (5-based in pomes and 3-based in bananas) is usually ignored.

Sagittal section of human head

Ten details were pointed out in section presented. While on the whole more than forty per cent of the students failed to make correct identifications (table 2), three levels can be distinguished in terms of the quality and entity of identification: high (cerebellum, spinal cord), middle (vertebral body, spinous process, tongue, mandibular bone, tooth) and low (great commissure, cervical muscle, epiglottis) which respectively correspond to nearly total, half and rare identification.

Table 2. Analysis of one hundred labsheets (sagittal section of human head), taking into account the quality of the identification of the elements pointed out. Absolute frequencies are presented.

	exactness	genericness	wrongness	none
great commissure	0	7	70	23
cerebellum	100	0	0	0
cervical muscle	2	31	44	23
vertebral body	43	29	21	7
spinal cord	67	3	24	6
spinous process	49	41	2	8
palatine bone, epiglottis	0	57	27	16
tongue	44	1	34	21
mandibular bone	56	0	30	14
teeth	58	0	29	13
total (%)	*41,9*	*16,9*	*28,1*	*13,1*

Students interviewed attributed the recognition of cerebellum to its frequent mentioning in every- day life ("We know that the cerebellum is there because one has to be careful to avoid banging the head from behind."); the difficulty concerned with tongue recognition correlates to its "unimaginable shape when mouth is shut" and that of mandibular bone to its "well known horseshoe-shape". The great commissure is "one of the *minor* components of brain", so identifications range from "brain" to "thalamus", "hypothalamus" or "hypophysis". The vertebral column is indicated as windpipe due to the perception of "the alternation of dark and clear rings" which would correspond to the main and specific feature of the windpipe, and the mandible as salivary gland, due to its position under the teeth.

Cross-section of human trunk

Ninety-four students choose to draw the section at the level of the heart (level A). As far as heart, lungs, vertebral column and rib cage are concerned, their absence in nearly one tenth of the drawings (table 3) has to be underlined. Not less surprising is the absence of the skin and subcutaneous layer, the oesophagus and breast-bone in one half of drawings, and that, almost systematic, of the skeletal musculature. Too frequent to be ignored is the presence (at level A) of the windpipe, the coplanar, ring-shaped ribs and the position, totally inside or outside the rib cage, of the vertebral column.

Table 3. Analysis of ninety-four labsheets (cross section of human trunk at the level of the heart), taking into account meaningful features from the point of view of graphic and anatomic competence. Absolute frequencies are presented.

labsheets		100
section level	A (*concerned in analysis below*)	94
	B (below the diaphragm)	1
	C (below the pelvis)	5
represented objects	heart	93
	lungs	94
	vertebral column	81
	rib cage	90
	breast-bone	46
	skin and subcutaneous layer	64
	oesophagus	48
	skeletal musculature	11
ambiguities, errors	windpipe (presence)	18
	coplanar and continuous ribs	13
	column inside or outside the cage	12
	microscopic elements (represented)	42
graphic plan	convenient utilisation of space	61
	reasonable arrangement of elements	5
	presence of empty spaces	37
	"island" arrangement	18
	"archipelago" arrangement	33

Moreover, as far as the use of iconographic language is concerned, one out of three students tended to draw a very small section which occupied less than one fourth of the available space.
Inside the sections tissues and organs – in various ways connected to each other – float in empty space or face each other across empty distances. This aspect was easily accepted by many of the interviewed students, due to the common belief that broad spaces between organs are needed in order to contain liquids (e.g. pleural fluid) and air. Only five sections present an acceptable contiguity among the anatomical elements considered.
One student out of two thought microscopic details (capillaries, bronchioles or pulmonary alveolus) could be represented in a section reduced to these dimensions.

5 Discussion

This study regards the work done by one hundred students (prospective primary school teachers), specifically concerning the degree of their scientific literacy, which is meant to correlate with that of graphic, visual literacy.
Taking into account the specificity of the task, the easy, unhesitating willingness of the students to draw must be foregrounded.

Scientific literacy

As far as knowledge is concerned, the analysis of students' drawings and explanations about fruits and human anatomy confirms a well-documented, serious limitation (Ginns & Watters, 1995; McNamara, 1991; Yates & Goodrom, 1990). They seem not to be able either to distinguish and name structures and components in fruits which are significant from a botanical point of view, or to focus on relevant features even if they have the fruit before their very eyes. They use almost exclusively a common, non scientific, language and show clearly that they actually refer and, if possible, make an effort to refer to their direct, every-day life experience of fruit. No memories emerge of their school experience consisting of "learning about" the subject: no information, no figures, no schemes, which are systematically present in secondary school textbooks.
The recognition of elements and organs in a human head sagittal section, which is obviously less affected by every-day life experience, puts in evidence the storage in the students mind of rote learned objects and relative essential features, which they seem to be trying to introduce into the representation.
A single object can be considered well-known since students looked for and correctly found it: the cerebellum. A few relevant elements appear

quite familiar since they were identified in the correct place with a correct, scientific word (e.g., the spinal cord). Many words corresponding to objects with approximate features and locations (e.g., the hypophysis) account for the scarce appeal of the correct, rich (maybe redundant) information in textbooks which all present figures similar to that in the labsheet: sagittal sections both of the brain (photograph or drawing) and of the head (NMR image).

Three main data can be drawn from the human trunk sections. Firstly, lungs and heart (large, complete organs, tidily arranged and well visible in the figure of the anatomical model) are quite always present in the drawings, as well as the vertebral column and the rib cage (which are not visible in the model): four pillars of the basic, shared knowledge of human anatomy. Secondly, though in textbooks the subject is usually treated as a sum of separate systems or apparatuses, these are not checked in order to reconstruct the arrangement of elements in the trunk: one out of three students leaves out the integumentary system, one out of two students leaves out the digestive apparatus, eight out of nine students leave out the muscular-skeletal system. Students seem not to have recalled images from textbooks nor to have thought of getting some suggestions by touching and exploring their own bodies.

Finally, once again, information collected in students minds seems to have been forced into the drawings (e.g., the microscopic elements).

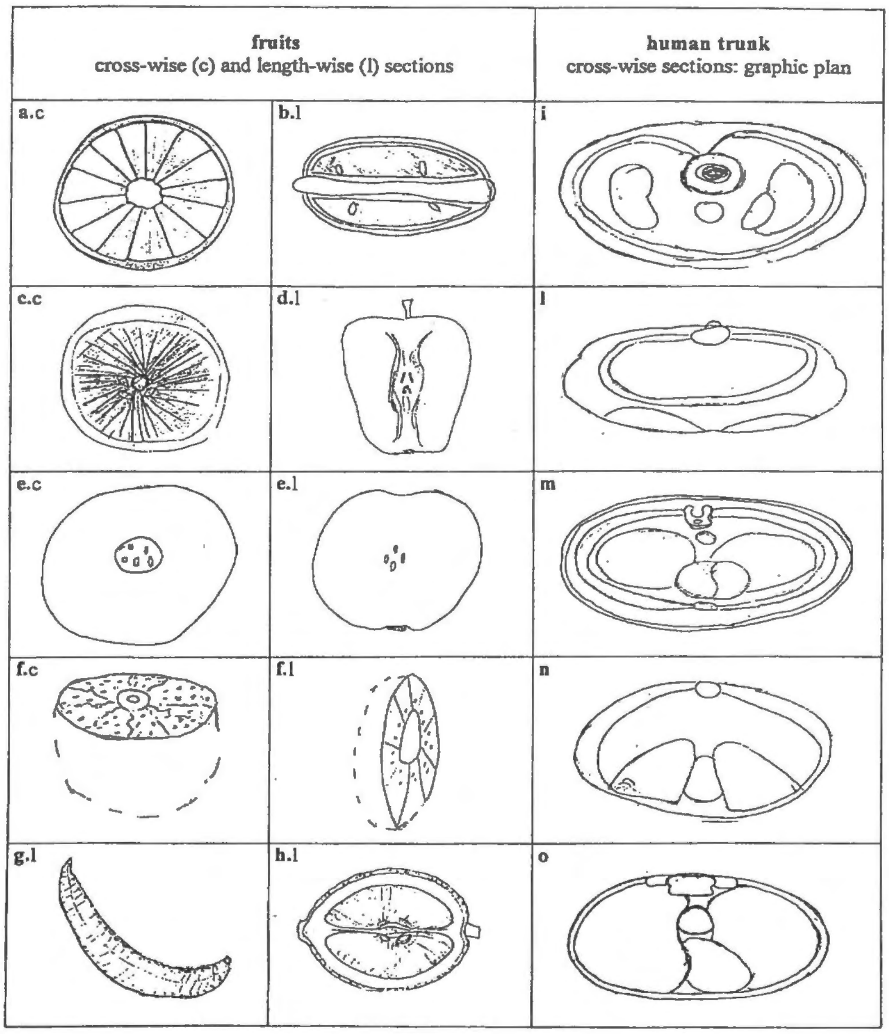
In summary, these future teachers show that they have at their disposal very few pieces of knowledge, display scarce training in reasoning about them and, to all appearances, that they are living in two separate worlds: a real one where objects and events cannot be regarded as "scientific", and a second one which is created at school, where "real" experience is banished by definition.

Visual literacy

The three tasks in the labsheets share some general aspects concerning the use (understanding and production) of graphic language; they differ in that the first one mainly asks for both a virtual and an actual comparison of drawings with real objects, the second one asks for a virtual comparison with represented objects (in secondary school science textbooks), the third one asks for an autonomous elaboration of related represented objects (the in perspective-image of anatomical model and many in-perspective images of single apparata in the textbooks).

As far as general aspects are concerned, frequency and weight of technical remarks support the hypothesis of an uncultivated competence: naive organisation of known components of well known fruits (fig. 1: a, b, c, d, e.c), incoherence of the orthogonal representation of the same detail/object (fig. 1: e and f), inadequate dimensional ratio among organs in the same trunk section (fig. 1: i), inadequate relation, on the whole, between the cross-section of the trunk and its representation in perspective, the anatomical model (fig. 1: i, l).

Figure 1. Some emblematic examples of students' drawings.



The ability to correlate details of the object with signs in its representation is illustrated mainly by means of fruit sections that highlight less or more unforeseeable forms of blindness both in the

oddness of drawings (fig.1: b, g) and in the poor (difficult) recognition of relevant missing details (such as thickness of esperidia mesocarp, chambers and endocarp of pome seeds, banana symmetry) when comparing the drawn drawing and the corresponding cut fruit.
The ability to "read" information about objects in figures is mainly documented by the worrying results of the second task, which indicate that students, when studying, do not take advantage of the textbook iconographic offerings and when engaged in interpretation of figures, do not point out meaningful and leading signs (colour intensity, shading, forms "altered" due to the section). Instead, they seem to invest the figure with their "verbal" knowledge.
The main characteristic of the human trunk sections is the singular way of arranging the drawn elements which in general appear separated by empty spaces (fig. 1: m), clustered, in the form of an "island" (fig. 1: n), or scattered in the form of an "archipelago" (fig. 1: i). This characteristic legitimates the hypothesis that correspondence between drawn image and real object is neither required nor perceived.

How do we train them?
In recent years it has gradually become clear the notion that primary school teachers tend to feel least qualified when teaching science (Berenson, et al, 1991) and to relate science teaching (in)efficacy to its inherent anxiety (Czerniak & Schriver, 1994).
It is time to take their problems (and the dedicated research) into consideration in the light of two conflicting facts: they cannot teach what they do not master and the knowledge they should master is excessively broad. Moreover, in the field of experimental science, note must be taken of some reassuring evidence: in western countries qualified science teachers maintain their worldview opened to magic, mysteric, religious and, in any case, pseudoscientific or irrational referents (Bandiera, et al, 1999). As a consequence the weight of both encyclopaedic scientific knowledge and compulsory scientific thought is less.
Therefore, primary school teacher initial training should essentially build awareness (e.g., which subjects one knows and which one does not know; how one's own belief mediates explanations, actions and learning; when a scientific thought or procedure is adopted, has to be adopted, can – in all the meanings of the word – be adopted) and attitude (e.g., learning from experience and experiencing what has been learnt; founding explanation on observation and on a previous description; looking for and comparing different points of view of an object or event, and different rational approaches).
To this end, primary and secondary schools should contribute by means of a careful selection of basic, generative topics in science curricula, and

above all by means of an effective enforcement of all the communicative tools. As far as biology is concerned visual-spatial tools appear to be crucial.
Each student carried out five of fifteen experimental activities that concerned educational actions aimed at the following punctual objectives: self-assessment on the understanding of a Science textbook (subject: photosynthesis), production and interpretation of sections (subject: vegetable and human anatomy), diagnostic utilisation of chemical reactions (subject: bone composition), critical analysis of popular cartoons illustrating scientific topics (subject: fertilisation, intra-uterine growth and birth), application of scientific knowledge and "laws" and detection of regularities in considered objects/events (subject: heredity, pedigree and Mendel's laws), work on a model (subject: variability, natural selection and evolution), experimental data interpretation (subject: muscular activity, regulation of pulse and breathing rate).

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Appendix

Instructions

1. You have at your disposal several varieties of fruit: apples, aubergines, bananas, cucumbers, kiwis, lemons, oranges, pears, peppers, tomatoes, zucchini. Choose one and imagine cutting through it cross-wise. Observe in your imagination the surface of the cut, and draw it, including the maximum number of details possible.
2. *Cut the fruit you have chosen and compare your drawing with the actual surface of the cut. Identify and note two details that you have accurately represented and two details that are missing in your drawing or that do not correspond in number, shape, or position.*
3. Now imagine cutting another of the same variety of fruit length-wise. Observe in your imagination the surface of the cut and draw it, including the maximum number of details possible.
4. Cut the fruit you have chosen and compare your drawing with the actual surface of the cut. Identify and note two details that you have accurately represented and two details that are missing in your drawing or that do not correspond in number, shape, or position.
5. Carefully observe the sagittal section of the human head represented in the figure. Write on the attached sheet, alongside the corresponding number, the names of the elements or organs you think you have recognised.
6. Carefully observe the anatomical model represented in the figure. Imagine that you have it at your disposal and that you have cut a cross-section at one of the levels indicated. Make a schematic drawing of what you expect to see in the section, noting the names of the organs you have drawn.
7. With the here-completed experience in mind, indicate what you believe to be the major difficulties one encounters when the aim is to correlate the features of a section with the features of the whole (three dimensional) object.

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LEARNING AND MEMORY - PROBLEMS OF INTEGRATING STUDENTS' CONCEPTIONS AND SCIENTIFIC KNOWLEDGE

Horst Bayrhuber & Jens C. Schletter
Institute for Science Education at the University of Kiel

1 Introduction

In German secondary schools the topic of "sensory organs and the nervous system" is taught in grade 10 and in grade 13. At both levels, neuroanatomy and neurophysiology are taught without reference to students' everyday conceptions or real life problems. The study presented here is part of a program which sets out to explore how neurobiology can be taught in contexts which relate to students' everyday lives and thus facilitate the processes by which the concepts become meaningful for the students. We chose the topic of "learning and memory" because this is a "real life" problem for the students, and it is one of the fields in which neurobiological knowledge has increased rapidly during the last years.

2 Theoretical Background

In contrast to other biology topics such as photosynthesis or genetics, there are only few references in literature to students' concepts of learning and memory and the neurobiological processes involved. In the bibliography compiled by Pfundt and Duit (1994), listing works on students' conceptions of biology topics, there is only one which deals with conceptions about the brain (Johnson & Wellmann 1982). Further information about students' conceptions of learning can be found in studies of learning processes and student achievement (e.g. Aguirre & Haggerty, 1993; Berry & Sahlberg, 1996; Stipek & Gralinski, 1996). These, however, give just as little insight into the neurobiological or psychological foundations of students' conceptions of learning and of how the brain processes information. In studies concerning self-directed learning, students were also questioned about their concepts of learning (e.g. Baird & Northfield, 1992; Haller, Child & Walberg, 1988; McCombs & Marzano, 1990; Simons, 1992; White, 1993).
As an initial attempt to remedy this inadequate supply of reference literature we asked 20 students in grade 13 about their concepts of learning and memory in open interviews (Schletter & Bayrhuber, 1998). The students interviewed used neurobiological and psychological terms (e.g. nerve cells or short term memory), but attached meanings to them that strongly deviated from their scientific meanings. Furthermore, the analysis of the interviews showed that the students' conceptions could be divided into two categories (Bayrhuber & Schletter, 1997):

- Conceptions derived from external sources were acquired in school, e.g. in grade 10, from books and/or from television. This knowledge, e.g. about the structure of the brain or of nerve cells is generally only slightly developed.
- Conceptions derived from internal sources come either from individual learning and memory processes, e.g. the preparation of term papers, or from experiences that can serve as models for learning and memory processes, such as use of libraries or work with computers. These are based on students' own reflections about individual experiences. Learning is, for example, understood as new information in class and memory described like a chest of drawers.

The interviews showed that the students interviewed make next to no connection between these two areas of conceptions. This suggests that the lessons had not promoted the integration of conceptions and scientific concepts and thus had not fulfilled an important condition for meaningful learning (Ausubel, 1968; Glynn & Duit, 1995). The fragments of knowledge which the students gained were neither scientifically sound, nor did they relate to everyday life (cf. Reif & Larkin, 1991). Mandl et al., (1993) found evidence of such fragmentation in connection with knowledge about physics, a phenomenon they term compartmentalization of knowledge.

The goal of the study described here, therefore, was to ascertain whether a restructuring of neurobiological teaching contents would enable a higher degree of integration to be attained between neurobiological knowledge on the one hand and the students' conceptions and experiences on the other.

3 Design

The study used an experimental control group design. For this purpose, two different teaching units of the same length were developed for the topic "learning and memory".

Half of each group was interviewed individually about their conceptions of learning and memory before the unit began. In addition, before beginning the unit, all students completed a questionnaire about their interest in the topic. At the end of each period or double period the students filled out a questionnaire about how interesting the lesson had been. These tests were intended to show if the lessons for both the experimental group and the control group were of comparable interest to the students. At the end of the unit all students took an unannounced written test about the scientific content of the unit. In addition to this, all students who had been interviewed before the intervention began were interviewed again, and also questioned about their grades over the past two semesters.

Table 1. Design of the main study

Experimental group (n=23)	Control group (n=22)
Pre-test Interviews with half of the students in the course Questionnaire about interest in the topic learning and memory (completed by all students in the course)	
Teaching the unit developed for the experimental group Questionnaire about how interesting the lesson was after each period	**Teaching the unit developed for the control group** Questionnaire about how interesting the lesson was after each period
Post-test Unannounced written test of knowledge completed by all students in the course Interviews with those students already interviewed during the pre-test	

Two questions were the focal point of the study. The first addressed the extent the preconceptions of the students interviewed in the experimental group and in the control group had moved towards scientific concepts. It was expected that the conceptions of those interviewed in both groups would shift towards the concepts taught in the lessons. We also anticipated that the conceptions of the experimental group would change more than those of the control group, since the typical pre-instructional conceptions were explicitly made the topic of the lessons in the experimental group. The second question was to what extent the students interviewed in both groups connected the knowledge based on reflection of personal experiences with what had been taught. As the students in the experimental group were expressly taught according to students' typical experiences and conceptions, it would presumably be easier for them to make the corresponding connections than for those in the control group.

4 Methods

The development of teaching materials

The lessons for both groups were planned so that the students in the control group also had a chance to change their pre-instructional conceptions in line with scientific concepts, to make connections between conceptions based on external and on internal sources, thus overcoming compartmentalization. This was made possible by using units of equal length, covering the same topics (s. Table 2). As mentioned above, the students' typical conceptions of learning and memory were expressly covered in the experimental group and their compatibility with the corresponding scientific concepts explored. This was not done in the control group.

Table 2. Lesson topics and their teaching sequence in the experimental group and in the control group

Lesson	Experimental group	Control group
1	The problem 'learning and memory'	Structure of the nerve cell I
2	Characteristics of short term memory	Structure of the nerve cell II
3	The interaction between short term and long term memory	Stimulation channels in the nerve cells
4	The division between procedural and declarative memory	Synapse procedures
5	Structure of the brain I	Cellular foundations of learning and memory I
6	Structure of the brain II	Cellular foundations of learning and memory II
7	PET (positron emission tomography)	Structure of the brain I
8	Cellular foundations of learning and memory I	Structure of the brain II
9	Structure of the nerve cell I	PET (positron emission tomography)
10	Structure of the nerve cell II	The division between procedural and declarative memory
11	Stimulation channels in the nerve cells	Memory models
12	Synapse procedures	Characteristics of short term memory
13	Cellular foundations of learning and memory II	The interaction between short term and long term memory
14	The problem of forgetting I	The problem of forgetting I
15	The problem of forgetting II	The problem of forgetting II
16	The working memory	The working memory

The following consequences for the lessons in the experimental group were the result of the explicit consideration of students' typical conceptions:

- In order to build a bridge between students' preconceptions based mainly on everyday experiences on the one hand and the neurobiological concepts on the other, the latter were also considered from a psychological point of view.

- The consideration of typical student conceptions played a role in determining the sequencing of the different teaching contents in the experimental group. The units began with contents which were close to students' pre-conceptions, to make the topic more accessible.
- In the different lessons the students of the experimental group were asked to express their own conceptions and to compare them with those of the other students. The purpose of this was to make especially those pre-instructional conceptions transparent which were based on students' own reflections about individual experiences.

The development of materials for the control group followed a scientific subject matter structure found in numerous textbooks. Neurobiological and psychological contents were also taught in the control group but psychological aspects were not integrated into neurobiological lessons. Nevertheless the lessons in the control group were just as interesting as those in the experimental group. The students' everyday world played just as important a role in the control group. It was, however, important that no explicit connections were made to typical student conceptions.
The following overview sets out the various content sequences in the experimental group and in the control group:
During the material development stage, individual parts were tested in grade 13, before the intervention study. After testing some of the parts were revised, but no major changes were necessary. Some of the materials developed for the experimental group have already been published (Schletter, 1998) and a larger publication is in preparation.

The questionnaires
As already mentioned we used different questionnaires. One about student's interest in the topic learning and memory, another about how interesting the lessons were and further one to test the knowledge after intervention. Examples of items are shown in the next slide.

The pre- and post-test interviews
For the pre- and post-test interviews we used the technique suggested by White & Gunstone, (1992), called interview about concepts, was used. According to White & Gunstone, knowledge about a concept is a function of the amount of various types of knowledge a person connects with it. Thus a concept comprises mental images and intellectual and motor skills as well as propositional knowledge (in the sense of declarative factual knowledge) and autobiographical experiences (in the sense of episodic knowledge). The interviews took account of these different dimensions of the cognitive structure.

To facilitate comparison between the results of the student interviews, an interview guideline was developed for both the pre- and the post-test interviews (cf. Bortz & Döring, 1995).
With respect to content, the guidelines for the pre-test interviews covered various aspects of the topic learning and memory. The questions covered neurobiology and psychology, as well as the context of in-school learning.
The post-test interviews were in two parts. Part one included some questions from the pre-test interviews to ascertain the extent to which the students' conceptions had changed in the course of the lessons. In part two the students were presented with various tasks which required them to apply the knowledge acquired in class and to connect this knowledge with previous experiences. These tasks had to do with scientific problems on the one hand and with problems from the students' everyday lives on the other.

5 Analysis

Analysis of the questionnaires
The quantitative instruments were used to determine possible systematic differences between the experimental and the control groups as well as between those interviewed and those not. We dispensed with a differentiated statistical analysis as this was not the main point of the study. We did, however, wish to make sure that the various groups could be compared with respect to the interview results. All of the questionnaires used in the study (initial interest in the topic learning and memory, level of interest in the individual lessons, level of knowledge at the end of the unit), together with the requested grades in German, mathematics and biology for the past two semesters, were analyzed with the help of quantitative methods (comparison of averages, t-test).

Analyzing the interviews
In order to compress the mass of interview material for interpretation, the transcripts were analyzed using a reductive qualitative content analysis procedure (Lamnek, 1993; Mayring, 1995). The corresponding category system had already been developed for and tested on previous work. For reasons of simplicity in the following slide only the main topics and their first-order categories are included; for analysis purposes these were further differentiated. Using this category system, the students' statements were coded according to various basic neurobiological and psychological concepts (learning, memory, brain). Further, the statements were interpreted with regard to the interviewees' structure of knowledge, with reference to dimensions of the cognitive structure

(White & Gunstone, 1992) and to the compartmentalization of knowledge hypothesis (Mandl et al., 1993).
All of the interviews were transcribed completely word for word and the data subsequently analyzed in two steps. The first step was summarize, paraphrase and code the statements in every interview in line with the knowledge structure categories. Then the doubles and paraphrases with the same meaning were eliminated. Using the transcripts it was then checked whether the paraphrases mirrored the meaning of the original statements. The paraphrased statements were coded for the second time according to the content categories. Within the framework of this categorization, the original category system was checked for completeness. There was, however, no need for modification. The categorization of the paraphrases from the individual interviews was then used to compile an overview of all interviews, which indicated the frequency of certain conceptions expressed by the students and gave an impression of the multiplicity of the conceptions mentioned.

Table 3. Categories for analysis of the interviews

Type of category	Main category	First order category
content categories	Learning	conceptions of learning
		learning strategies
	Memory	conceptions of memory
		processing, retaining and recalling information
		forgetting
	Brain	macroscopic anatomy of the brain
		microscopic structure of the brain
structure of knowledge categories	cognitive structure categories	propositions
		mental images
		episodes
		intellectual and motor abilities and skills
	compartmentalization of knowledge categories	origin of conceptions
		connections between conceptions

Within the analysis framework, a section of some of the transcripts was assigned to the categories mentioned by a second, external person to see whether the criteria of interrater reliability was fulfilled (cf. Flick 1995). The comparison of the categorizing between the two interraters showed almost complete agreement, only in a few cases was there disagreement.

6 Results

Scholastic achievement and interest in the experimental group and the control group

The comparison of **scholastic achievement** in German, mathematics and biology showed that both groups could be rated almost equal. There was a slight tendency towards advantage for the control group, but this was not significant.

The questionnaire about **pre-instructional interest** showed only minor differences between the two groups. The group comparison in the form of t-tests showed that the beginning interest is slightly higher in the control group than in the experimental group.

In view of these results, it was assumed that the interviewed students in both groups were comparable with regard both to their scholastic achievements and to their pre-instructional interest, so that differences in the post-test interviews could be attributed to the effectiveness of the treatment.

The questionnaires about **students' interest in a lesson** administered after the individual periods indicate that the lessons are generally regarded positively.

A continuous increase or decrease in the level of interest indicated for the lessons during the period of intervention could not ascertained either in the experimental group or in the control group. It was, however, shown that students in the experimental group in particular found the lessons with a direct reference to their lives especially interesting. Interest in the more neurobiological lessons was more limited. In the control group these differences were not as marked. The comparison of the periods covering the same topic between the experimental group and the control group indicated that the students in the control group tended to rate these periods higher or sometimes significantly higher. In any case the difference in the level of interest in lessons cannot explain the possible better results of the experimental group in the post-test interviews.

Results of the written knowledge test

The analysis of the unannounced questionnaire showed that a large number of the students in both groups were able to indicate the meaning of most of the basal concepts in the unit. The experimental group and the control group had comparable results; the differences have not proved significant.

Results of the interviews

a)Development of students' conceptions

When the pre-test and post-test interviews were compared, the **conceptions of learning** had changed in both groups as a result of the intervention. In the pre-test interview those questioned made a clear distinction between learning at school (relatively unimportant knowledge, remembered only for a while) and learning in an everyday context (important knowledge stored long-term). In contrast the answers in the post-test drew more on neurobiology and psychology: the majority said that the formation of associations is one of the most important characteristics of learning. In addition the connection between learning and the storage of information in the nervous system was often mentioned.

With regard to conceptions of **learning strategies**, the same type of changes occurred in both groups, i.e. towards a constructive conception of learning. In the pre-test interviews those from both groups questioned mainly mentioned reproductive strategies. Only a few, for example, mentioned writing summaries as active exploration of material to be learned. In the post-test interviews about half of the students emphasized that when learning they would make thought connections between the contents to be learned and the information already acquired. In their view such knowledge can be retained more easily than knowledge which is not as well connected, as the following quotation from a member of the experimental group shows:

When new information is taken up into the memory and you already know something about the topic, then it is added to the old information. Whatever aspects you connect with the new information, this aspect is added to. When you can connect one thing with various things then you store it in relation to each of the various things, i.e. not just related to one, but several. Then, when you call on it you can access it from different sides.

There were only slight differences between the groups with regard to changes in the **concepts of memory**. In the pre-test interviews the students in both groups either believed that information was stored in the brain in isolated bits, like storing things in drawers or like books in the library, or were not able to describe any model of memory. In the post-test interviews, the majority of those interviewed still allowed the interviewer's suggestion that memory could be described using a library as a model. 72% of the experimental group and 66% of the control group did, however, emphasize the importance of the network of inter-connected information in the brain, thus setting the right limits for the library model. The conception that the information itself was fixed forever *in* the nerve cells changed only in a few cases between the pre-test and post-test interviews. This would indicate that the concept of information storage given in the lesson was not convincing. It could be that in the students' view storing by memory possibly requires assigning information to a material unit, corresponding to the letters in a text or the magnetic particles on an audio tape.

The nerve cells are connected when learning. And what is in the nerve cells now is probably the result of experiences, i.e. more or less the storage, and they are connected together. And when these connections are destroyed, then you forget. The information is stored in the nerve cells. When, for example, the nerve cells are relatively large, then it is probable that several bits of information are stored in one nerve cell. And when they are tiny, then only a little information can go into them.

The students in the experimental group have a deeper understanding of **processing, storing and recalling information** than the control group. In the pre-test interviews, for example, a scientifically incorrect concept of short term memory dominated in both groups. According to this, information needed for a test on the following day is stored in the short term memory. In the post-test, a majority of those interviewed from the experimental group (72%) had developed an adequate conception of short term memory and explained this with examples from everyday life; whereby most of those interviewed from the control group (77%) had not changed their original (incorrect) idea of short term memory. The correct answer from a student in the experimental group is given in the first of the following two quotations. The second quotation is from a student in the control group.

Short term memory is when only very little information fits in and even that not for long, only a few minutes or so. You need it when you hear something and you have to write it down. Or when something is dictated, where you have to remember a sentence and then write it down.

As I said earlier, when you glance at something just before a test so you can write it down in the test. That is probably what you have from short term memory, because just before you stored it - you cannot really say you studied it. Okay, I would say that someone who starts to learn the day before a big test stores everything in the short term memory as compared with someone who studied the whole time. That is someone with a long term memory.

With regard to explaining the fundamentals of **forgetting**, both groups showed clear differences when comparing the pre-test and post-test interviews. In the pre-test interviews the majority pointed out that information is deleted when it is forgotten, like data being deleted from a disc. In the post-test interviews about half of those asked from both groups connected forgetting with the biological concept of nerve cell networks and the reduction of the nodes (synapses) in the neuronal network. Furthermore, in the post-test interviews most of the students in the experimental group were able to differentiate between temporarily

disturbed access to information that is still available and information which has been deleted and is not recoverable, and were able to explain this with the help of the neuronal network conception. The following is from a student in the experimental group.
When you cannot remember something and you think about it and then you can remember it, then you did not really forget. It was probably blocked by a synapse. When you really have forgotten it, then it has gone and you will never remember it - the information has been deleted somehow. But in the case of this blockage it is still there.
Knowledge about the **anatomy of the brain and the microscopic cell structure of the brain** was mainly tested by means of a written examination. There were no direct questions about this topic in the post-test interviews. Instead, those interviewed were to contribute the corresponding knowledge on their own when answering questions about other topics and show to what extent they were able to not just repeat what they learned, but to apply it. It turned out that the students in the experimental group in particular used their knowledge about nerve cells in the post-test interviews to explain, for example, the effectiveness of repetition. When the knowledge about these two topics was too superficial in the pre-test interviews, then the written test at the end of the lesson showed that they had acquired the necessary knowledge.
In summary, the intervention did not result in remarkable difference between experimental and control group with regard to the *development* of students' conceptions.

b)Overcoming the compartmentalization of knowledge
We tested whether the students interviewed from the experimental group were in a better position to connect the knowledge acquired through personal experience with scientific knowledge than those in the control group. The question whether the interviewed students from one group were able to solve science-oriented problems just as well as the ones from the other was also addressed.
The question of **compartmentalized knowledge** was studied, based on conceptions from internal sources, i.e. from reflections about individual experiences. The following two groups of questions concerning students' conceptions about (a) effective learning and (b) forgetting (conceptions from direct individual experience) were asked.
a) Imagine you have to make an oral presentation on "How to prepare for a test". What would you say?
b) What can you do during a test if you cannot remember something?
Two further groups of questions concerned conceptions about the structure and function of memory (conceptions from (c) indirect and (d) direct individual experiences).

c) Imagine you are talking with a classmate or a friend about memory. The person you are talking to says he/she imagines you can compare your memory with a library. What would you say to him/her? Do you agree with this description or would you correct it?
d) What do you understand by short term memory? Why do you need it?
The students gave various answers to the questions a) and b). These were subdivided according to the following criteria. First the answers given by each student interviewed were classified as neurobiological (N) or psychological (P) concepts. Then the individual answers were rated correct (+), insufficient (o) or incorrect (-). In addition, the number of answers assigned to the six subgroups (N+, No, N-, P+, Po, P-) was counted. Finally for each student the subgroups were ranked according to the number of answers assigned to them. The subgroup to which the most answers were assigned was placed on top of this list (N+ on top, for example, means the answers in the subgroup containing the most answers were correct and referred to neurobiological concepts). In Tables 4, 5 and 6 only those students were taken into account who were characterized by N+ or P+ on top of their individual ranking list.

Table 4. Numbers and percentages of students characterized by N+ or P+ on top of their individual ranking list of answers to questions a) ("presentation about test") and b) ("forgetting") (NEG: 11 students, NKG: 9 students)

Question "presentation about test"		Question "forgetting"	
Number of students EG	Number of students CG	Number of students EG	Number of students CG
9 (81%)	6 (66%)	6 (54%)	3 (33%)

Table 5. Numbers and percentages of students characterized by N+ or P+ on top of their individual ranking list of answers to questions c ("library memory model") and d ("short term memory function") (N_{EG}: 11 students, N_{KG}: 9 students).

Question "library memory model"		**Question "short term memory function"**	
Number of students EG	Number of students CG	Number of students EG	Number of students CG
8 (72%)	5 (55%)	8 (54%)	2 (22%)

If the answers referring to neurobiological and psychological concepts are compiled for **all questions** regardless of the subgroups a - d, the findings are as shown in Table 6.

Table 6: Numbers and percentages of students characterized by N+ or P+ on top of their individual ranking list of all answers a – d. (NEG: 11 students, NKG: 9 students)

Number of students EG	Number of students CG
10 (91%)	4 (44%)

According to Table 6 the experimental group's answers were more often correct. This is true for fewer students in the control group. This would mean that the students interviewed in the experimental group had moved closer to scientific concepts than those interviewed in the control group.

7 Discussion

Investigation instruments

First, it must be noted that the 'interview about concepts' method developed by White & Gunstone (1980, 1992) has proved suitable for planning and conducting student interviews. It has been shown that especially in the case of a relatively abstract topic like the neurobiological foundation of learning and memory, students' conceptions relevant for class are not only determined by their pre-knowledge of biology, but to a great degree by their conceptions and experiences which, from a scientific standpoint, are only indirectly connected to the topic. As the students do not have the corresponding neurobiological and psychological knowledge, they rely on conceptions they know from everyday life (cf. Reif & Larkin, 1991), such as the image of deleting computer data for forgetting. Since White & Gunstone's method directs their attention not only to propositions but also to mental images, episodes and skills, they are made aware of such indirect conceptions and it becomes possible to build up a comprehensive picture of students' pre-knowledge structure.

Results

Due to the limited size of the sample, generalizing the results becomes a problem (re: generalizing qualitative data, cf. Lamneck, 1993). The statements made by many of those interviewed evidenced coincidences.

This would indicate that typical conceptions of learning and memory were recorded, which should also apply to other populations. The same is true for the pre-instructional concept of short term memory. Coincidences arose again and again in the preliminary study (Schletter & Bayrhuber, 1998) and in the pre-test interviews in the main study in all of the groups. A larger, quantitative study could give an idea of the frequency of the various conceptions, but the results here indicate that *typical* conceptions were acquired in this study.

With regard to the results of the interest in the lessons, the somewhat more limited interest shown by the experimental group is evident, especially in the periods covering neurobiology. This result fits the statements made in the questionnaire about pre-instructional interest, where the experimental group scored lower than the control group. These findings lead us to assume that the reduced interest in the lessons is due neither to the sequencing of the lessons in the experimental group, nor to the contents being taught, but rather it is due to their general lack of interest in the topic learning and memory.

In the previous study (Schletter & Bayrhuber, 1998), as well as in the pre-test interviews in the main study, a compartmentalization of knowledge was observed in both groups and thus the corresponding hypothesis proposed by Mandl et al. (1993) supported. An integration of the various areas of knowledge partially succeeded in the experimental group and in the control group. But the students in the experimental group succeeded in connecting the psychological and neurobiological concepts with their own experiences better than those in the control group, though not completely. As an approximate idea one can, however, assume that the explicit consideration of students' conceptions in the experimental group promoted the integration of teaching contents with pre-instructional conceptions based on reflection of individual experiences (on *internal* sources). With regard to the change in conceptions based on *external* sources, our results indicate that taking pre-instructional conceptions explicitly into account is no more effective than teaching purely scientific lessons. These results demand support by further evidence.

In the literature it is discussed whether the changes in students' conceptions can be more fittingly described as conceptual change (cf. Driver, 1989; Posner et al., 1982) or as conceptual growth (cf. Carey, 1985; Stavy, 1991). In the case of this study, it has been shown that both models have declarative power. As expected, it showed that many students changed major parts of their externally derived conceptions. These were usually conceptions that had not been much elaborated and were not completely wrong. In this case, conceptual growth would be an appropriate term, as the corresponding conceptions are differentiated, growing closer to the scientific concepts. In contrast, conceptions based

on the reflection of one's own experience (internal sources) can only be replaced by the corresponding psychological or neuro-biological concepts (conceptual change) in the progress of learning.
On the whole the results of this study indicate that the growth of students' conceptions based on *external* sources cannot be considerably influenced by explicitly addressing students' conceptions in class, whereas the change of conceptions based on *internal* sources can be supported by this procedure.

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AN INTERACTIVE COURSE FOR STUDENT TEACHERS: SOME CUES ON BIOLOGY KNOWLEDGE AND TEACHING MODELS

Elena Camino, Elena Casassa & Anna Perazzone.
Research Group in Science Education, University of Torino (Italy)

1 Introduction

A new, four-year degree course in primary education science designed for the cultural and professional training of both nursery and primary school teachers (Bandiera, 1996) was launched in Italy during the academic year 1998-99.
Two thirty-hour courses in biology education and geology education form part of the first-year curriculum.
The course on biology education was entrusted to one of the present authors (Camino): in collaboration with other members of the Research Group, she worked out a programme and prepared teaching materials.
During the Course – through a process of Action-Research - the Group assessed the level of participation of the students, their mastery of scientific terms, their degree of understanding of the basic notions of biology and their ability to pass on their knowledge as teachers. This survey was conducted with two aims in mind:

- progressive preparation of teaching materials designed to clarify doubtful points, examine topics in greater depth and stimulate reflections;
- gathering of the information needed to draw up a final evaluation of the teaching/learning process.

The results of the first year's research have been described in a thesis (Casassa, 2000). Further work has been done during the second academic year (1999-2000).

2 The background

Planning of the biology course was complicated by certain constraints imposed by the degree syllabus: the course is given in the first year, that is before students have had time to think about the psychological and pedagogical aspects of learning, and about teaching methods in general. Moreover it precedes those devoted to mathematics, physics and chemistry: subjects usually regarded as introductory insofar as they provide concepts applicable throughout the much wider field of the natural sciences.

Attendance at courses is neither mandatory (so much so that some courses and/or laboratory sessions are held at the same times), nor customary.
Most students, therefore, attended the course intermittently. Only 30 to 45 of the 186 enrolled were present on each occasion. This lack of assiduity in an interactive course obviously means that absentees miss much information that cannot be found in their lecture notes because it stems from direct listening and from the discussions that take place between a lecturer and his audience.

3. The objectives and contents of the biology course

The course set out:
- to help students arrange the main concepts of biology in a flexible and dynamic network;
- to help them to realise that biology is a key to understanding of one's self, both as an individual and as a member of a community and an ecosystem;
- to train them to adopt different viewpoints and ways of reasoning in their interaction with the natural environment;
- to encourage them to consider the function of language as a vehicle for the conveyance of both information and a vision of the world, and to use it with awareness, mastery and appropriateness.

As to the contents (McWethy, 1994), it was decided to concentrate on some transverse subjects and identify those of their concepts that are form part of the structure of biology and are easily translatable into a language that children can understand (Giordan et al., 1994):
- living beings as individuals with a personal and a communal history;
- the levels of organisation of living beings;.
- the variety and singleness of living beings;
- webs of relations and flow of information among living beings.

4 Preparation of the materials

The teaching materials prepared for each topic (diagrams, pictures, readings, results of didactic researches, open questions, etc.) were designed to:
- favour the emergence of mental representations and cognitive obstacles;
- test the degree of confidence of some basic concepts, and the ability of (a) linking them together; (b) using them in various contexts;
- assess the attitudes towards teaching approaches;
- encourage discussion about implied assumptions and values in science.

These proposals set out to engage the cognitive faculties of the students. They were also intended to involve them emotionally and stimulate them to discuss among themselves, the aim being to illustrate the complexity of learning processes, in which affectivity, curiosity and active participation through discussion and the putting forward of suggestions and arguments are essential ways of making new knowledge part of one's self and blending what is new with what is already known.

5 Features of the experiment

Collection of data during a research forming part of a didactic experiment of Action-Research is associated with both difficulties and opportunities:

- the teacher's responsibility to provide students with an adequate service means that previously prepared experimental protocols may have to be adjusted to the needs that arise, with the result that the data collected are not always uniform, readily comparable and sufficient in number for quantitative assessment;
- close cooperation between the teacher and the researchers (in the case in point, the teacher was also one of the researchers) ensures the smooth and effective insertion of such changes as may be regarded as necessary along the way;
- involvement of the students gives them the chance to think about an unconventional teaching method.

The collection of experimental data was subordinated to didactic priorities, so that changes introduced into the protocols illustrate – to a certain degree - the unfolding of a teaching/learning process in which topics are faced with a reflective and critical approach, and feedback is continuously sent back to modify the program initially set.

6 Collection of the data

The data used in the research came from two sources:

- individual or small-group activities undertaken during the courses: written answers to questionnaires, free comments, drawings, diagrams. These were examined immediately after the lecture and the results were discussed with the students during subsequent meetings;
- the results of a written examination in which the students were required to answer two questions, designed to check respectively their acquisition of disciplinal knowledge and their didactic abilities. These results could not be used to evaluate the effectiveness of the teaching once it became clear that the lectures were being attended by a small and discontinuous number of students. They were none the less a useful indication of their mental representations and cognitive

hurdles, which were often unresolved at the time of the final oral examination.

The research covered the students enrolled for the first year of the Turin University degree course in primary education science (186 in 1998/99 and 186 in 1999/2000), and 25 students taking a similar course at Aosta in 1999/2000. Thirty-two written answer papers were corrected: 22 students passed (and were thus entitled to take the final oral examination) at their first attempt, 15 at subsequent attempts.

7 The subjects and aspects dealt with

During the Course the following topics were presented and discussed with the students: peculiarities of living beings; unity and variety; interconnectedness and time scales in life.

To keep within the space allotted for this paper an account will be given of only two sets of results, namely those concerning:

- the relations between living beings themselves and their relations with the abiotic substrate of their environment;
- the temporal evolution of living beings and their environment.

These are not so much subjects to be learnt as complementary ways of looking and interpreting that can be developed through the study of biology. The first focuses on the processes, functions and activities that connect the nodes (i.e. organisms and substrate) of a complex network of relations and interdependences, and in this way promotes the full understanding and acquisition of biological evolution - another transverse concept (Longo, 1998).

Our aim in determining whether and to what extent students were able to use their knowledge of biology to discover, link and organise relations in space and time and then reprocess them for teaching purposes was to reveal the interpretation patterns they usually employed and their mastery of scientific terminology (Sutton, 1992 and 1996). It was also expected that examination of their written didactic proposals would give an indication of their "teacher" models and their level of awareness of the way in which children learn a particular subject.

The data collected were to be used to re-elaborate our teaching tools directed to promoting the acquisition of both an ability to systemically read the ecological and evolutionistic components of the environment, and adequate teaching skills.

8 Webs of relations

Activities during the corse

1) Looking for relations

Groups of 5-6 students were given 19 paper figures illustrating the components of an ordinary kitchen and asked to link them together on a

cardboard backing and to write down the link words. This test was designed to assess their ability to determine relationships between living beings and their environment.
Fifteen layouts were produced. The 218 linear relations determined by the students were grouped in five categories. Over half the relationships (n = 115) are trophic and only 12 (5%) are ethological.
2) Language and analogies
Each group was then asked to define an "alimentary network". Three types of definition were given by the students: "a set of linked and interwoven relations", "a chain" and "a cycle". Most students were not aware that a specific scientific concept corresponds to each of these analogies.
The same conclusion was drawn from an examination of primary school textbooks: many authors help to create misconceptions by using the words network, chain and cycle indifferently.
Lastly, the students were asked to think about the difference between day-to-day language, in which words are used with a variety of meanings, and scientific language, in which every term has a single, precise meaning whose understanding is functional to the comprehension of a concept and its level of abstraction (Peterfalvi et al., 1986).

Answers to the questions in the written examination
The written examination was composed of questions on disciplinal topics (A) and on their didactic transposition (B).
(A) Disciplinal questions
1. List some of the relations between living beings. Specific whether anything is exchanged, and if so what, in each relation. Give examples.
2. "A tree can be used to illustrate different types of relations between the components of an ecosystem. It is a source of food for many animals (birds, insects, etc.). Other animals use it as ....". Continue this explanation and give examples.
3. "The environment is a network of relations". What is meant by this expression and what sort of relations may be found in an environment?
The forty completed papers (some students gave multiple answers) provided 59 sentences, each indicating a relation. These sentences were placed in six categories that partly coincide with those used for the kitchen patterns. The relation that appeared most frequently regarded the exchange of matter and energy. It was thus in line with the prevalence of the trophic category in the previous test.
(B) Teaching questions
Systematic and quantitative assessment of these data was impossible because the answers were too few and too varied. Qualitative evaluation, however, gave an indication of the level of the students' understanding of the concepts and the reference models they used in sketching out a

teaching path. Two of the questions and some of the answers obtained are illustrated below.

1. *"Plants start a food chain by taking in inorganic materials and assembling them in organic compounds"* (This sentence was taken from a primary school textbook). *Describe the "cognitive obstacles" an 8 to 9-year-old child might encounter in reading this sentence. Show how you would "translate" the concepts it contains to enable such a child to understand them.*

- ✓ Plants start a food chain in the sense that they first feed themselves and then they also give food to us
- ✓ ... by analysing different types of plants and their leaves one can make others understand the autotrophic functions of vegetal organisms
- ✓ ... organic compounds are complex substances, such as proteins, lipids, fats, and carbohydrates.
- ✓ ... a cognitive obstacle is the fact that light and the carbon dioxide that plants capture are invisible..

The first answer is an example of the misconceptions that arise when students seek to get their knowledge across to children. Confusion between definition and explanation is evident in the second answer. The fourth answer rightly indicates a difficulty teachers have to bear in mind, but does not suggest a way of overcoming the obstacle.

2. (Students were given a drawing of a food web in the sea) *What is shown in this drawing ? Describe it and then use your description to prepare a simpler pattern you could employ to teach older primary school children.*

- ✓ This diagram shows a "water" food network. Each living being must eat to survive and so larger living beings eat smaller beings
- ✓ This diagram shows the cycle of matter. It is a closed schema because it shows the birth, growth, death and decomposition of an organism. It could also be explained by completely changing the example: the water cycle. I would use posters to show children the meaning of a food chain

The first answer contains two misconceptions: network = chain; larger organisms eat smaller organisms. The second answer fails to identify the marine food network. It also reveals the confusion associated with the word "cycle" when used in different contents.

9 Evolution

Activities during the course

1) Drawing

Discussions with the students about the unity and diversity of living beings, biodiversity and classification systems were followed by a test

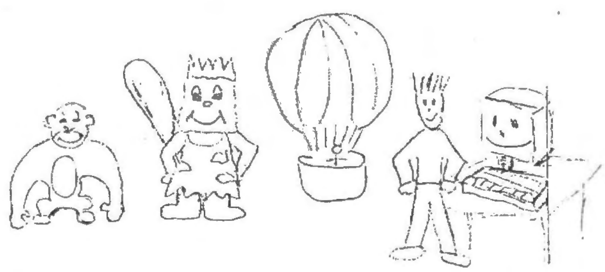
designed to investigate their notions of the concept of evolution. The instructions were:
"*Imagine you are a primary school teacher. You want to tell children something about evolution and decide to introduce this concept in the form of a drawing or a graph*".
The 55 drawings produced were divided into seven categories:

CATEGORY	No.
A life cycle	15
Evolution of man	14
From the primordial soup (fishes, dinosaurs, monkeys) to man	9
A tree with several branches	5
The "case" of giraffes	5
Diversity of living beings	5
From the simple to the complex	2

27% of the students associated the concept of evolution with that of the life cycle, 25% saw evolution as a process concerning human beings, and 41% regarded man as the end product of evolution. Two of these drawings are shown below:

a) Mental representation associating evolution with the life cycle

b) Man's biological and cultural evolution



2) Linguistic ambiguities

Immediately after finishing their drawings, the students were asked: *"What does the word 'adaptation' mean in everyday language and in scientific language?"*

The answers showed that most students believed that adaptation always refers to a process whereby single individuals adjust to suit their surroundings. There was no awareness of time scale differences, nor of the biological mechanisms involved when the word is used in evolutionary biology.

Answers to the questions in the written examination

Evolution was also the subject of disciplinal and teaching questions in a written examination.

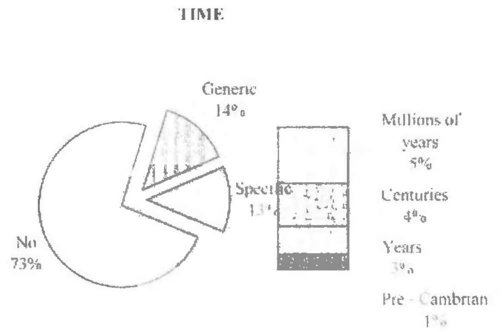
(A) Disciplinal questions

1. *The concept of the evolution of living beings requires a knowledge of some biological processes. Name at least three of these processes and explain their significance and mechanisms.*
2. *Define the meaning of adaptation in a context of evolutionary biology.*
3. *Living beings have adapted to their environments during the course of evolution. What does "adaptation" mean? Illustrate and give examples of its mechanisms.*
4. *Mutation – natural selection: what do these two terms mean in biology? How are they related to each other?*

The 50 answers received were examined according to:

the subjects of evolution. *Species* and *single individuals* were seen as the subject of evolution in 35% and 24% of the collected answers respectively (n = 79). More generic definitions – *organisms* and *living beings* – were used by 14% and 16%, while 3% thought that *animals* were the subjects of evolution. A *population* was never proposed as the possible subject of evolution.

The time scale. The concept of time did not appear in 73% of the answers. Generic references and specific references were made in the remaining 14% and 13% respectively.



The role of the environment. This concept was only present in 14 answers. No function of the environment in the evolution of living beings (or vice versa) was mentioned in the other 36.
Evolution mechanisms. Eleven answers regarded evolution as the result of chance in sentences such as:
"The environment selects species: those that succeeding in adapting to it survive, those that do not become extinct. This is the result of chance". In 36 answers appeared the idea of intention: for example, *"Adaptation is a process in which individuals modify their behaviour to fit themselves into their environment."*
The meaning of the other 3 answers was too uncertain to allow their inclusion in either category.
Genetic features associated with evolution: mentioned in only 25% of the answers.
The trend. Numerous students expressed the idea that evolution tends to result in an improvement, as in these answers:

- *The environment selects* the best individuals
- *Evolution* = change for the better
- *Adaptation means* the best development of the abilities most useful *for survival in the face of change*
- *Species try out new solutions to secure* a better life *for themselves*

The answers to questions (1) and (4) were also looked at more closely to see how far the students had managed to join key concepts together so as to work out an interlinked idea of evolution. Apart from the terms "mutation" and "natural selection" provided as a pair in one of the questions, very few key concepts, such as duplication of DNA, sexual reproduction and transmission to subsequent generations, were mentioned. The notion of variety was ignored.
In keeping with the already described meaning assigned to the word "adaptation", the answers as a whole indicated that the students' idea of evolution was closer to that of Lamarck than to that of Darwin. In addition to their scanty knowledge of science, it may be supposed that this misconception equally stems from the ambiguous language used in textbooks and popular science publications.
(B) Questions in didactical aspects
Here, too, the answers gave an indication of the level of the students' understanding of the concepts and their implicit teaching models. Two of the questions and some of the answers obtained are illustrated below.
1. A sense of "geological time" is very difficult to grasp, especially for young children. What means would you use to help them appreciate the difference between the lifetime of a person and the length of time during which there has been life on the earth ?

- ✓ One way that could help children understand the length of their lives by comparison with life on the earth consists of reminding them of how long living beings have existed on our planet...
- ✓ I would arrange a couple of teaching excursions, one to a place close to the mountains... I would ask them to look around and guess how old the mountains could be.

Both approaches reveal a similar level of unawareness of the limited extent of a young child's ability to form an abstract idea.

2. From a family tree to the tree of evolution. How would you prepare a teaching module on this subject for primary school children ?

- ✓ I would go through the stages of evolution with the aid of pictures, diagrams and representations
- ✓ ... by getting the children to draw their own family trees. We would then look at the time that has gone by: great-grandparents are so different and so far away. Even so, there is a saying in a particular family that someone has red hair like granny's uncle. The children would be able to think about their own similarities and differences.

The first student would use descriptions, explanations and drawings, the second would be concerned with getting children to think for themselves.

10 Conclusions

The knowledge of the students

The tests used during the course brought out both the previous knowledge and the misconceptions of the students. Certain conceptual obstacles emerged, as in the experience of other authors, while discussions with the students on scientific and linguistic aspects enabled them to think about the appropriate use of language and their ability to put together and integrate what they knew.

Relations

The failure to recognise the fact that network, chain and cycle are analogies was used as an opportunity to give a fuller account of the assumptions in these concepts and encourage the students to talk about the level of abstraction hidden in apparently easy subjects. These matters have been individually dealt with by Peterfalvi et al. (1986). We, too, observed conceptual obstacles to the understanding of alimentary relations and to the correct use of their associated metaphors.

Stimulation of a systemic view of the environment through the use of the cards and the examination questions resulted in the identification of very few types of relationship. Environment as a complex system is hardly perceived, even though the course itself had been founded on this form of interpretation.

The choice of cards for the relationship exercise may have restricted the creativeness of the students by offering limited stimuli to identify non-alimentary relations and focussed their attention on predator-prey relations. Nutrition, too, is readily recognised as a primary need common to all living beings (Perazzone, 1994). In addition, the difficulty of conceptualising gases as matter (Astolfi et al., 1993) makes it less easy to detect the connections between plants and animals.
Why the students found it hard to recognise a relation of parentage, or one linked to functions and/or behaviours (selection of a den, relations of cooperation, etc.) ? This may stem from the dichotomy between school learning and personal experience: knowledge that is obvious in daily life has no active counterpart at school, and vice versa (Dodman, 1999; Casassa, 2000). Alimentary relations between living beings are those most studied and described in textbooks, including the use of specific analogies. They are thus the first that come to mind when an answer has to be given to a question in a school-like setting.

Evolution and adaptation

As observed by Dagher & Boujaoude (1997), the main misconceptions were:

- the end product of evolution is man (also regarded by many students as the most "perfected" form)
- monkeys have evolved into humans
- evolution is a process that primarily concerns individuals.

Moreover, as shown for college students by Ferrari & Chi, (1998), few of those who thought about evolution used a sufficiently extensive time scale or concepts (e.g. "population") that were appropriate and correctly interlinked (e.g. genetic features, the role of the environment, transmission of information).
These results, together with the observation of the unawareness of the meaning of the term "adaptation" in evolutionary biology, in addition to bringing to light a sketchy biological preparation in the high school, enabled us, thanks to subsequent discussions with the student, to realise that many of them were using concepts mediated by other subjects, especially psychology and pedagogy, without reflecting on possible changes in meaning linked to changes of context.

Reasoning about one's own knowledge

A critical feature that appeared in the activities conducted during the course and in the final examination was the surprise and embarrassment displayed by the students when asked to express concepts in their own words, determine the main points of a topic, devise links between subjects in biology and express biological subjects in a language suitable for young children. Such knowledge of biology as they had was superficial and expressed in words and definitions learnt by heart and never weighed up and made part of their own thinking.

When they actually managed to arrange their ideas about even very simple subjects in an independent, creative fashion, they appeared to have crossed a horizon into a stimulating new world with many things to be explored, though the data obtained so far are not enough to show whether this is really the case.

Didactic "transposition"

The answers to the didactical questions provided valuable information about the students' misconceptions of disciplinal knowledge and their implicit teaching models (Hewson & Hewson, 1997). Very few saw themselves as having pupils with whom they could engage in dialog and discussion. The difficulty in grasping the meaning of the questions and limiting the boundaries of the answers (already apparent in the contents questions) is translated, in the case of teaching suggestions, into proposals that often lacked a common thread, wherein activities of a very different kind were suggested as the result of an association of ideas, or even because they sounded similar.

The fact that the students rarely made a habit of thinking in depth was again apparent. They were barely aware of a young child's ability to reason and wonder about things, on the one hand, and of the level of abstraction of more concepts, which end up by being meaningless labels for primary school children, on the other.

Evaluation of our teaching proposals

When compared with the objectives set at the start of the course, the results showed that our teaching proposals were inadequate. This, we feel, was partly the outcome of the low level of both the students' previous scientific education (many said they had never learned anything about biology) and their attendance.

Some features, however, could be usefully improved by changing the teaching proposals themselves:

- correction of weaknesses and incongruences in the proposed activities
- devotion of more time to systematic thinking about ways of acquiring knowledge

The activity with the cards has, in fact, been altered. Attention is now initially drawn to the variety of interdependent relationships to be found in an ecosystem, and to the fact that an observer may well focus on some relations that are more readily discerned, or which interest him for practical reasons or because they form part of his studies. Then the cards' activity is proposed, which explicitly underscores alimentary relations and is the prelude to further thought about specific concepts, such as the cycle of the elements and the biomass pyramid.

The data collected with regard to evolution - fragmentary notions, failure to perceive the time scale, and the fact that the students found it hard to think of evolution as a process - suggest the preparation of tests that require identification and linking of the structuring concepts indispensable for a correct interpretation of evolution, and encourage students to think about its linguistic aspects (Slisko & Dyksta, 1997).

Primary school textbooks have been occasionally subjected to critical examination during these two years. This work has proved both interesting and stimulating. Our intention is to both extend it and apply it at several levels: scientific contents, language, pictures (e.g. Kearsey & Turner, 1996), the idea of science that is conveyed.

General considerations

In view of the low level of the initial knowledge of the students and their irregular attendance, one way of reorganising the course would be to devote more time to the acquisition of knowledge by replacing group discussions and thought sharing with conventional lectures. But the elements we have collected and the support of authoritative opinions (e.g. Hodson, 1998) suggest further experimentation of activities that involve the students directly and use various approaches to biological knowledge:

- the disciplinal approach, which stimulates to wonder about the ways in which new knowledge is built up and recounted by the scientific community (selection of the variables, invention of metaphors, etc.);
- the individual approach: this translates into awareness of the relations that we as living organisms weave with other living beings, present and past, and with the continually changing environment;
- the teaching approach: this encourages thinking about how and to what extent we master what we know and are able to "translate" it through the appropriate selection of words and concepts so as to enable young children to make use of it.

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HANDS ON ACTIVITIES IN GENE TECHNOLOGY EDUCATION DO STUDENTS GAIN FROM THEIR EXPERIMENTAL EXPERIENCE?

Dorte Hammelev
IMFUFA, Roskilde University

1 Background

As gene technology plays a very important role in modern society it is an important part of the biology curriculum in the Danish educational system too. Recent studies like the Eurobarometer (1997) show a fairly low understanding for DNA and DNA-technology among ordinary people. That study is carried out on European adults. Another study carried out in the UK on 14 - 16 years students show limited understanding of DNA-technology although these students showed a good general understanding of genes (Lewis, J. et all 1997). A small Danish survey presented to both 14 and 16 years students using some of the Eurobarometer probes showed a questionable understanding of genes and their function (Frandsen, K-E., et all. 1999).

Although the main reason for doing labwork with students according to the teachers is to help students to link theory and practice (Welzel, M. et al 1999), research in this field, reviewed by Hodson (Hodson 1993), states that this type of work do not always give the students a better theoretical understanding. However these findings are not conclusive, and it is my point of view that the learning outcome depends on the context, the learning environment and how important the content is for the students. As a part of the learning environment the types of labwork and how they are carried out means a lot. Johnstone and Wham focus on the importance of creating a suitable learning environment doing labwork to avoid the students' minds to be overloaded working with too many new questions, apparatuses and unknown equipment at the same time (Johnstone, A. H., and Wham, A. J. B. 1982). Therefore preparation of the lab sessions are very important. But the debriefing of the labwork, results including the applications and implications in the socity might be the most important part of the practical work to help students to link theory and practice.

Teaching students in a certain subject besides teaching factual knowledge means introduction into the special subject culture too, (Brown, J. et al 1989). Experimental labwork in e. a. DNA technology plays a central role in the biotechnology culture. It is therefore not possible to introduce students into that subject without introducing them to the culture of DNA-technology. This is also why the Danish biology curriculum, that

experiments and other practical work have to be an integrated part of the subject taught, with the expectation of creating a better understanding of biological theory and scientific working methods. One of the reasons for introducing the DNA-labworks were to make the teaching in DNA-technology more authentic which according to Ausubel is one of the basic conditions for meaningful learning (Ausubel et al. 1978). Brown et al (Brown, J. et al 1989) emphasise too the importance of authenticity for situated learning. Performing problem solving labwork with DNA-analysis similar to those solved in professional life might create such a situation especially if there in the debriefing is refered to the professional use of the same technique.
This study compares students' different conceptional knowledge on DNA and DNA-analysis methods with their experiences working with different types of labwork during their A-level course. The tool is an analysis of the students' performance to a task from the National A-level examination paper 1999. Further it is discussed whether the wordings of the examination questions investigated are appropriate so the students answer along the lines expected. Using this method it is not possible to investigate how the students have been introduced into the different types of labwork and how the lab. sessions have been carried out and debriefed. The study will only focus on to which extend the students are able to use their gained practical experienses in performing the examination task examined.

2 Types of gene technology labwork used at A-level biology in Denmark

Biotechnology as such is a compulsory subject within Biology. As a part of teaching in biology Danish teachers do different biotechnology labwork together with their students. The following list of labwork is based on teachers' annual report to the Ministry of Education for the school year 1998/99 on prepared materials for the A-level examination. Altogether 171 classes did A-level biology in the school year 1998/99. The prepared examination materials of 167 classes were examined with special focus on practical labwork using the teachers annual report to the Ministry of Education as source. This is 98% of all A-level classes this year. The number of students in these classes will vary from 5 to 28. Table 1 summarises the teachers' information on their 167 classes' labwork.
A-level students have to include 15 reports on different labwork in their prepared examination materials, but it has to be negotiated between the students and their teacher in which subject the labwork and the reports are done. Thus all A-level students do work with biotechnology but they do not all work practical in the lab with this subject. 59% of all A-level

biology classes have included one or more of the above described labwork in their prepared materials in 1999. The rest, 41% the classes only include theoretical texts on biotechnology in their prepared examination materials.

Table 1. Percentage of classes doing DNA-labwork at A-level. Source: Teachers annual report to the Ministry of Education on prepared materials for the A-level examination 1999.

Cleaning up DNA from onions or other biological materials	31%
Cleaning up bacterial DNA, Plasmids etc.	6%
Transformation of bacteria or yeast	8%
DNA restriction analysis and electrophoresis	31%
Electrophoresis of amino acids or proteins	18%
Analysis of the size of different fragments of DNA	< 1%
PCR technique	< 1%

3 Analysis of the examination task performed

An examination paper contains two major tasks which need a detailed performance, and four to five smaller ones which are expected to be more briefly performed. The students have to choose to perform one major and two of the small tasks. The duration of a written examination is five hours. All materials, books reports etc. used during the course, are available for the students during these five hours.

I have investigated whether the students performance on the first questions (Aa and Ab) of the task *Menkes disease* (see below) reflect their practical experiences from their labwork. The task's A questions are as follow:

Menkes disease

Menkes disease is a rare hereditary disease due to a mutation in a gene coding for a copper transporting protein. The gene can be detected by a DNA-analysis.

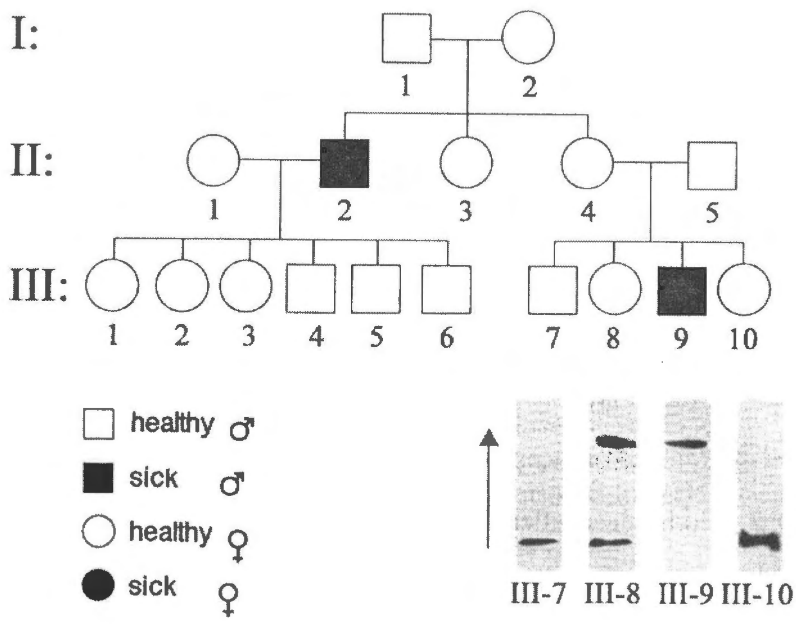
Questions to be answered:

Aa. Based on information given in figure 1, present a possible explanation on how the gene for Menkes disease is inherited. Include possible genotypes for the persons II-1, II-2 and III-8.

Ab. Explain how a DNA-analysis as the one shown in figure 1 can be done.

The B questions are not included in the investigation due to no relation to gene technology.

Figure 1. Family tree from a family where Menkes disease occur including a DNA-analysis on some of the family members.



4 Factual information on the A-level biology in Denmark in 1999

A-level students have to pass both a written and an oral examination. Altogether 2649 A-level biology students sat for the written part of the examination in 1999 only 42% of those students had chosen the exercise on Menkes disease. I got permission from 102 students from all over Denmark to use their answers anonymously in my investigation. Two of the answers had to be left out due to bad copy quality. That gave me exactly 100 answers to examine. This is 9% of the students that actually performed the task investigated.

5 Research questions

When working with gene technology students get different images of DNA and how to investigate it. This is among other things due to the fact that DNA can only be recognised if special investigation methods are used. The result of using for example a DNA analysis - a gel picture as seen in the figure 1 - therefore contributes to the envision of what DNA looks like so to speak, how it behaves in the analysis, what is possible to investigate and where the limits are for what is possible to investigate using a specific method. This leeds to the following research questions:

- Do students who have worked with different labwork within DNA-technology during their course show a better understanding with less misconceptions in their written examination than those who did not do labwork?
- Is the examination questions investigated a fair test of the students conceptional knowledge of DNA-technology ?

6 The investigation method

The students' answers on question A was coded using the following categories. (The numbers in the parenthesis behind refers to the database. A total list of codes will be given in the appendix):

1. *The answers show understanding for the principals of a DNA-analysis. (code 3 and 4).*
2. *Connection between theory and practise is shown in the explanations given incorporating the gel-picture (code 6).*
3. *Students' expressed images on DNA and DNA-analysis are described, (code 10).*
4. *The labwork students have worked with during the course. Information from the teachers annual report to the Ministry of Education 1999 (code 11).*

The coding has been discussed with three different colleagues, all experienced in marking written examination papers. The codes that were valued differently were changed. The data programme Excel has been used to handle the coded answers.

7 Results and comments to the results

Does the answer show an understanding for the principles of a DNA analysis? (code 3, 4).

* 67% of the students present a correct explanation of varying length of the principles of a gel electrophoresis. This is coded as "3a".

* 18% of the students describe gel electrophoresis without any explanation, or just use the words "gel electrophoresis" in their answers. This is coded as "3c".

* 15% of the students present a wrong or do not refer to gel electrophoresis as a method, (coded as 3d + 3e).

* 24% of the students give a correct explanationof veaying length of the principles of a procedure before the electrophoresis, the restriction analysis or PCR. This is coded as "4a".

* 13% of the students describe restriction analysis without any explanation, or just use the words "restriction analysis" in their answers. This is coded as "4c".
* 63% of the students present a wrong explanation or do not refer to restriction analysis at all, (coded as 4d + 4e).
The overall impression is that the students are very economical with their writings. Some write extremely short answers. The reason could be that they have desired to spend their time on other tasks. To discuss whether a short or no answer implies lack of knowledge I combined code 3 with code 4. There seems to be no connection between the students that present the correct explanation of gel electrophoresis (3a) and those presenting the correct explanation of the restriction analysis, the first part of an DNA-analysis, (4a). Another, later, study on a group of A-level students answering the same question, or a rephrased version whom I interviewed later shows that the students know much more than they write. In this study the students all knew about the whole procedure but found it equally just as important to explain the electrophoresis procedure. This was due to the gel picture in figure 1, which for them only had to do with the electrophoresis procedure, (Hammelev, D. 2000 unpublished). Consequently all the students' knowledge on the subject are not reflected in their answers of the question but have to be investigated with other means e.g. interviews.

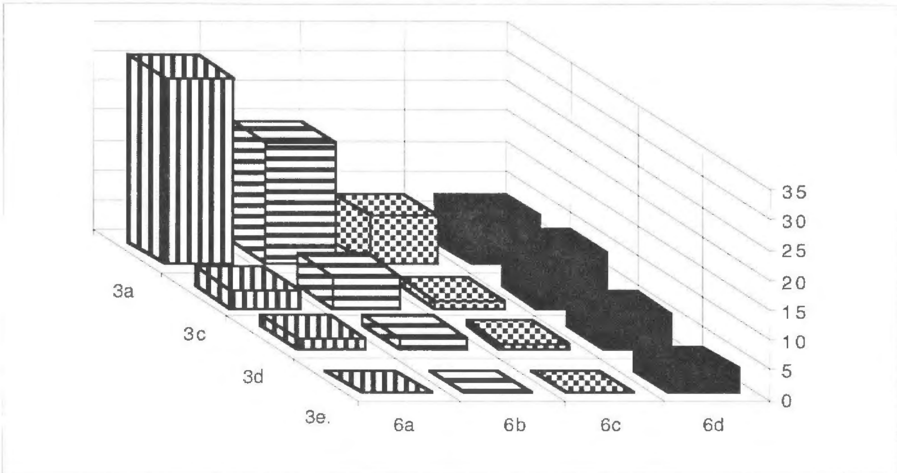
Do students connect theory and practise in the way they incorporate the gel picture in their answer (code 6)?
* 36 % of the students use the picture in a theoretical explanation of a DNA-analysis. This is coded as "6a".
* 27% of the students only use the picture in the explanation of question Aa (the genotypes) with no reference to the gel electrophoresis method. This is coded as "6b".
* 10% do only describe the picture without any interpretation coded as "6c".
* 27% of the students do not mention the picture at all coded as "6d".

8 A possible relation between theory and practice (code 3 + 6)
Do students who demonstrate understanding of the electrophoresis procedure (code 3) also integrate the gel picture from figure 1 in their explanation of the procedure (code 6)? Figure 2 shows the result of the investigation. The meaning of categories is summarized below:

3a: Any explanation, short or more extensive, of what the principal of a gel electrophoresis is.
3c: Description of or referring to gel electrophoresis.
3d: Wrong explanation of gel electrophoresis.

3e: No references to gel electrophoresis.
6a: Theory included in the analysis of the gel picture
6b: The picture is only used in the explanation of question Aa
6c: Description without explanation
6d: The picture is not mentioned at all

Figure 2. Do the students link theory with practice?



There is no clear distinct relationship between the two sets of data, but two different types of students' profiles can be drawn from figure 2:
Students profile I: Correct explanation of the gel electhrophoresis procedure (3a) referring to and related to a correct explanation of the gel picture (6a). This profile encompass 31 % of the students.
Students profile II: Correct explanation of the electrophoresis procedure (3a) but not referring to or relating it to the gel picture. Consequently they do not relate theory to practise. This profile encompass 20% of the students. Whether these two profiles of students can be maintained when scrutinised by other methodological means e.g. interviews are postponed for further investigation and not included in this study.

What images do the student have on DNA and DNA-analysis? (code 10). (Special expressed images are described later).
* 63% of the students show correct images of DNA and DNA-investigating methods in their answers (10a).
* 6% of the students show both correct images and misconceptions in their answers (10a,b).

* 24% of the students demonstrate misconceptions in their answers (10b).
* 7% of the students do only refer to or repeat the text from the exercise. These are therefore coded as "no images" (10c).

9 Special expressed images

60 students expressed more specific images of DNA and DNA-investigating methods in their answers. They are coded as 10aa. The misconceptions are coded as 10bb.

Correct images (10aa) are represented by statements like:

"III-10 has a thicker DNA-band in the picture because it is from a woman with two X chromosomes" or "from the picture it is seen that III-8 and III-9 have a gene in common",

"Through mutation the DNA-fragment obviously become smaller.. (some mention loss of a base sequence)..., and will therefore move faster in the electrophoresis gel" or .."restriction enzymes cut DNA differently if a mutation occurs causing differences in speed of migration" (in a electrophoresis gel). 32 students have expressed statements like these.

Misconceptions (10bb) are represented by statements like:

"Whole chromosomes are migrating in the gel, here X and Y, "It is protein that is investigated in a DNA-analysis" or explanations of DNA and protein are mixed up. "DNA and RNA are actually proteins so they can be separated too in an electrophoresis", "The gel picture shows the result of a base sequence analysis". 28 students have expressed statements like these.

What sort of practical labwork have the students worked with during the course?

(Information from the teachers report to the Ministry of Education, code 11).

Four types of labwork have been chosen as the basis for this investigation.

1. Restriction analysis of DNA,
2. DNA cleaning procedures using different materials, onions, bacteria etc,
3. Protein- or amino acid electrophoresis, all done in the school. These labwork activities have all been carried out in the school lab.
4. Some classes have participated in an outside school labwork activity e.g. a course given at a university where they have worked with different advanced techniques like base-sequence analyses including gel electrophoresis on the DNA fragments.

Some classes have worked with more than one type of the labwork. Other classes have not worked with any DNA labwork at all. By chance all the students in this survey that have worked with protein- or amino acid electrophoresis, had labwork experiences with DNA cleaning procedures using different materials. Students labwork experiences are categorised (see appendix) and recorded as follows. The persentages show how many students have done the actual labwork:

11a. Restriction analysis of DNA	22%
11e. DNA-cleaning procedures using different materials, onions, bacteria etc	19%
11b. Both 11a and 11e	10%
11g. Protein- or amino acid electrophoresis + 11e	12%
11d. Outside school labwork activity	11%
11f. No DNA labwork experience at all.	26%

10 Understanding of methods and practical experience (code 3 + 11) Possible relation?

In figure 3 understanding of the method of electhrophoresis (code 3) is related to practical DNA lab. experiences gained through the A-level course (code 11) to investigate the possible connection between theory and practice. The meaning of categories is summarized below:

3a: Any explanation, short or more extensive, of what the principal of a gel electrophoresis is.
3c: Description of or referring to gel electrophoresis.
3d: Wrong explanation of gel electrophoresis.
3e: No references to gel electrophoresis.

Two findings can be drawn from figure 3. First it seems that doing practical labwork pays off in that respect that students with individual experiences from labwork give more and better explanations of the electrophoresis procedure than those without experience (11f). Secondly more students from the 11b- and 11e group give a correct explanation of the electhrophoresis than students from other groups. This is an interesting finding due to the fact that the 11e group have not been working with the electhrophoresis procedure investigated. An explanation could be that a DNA cleaning procedure is simple enough to give the students time and excess of mental energy to survey the procedure and be familiar with the concept of DNA. Surprisingly the 11a group do not explain the method as correct as the 11b- and 11e group even so that they have done the actual DNA analysis could be that the procedures have stressed the students in their demanding elaboration that have caused students minds to be "unstable and overloaded" so they are unable to react sensibly described by Johnstone and Wham (1982). The

DNA-restriction analysis is often carried out using a kit in contrast to the the electhrophoresis of protein or amino acids. The last set up might create a more fruitful discussion and debriefing in the classroom on the procedure and the application of the technique. Further work to be able to explain students' different use of gained lab. experiences is necessary and not included in this paper.

Figure 3. Relation between method understanding of the electrophoresis procedure (code 3) and the students' labwork experiences based on the teachers' annual report (code 11). Each category is made up in percentage based on the whole group.

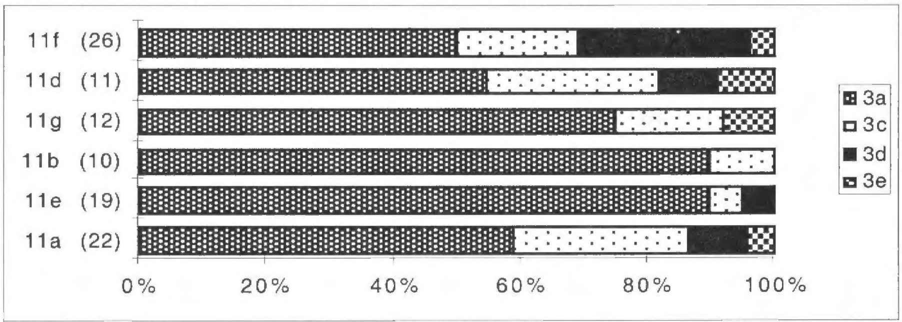
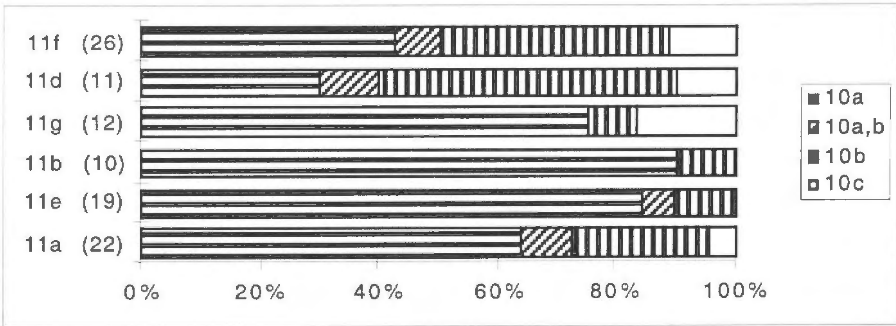


Figure 4. Match between students' images of DNA (code 10) and their labwork done during the course (code 11). Each category is made up in percentage based on the whole group.



The students' use of their lab. experiences can also be investigeted by relating the labwork done during the A-level course (code 11) with the students' images of DNA and DNA-analysis (code 10). This is done in figure 4. The meaning of categories is summarized below:

10a: Correct images
10a,b: Equal amount of correct answers and misconceptions
10b: Misconceptions
10c: No images

Figure 4 shows that students with experimental experiences on the whole have expressed more correct images of DNA and DNA-analysis compared to students without experimental experiences, (11f) except for the 11d students. These students with experimental experiences from an outside school labwork activity have the highest proportion of misconceptions at all, even higher than those without experimental experiences. Only 25% of these 11d students express correct images. This reflect the view that doing experiments is of little value, if the students cannot survey the experimental situation. Students following an outside school labwork activity will often be mentally overloaded as described by Johnstone and Wham (1982). It could among other things be due to many new and advanced apparatuses and a stressed programme to fit in as techniques as possible. This will often be a demand from the teachers that would use the opportunity to show the students the authentic use of certain procedures, which are difficult to carry out at the school. Therefore these courses have to be planned very carefully together with the teacher to make a meaningful learning situation for the students. Possibly lack of sufficient debriefing after the lab seccesion or prosponed to later back at school can be another explanation.

The reason why the 11b group have the highest score at all (90 % of the students express correct images) could have to do with the fact that the 11b's have spend much more time in the lab. possibly more than one day. In that respect the 11g group show a high understanding too (with 71% of the students showing correct images) in comparison with 11b. It is not as high as the 11b due to their work with another method of electrophoresis.

To investigate the difference between those students that have worked in the school lab. with DNA investigations with those that have worked in an outside school activity and those that have not worked with DNA labwork at all the three groups are compaired in figure 5. The meaning of categories is summarized below:

10a: Correct images
10a,b: Equal amount of correct answers and misconceptions
10b: Misconceptions
10c: No images
11a,e,b,g: Labwork done in the school lab
11d: An outside school labwork activity
11f: No DNA labwork at all.

Figure 5. Match between students' images of DNA (code 10) and their lab. experiences (code 11). All students that have done labwork in their school lab. is shown as one group.

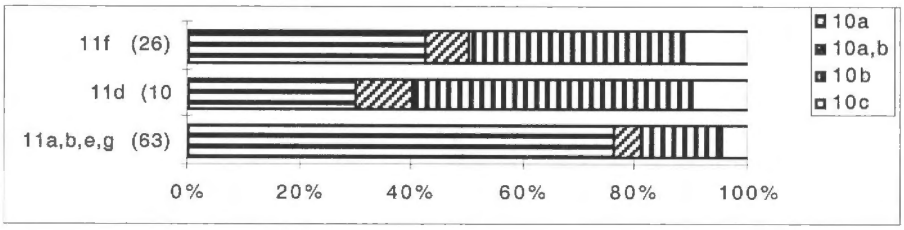


Figure 5 shows that students that have worked in the school lab. have far better understandig and more correct images on DNA and DNA technology than both students that have done labwork outside their schoollab or those or those without DNA labwork experiences. 76% of the school lab group (11a,e,b,g) show correct images in their explanations when performing the task given in the examination paper. Only 30% of the outside school labwork group show correct images. In contrast 42% of the group without DNA labwork experiences show correct images.

11. Discussion

Looking at the relations between the expressed images/misconceptions described in details in *"9. Special expressed images"* lab. experiences sharpen the tendency already seen in figure 4. 61% of the 31 students that worked at school express correct images. 50% of those not doing DNA investigations at all (11f) and only 20% of the outside school labwork activity group (11d) express correct images. This emphasize again the viewpoint that the experimental environment has to be planned and debriefed very carefully to ensure a decent outcome for the students.Unfortunately the investigation method chosen cannot be used to gain information about the instruction given before carrying out the labwork. Neither can the method be used for information about what have been discussed in the debriefing.

The use of labwork like DNA analysis in teaching gene technology could possibly create an authentic learning situation for the students, one of the basic conditions of meaningful learning, which is originally described by Ausubel (Ausubel et al. 1978). On the other hand it depends very much on whether the students find the DNA analysis labwork authentic, and whether the labwork manual gives students a chance to adapt the investigation, so they feel ownership for the investigation. My study cannot answer this question. But the investigation can record the results

of doing labwork, namely the students' actual use of their individual labwork experiences in their answers.
The actual way the two sub questions Aa and Ab are phrased as two different questions is not helping the students to see the connection between them. On the other hand the gel picture shown as an integrated part of figure 1 could possibly be helpful for the students, but it is not possible in this study to verify whether the students actually see this connection.
A teacher's role will often be questioned in situations where it comes to students' performance in an examination situation, but the students' answers given in this investigation seem to be very individual with no reference to certain group specific explanations for the actual classes examined.

12. Conclusions

It can therefore be concluded from the study:
* Students introduced to the central parts of the biotechnology science culture represented by the labwork develop a more correct conception on DNA and DNA-investigations as a whole
* The type of labwork chosen is very important due to students' ability to survey the investigation done in the lab. It is important not to create a situation that could cause students' minds to be "unstable and overloaded". The most simple labwork with known and simple equipment seems best to support the students' correct images. Alternatively they have to work with more than one DNA-labwork for a comparatively long period.
* The classes that have participated in an outside school labwork activity seem not to have gained a better conceptions of DNA, possibly due to overloading.
* The way question A is constructed does not support the students in the best way to express their knowledge and images of DNA. On the other hand it is not clear whether a rephrased question will change that.

13. Reservations

* The number of examination scripts examined is only 100 and when the answers are divided into groups with different labwork experiences, some of them become very small. Especially the 11b-, 11d- and the 11g category is fairly small. The category 11d only contains students from two classes. It could be a question about the way these two specific courses have been carried out. It has therefore no meaning to do statistic calculation on the different sub categories sat up. On the other hand there

is no doubt it is worth examining these courses in relationship to students images on DNA-technology.

* It is a real problem to investigate only a part of a whole examination script due to the fact that the students themselves choose where to emphasize their answers and therefore devote time.

* Coding students' answers too can always be discussed especially when trying to code students images implied in their answers.

* Not all students have participated in all the labwork due to absence. That will especially be a problem for the outside school labwork activity (11d) because there is no chance for them to have another go on results or apparatuses etc. later than the actual lab. day

* It is sometimes difficult too to follow students' argumentation in their answers. That may be due to the very short time they have to answer the questions. Some do not use any arguments at all. They use only the words from the text in the task.

* This study is not able to tell what other experience the students have gained from the courses outside school.

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Appendix

TOTAL LIST OF CODES

1. Does the answer show an understanding for the principles of DNA-analysis? (code 3 + 4).

3a: Any explanation, short or more extensive, of what the principal of a gel electrophoresis is.
3c: Description of or referring to gel electrophoresis.
3d: Wrong explanation of gel electrophoresis.
3e: No references to gel electrophoresis.
4a: Explanation –short or more extensive– of what the principal of a restriction analysis is.
4c: Description or just mentioning "restriction analysis".
4d: wrong explanation of a restriction analysis.
4e: No mentioning of "restriction analysis".

2. Does the student connect theory and practise (the investigation methods) in the explanations given, or In which way incorporate the students the gel picture in their answer? (code 6).

6a: Theory included in the analysis of the gel picture.
6b: The picture is only used in the explanation of question Aa.
6c: Description without explanation.
6d: The picture is not mentioned at all.

3. What sort of images does the student have on DNA and DNA-analysis? (code 10). (Special expressed images are described).

10a: Correct images.
10a,b: Equal amount of correct images and misconceptions.
10b: Misconceptions.
10c: No images.

10aa expressed correct images.
10bb expressed misconceptions.

4. What sort of practical labwork have the students worked with during the course? (Information from the teachers report to the Ministry of Education 1999, code 11).

11a. Restriction analysis of DNA.
11e. DNA-cleaning procedures using different materials, onions, bacteria etc.
11b. Both 11a and 11e.
11g. Protein- or amino acid electrophoresis + 11e.
11d. Outside school labwork activity.
11f. No DNA labwork experience at all.

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COPING WITH THE ABSTRACT AND COMPLEX NATURE OF GENETICS IN UPPER-SECONDARY BIOLOGY EDUCATION – INTERIM REPORT OF A DEVELOPMENTAL RESEARCH PROJECT

Marie-Christine P.J. Knippels, Arend Jan Waarlo & Kerst Th. Boersma
Centre for Science and Mathematics Education, Department of Biological Education, University of Utrecht, The Netherlands

1 Introduction

Genetics is known as one of the most difficult topics in biology courses for both students and secondary science teachers (Stewart, 1982; Finley et al., 1982; Bahar et al., 1999). Numerous studies concerning secondary school and university students, have reported difficulties students encounter in understanding the concept of inheritance (Smith & Simmons, 1992; Stewart & Hafner, 1994).

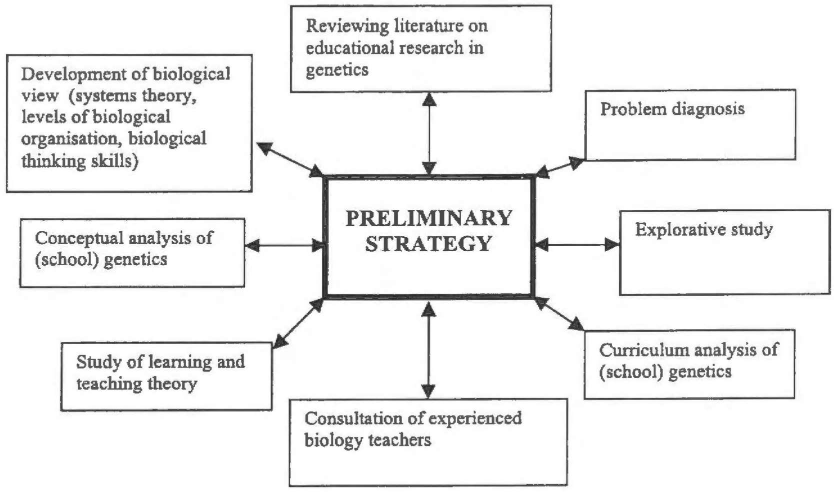
This study aims at developing an adequate and research-based educational strategy for learning and teaching genetics in upper-secondary biology education. The research approach can be characterised as 'developmental research' (Lijnse,1995).

2 Design of the study

Developmental research implies that in developing and testing adequate solutions to learning and teaching problems, both theory and teaching practice play an important role. Educational researchers and teachers co-operate in defining and developing learning activities and testing these in classroom settings. Several rounds are needed to optimise the strategy.

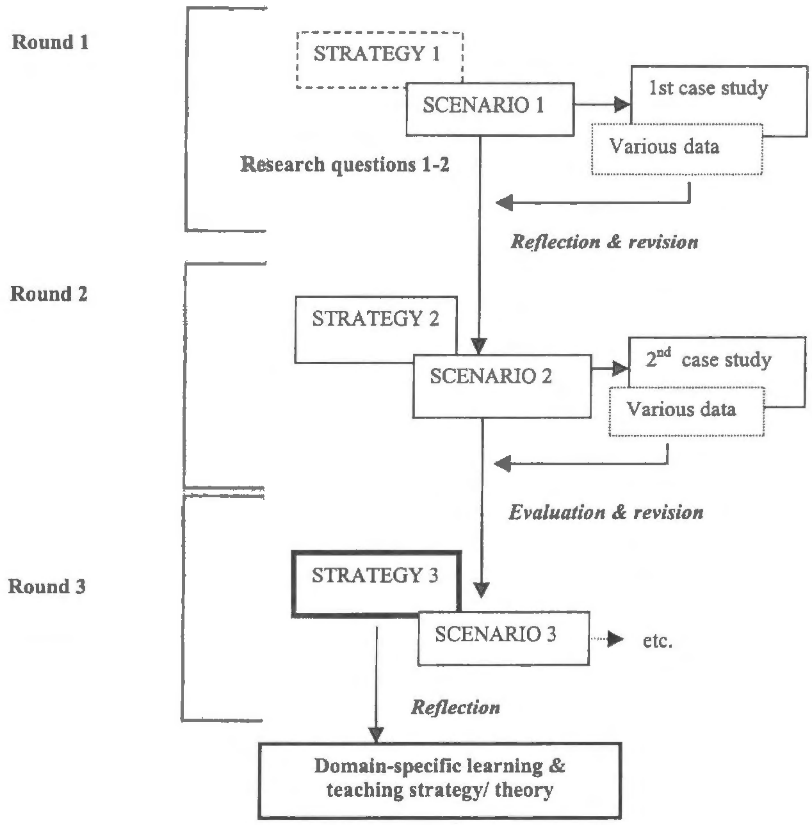
In this project three empirical cycles in different schools (case studies) have been planned, preceded by an analysis and an explorative stage. In the analysis stage, the main difficulties in genetics education were identified. In the following explorative stage, more in-depth data about these difficulties have been gathered using various sources, both theoretical and practical. Subsequently, focus was on idea building and defining criteria which an adequate learning and teaching strategy, based on these different sources, should meet (figure 1). A preliminary educational strategy has been constructed and tried out in practice.

Figure 1. Development of a learning and teaching strategy: an extensive interplay between various research activities and strategy-in-the-making



In the developmental research approach, the strategy will evolve in a process of cyclic empirical testing of scenarios, i.e. successive case studies (figure 2). A scenario is a context specific, detailed description of the expected teaching and learning processes, including teaching and learning activities and intended learning outcomes. It is a set of 'hypotheses' to test empirically the adequacy of the strategy. When the scenario runs in practice, data are collected and analysed in order to evaluate the scenario and its underlying strategy. Subsequently, the evaluation outcomes are being used to adjust the scenario and the strategy in order to make them more adequate. The revised strategy and scenario will be tested in a second case study, i.e. second empirical cycle. So, developmental research is a kind of learning process itself through reflection on research activities and findings, resulting in a domain specific learning and teaching strategy or theory (figure 2).

Figure 2. Cyclic development of a domain-specific learning and teaching strategy



3 Main difficulties in genetics education

In the analysis stage of the study, the main difficulties in teaching and learning genetics were identified by reviewing the literature and additional focus group interviews with 19 Dutch upper-secondary biology teachers. Two key issues were selected and are being addressed in this study, i.e. the *abstract and complex nature of genetics* (Knippels et al., 2000).

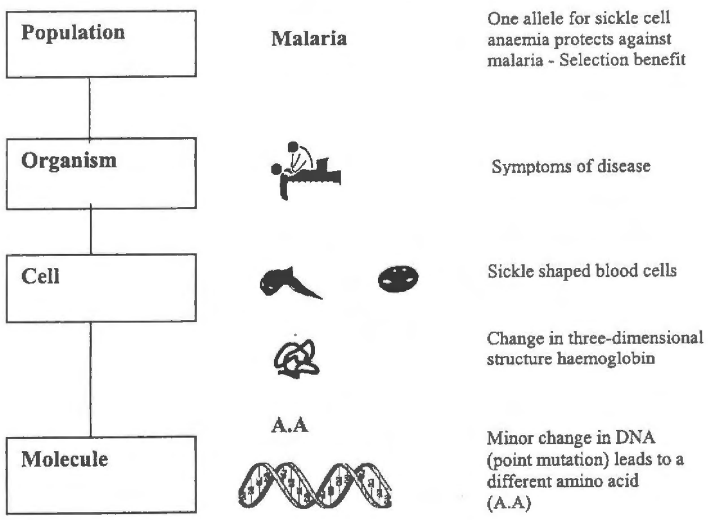
In teaching practice a separation in time and space of Inheritance, Reproduction and Meiosis results in abstract subject matter. The complex nature of the subject of genetics refers to the manifestation of heredity phenomena on different levels of biological organisation, and the corresponding use of different vocabularies. Adequate understanding requires backward-and-forward thinking between molecular, cellular, organismic, and population level and connecting the vocabularies.

The literature study also revealed that there is a gap between theory and practice: articles on genetics education are either research based, i.e. description and analysis, or can be characterised as practical notes. The former often get stuck in rather vague 'implications for educational practice' and the latter merely provide solutions to practical problems without scientific explanations. The developmental research approach promises to narrow the gap between theory and practice.

4 Need for explicit biological thinking

In this section the complex nature of genetics and the need for explicit biological thinking, will be illustrated by the example of sickle cell anaemia. It will be clear that in order to understand how a lethal genetic disorder could survive natural selection, one should be able to use the concept of 'heredity' on different levels of biological organisation. A minor change in DNA (point mutation) leads to a different amino acid, resulting in a change of the three-dimensional structure of haemoglobin and blood cells, which cause problems in the blood circulation and a lower oxygen absorption. This will result in symptoms of the disease (organismic level). On the population level sickle cell anaemia heterozygosity is related with protection against malaria. Due to this selection benefit the sickle cell allele remains in the population (see figure 3).

Figure 3. The complex nature of genetics: manifestations of sickle cell anaemia on different levels of biological organisation.



So, inheritance on the organismic level can be explained by describing phenomena on the lower levels and using different concepts. An adequate understanding requires backward-and-forward thinking between those levels of biological organisation. Biological thinking in general includes backward-and-forward thinking between levels of biological organisation and using appropriate vocabularies. A biologist (e.g. teacher) has interiorised this thinking skill and uses it automatically. Students trying to learn genetics get into trouble, because biology teachers and schoolbook authors often jump implicitly from one level to the other.

5 Towards an adequate learning and teaching strategy

In order to promote biological thinking skills and to overcome the identified learning difficulties, we started with idea building and defining criteria concerning an adequate learning and teaching strategy. In addition to the biological and genetic considerations discussed in the previous section, qualitative data were collected through various sources in an explorative study: twelve lessons of a traditional upper-secondary genetics course were observed and audio-taped. The open interview method was used to clarify the biology teacher's rationale of his genetics education practice. Furthermore, the 22 students were asked to keep a personal notebook in which they had to reflect on their learning outcomes, perceived difficulties, and questions that had come into their mind. Additional twelve face to face interviews were conducted and audio-taped, to gather more in-depth information on their observed and reported learning difficulties and to probe their genetic reasoning skills.
The audiotapes were transcribed and analysed by close reading of the protocols, and highlighting the genetic reasoning patterns of the students. The most salient results were, that students had difficulties in relating the process of meiosis with the content of the genetics lessons. During the genetics course the mono- and dihybrid crosses were discussed and the students had to solve genetics problems. In the interviews most students did not realise, or were unable to explain, the relationship between meiosis and the representation of a monohybrid crossing in a Punnett square. Some students literally said: *'I can't remember much about meiosis, because it was one year ago that the subject was taught'*, although they used this process implicitly every time they had to solve a monohybrid cross. Most students were well aware that both parents pass on genetic information to their offspring, but there was confusion about what exactly is passed on, and what the relationship is between the process and products of meiosis. Moreover, students had difficulties with the chromosome concept and especially with homologue chromosomes. They were either not aware of the fact that there are pairs of chromosomes, or they thought that homologue chromosomes were

identical. Students were often confused by genetics terminology. The findings are similar to those of Lewis *et al.* (2000a; 2000b).

Besides the explorative study, data were collected through iterative consultation of experienced biology teachers and through conceptual and curriculum analysis of (school) genetics. Gradually, promising learning activities and their sequence emerged and were transformed into a preliminary strategy for learning and teaching genetics.

So, the first educational strategy was based on the different research activities mentioned above and depicted in figure 1, and resulted from an extensive interplay between the analysed outcomes of these activities. This strategy, which aims at coping with the abstract and complex nature of genetics, meets the following criteria:

- To adequately sequence the subject matter, genetics education should start on the concrete organismic level students are familiar with, and gradually descend to the cellular level.
- The relationship between meiosis and inheritance should be dealt with explicitly.
- Two main lines, the somatic line and the germ line should be distinguished.
- Students should explore the relationships between the levels of organisation themselves (active and co-operative learning) guided by the structure of learning activities and/or teacher.

This preliminary strategy was elaborated into a scenario and tried out in the first empirical round (figure 2). The scenario consisted of 6 lessons, which met the main criteria stated above. The case study concerned two classes, 8 and 16 students respectively, of the highest levels of pre-university education (18 year old students). Qualitative research data originated from different sources: classroom observations; content analysis of completed worksheets, 24 written tests and 2 think aloud protocols of individual students; interviews with the teacher; teachers' reflections; students' logbooks; audio taped classroom and group discussions.

The intended learning outcome can be characterised as a competence: students should be willing and able to use genetics concepts meaningfully, i.e. they should be able to distinguish the levels of biological organisation, to see the relationships between those levels and to relate sexual reproduction and heredity.

The data derived from this first case study have been analysed in order to answer the following research questions:

1. How does the scenario work, i.e. what are the evoked learning processes and outcomes?
2. What indications can be extracted from comparison of the observed learning processes and outcomes with the scenario, for revising the learning and teaching strategy?

Based on the evaluation of the first case study, the scenario and the underlying educational strategy will be revised and tested in a second case study (figure 2).

6 The first scenario in practice

The first empirical round focused on generating new ideas and on experiences with the scenario and doing practical research. It was not yet a fully cut-and-dried strategy. There were practical restrictions concerning time and the period in the academic year in which genetics is taught.

The scenario of the first case study dealt with the relationship between meiosis and inheritance and with distinguishing the somatic line and the germ line. Students started on the organismic level by reflecting on external features, looking at themselves and their families, and giving examples of genetic traits. Students also had to elaborate on the influence of upbringing and environment on genetic traits. The purpose of this class discussion, which is the first part in the educational outline, is that students come across questions, i.e. how is it possible that you look like your parents, but are not identical to them? This activity came up to our expectations. Students wondered about what exactly genetic traits are. Their reactions incited the teacher to raise all kinds of questions, like the next transcript quotation will show (Teacher: *T*; Student: *S*):

T: *Oke, so now we are back to features like nasal profile, length of fingers, shape of the tongue. All genetic traits. But you said aids is hereditary? How do you inherit aids?*
S1: *From mother to child.*
T: *Yes, but how do you inherit it?*
S1: *When one of your parents is a carrier.*
T: *When one of the parents carries aids, the children will get it.*
S2: *Could be.*
T: *So, what we discussed in lower-secondary biology class about contamination and save sex, that was all for nothing?*
S1: *No, because it is also possible to get it when you are carrier of the disease and have sex with some one else, then you can pass it on.*
T: *Yes, is there anyone who can feel the differences between being a carrier of aids and being a carrier of an hereditary heart disease or breast cancer?*
S3: *Yes, heart disease and breast cancer are in the genes and aids is a virus, that's not in your genes.*
T: *But you could say that aids is a trait, whether it is hereditary or not?*
S4: *I think it is not hereditary, unless you get aids by a mutation in your genes.*
S3: *But when it is hereditary, then it only has to be due to the genes, so aids is not hereditary.*

After this introduction on the organismic level, groups of students had to solve a problem concerning the relationship between sexual reproduction and gamete formation (meiosis), i.e. 'How will the offspring be affected when a mutation occurs a) in the genetic material of a gamete b) in the genetic material of a colon cell? Explain your answer.'

Because students had to solve this problem in groups they had to explain their concepts of inheritance in their own words to each other. For students the main purpose of this task was to discuss their prior biological knowledge and to clarify their ideas. The group of students had to relate the features at the organismic level and cellular level themselves, and they had to distinguish between the somatic line and the germ line. The questions and difficulties they encountered in understanding and using the genetics concepts on a particular level of organisation, directed them to a next learning activity.

One of the following learning activities was a chromosome practical, in which students had to simulate processes and relate the genetic concepts on the organismic level (genetic traits, sexual reproduction) with the concepts and processes on the cellular level (meiosis, chromosomes, genes, alleles). A box with paper strips which differed in length and colour (representing chromosomes) was available for every group of students. Students had to pick four genetic traits of a well known family. Next, they selected three pairs of chromosomes out of the box in order to constitute a somatic cell of the father and a somatic cell of the mother. Subsequently, they needed to form gametes by the process of meiosis and finally to make a correct gamete combination for the offspring. So students have to relate various concepts and processes on the organismic and cellular level. This chromosome practical was successful, because students were enthusiastically discussing their genetic concepts and difficulties they encountered in simulating the processes. The visualisation of the genetic processes on the organismic level and cellular level and the fact that they had to actively carry it out with strips of paper and genetic traits of a real family, made them understand it much better.

So, the strategy in this first case study was based on *descending* from the organismic level via the cellular level (to eventually the molecular level) and relating the genetic concepts of these levels. The learning activities had been designed in a way that students would encounter problems (questions) which might motivate and invite them to participate in a next learning activity in order to answer their question. By co-operative learning the students got actively involved in the integration of new concepts into existing knowledge.

We saw that most students were able to descend from the organismic level to the cellular and that they could describe the relationship between meiosis and inheritance. The written test showed that 19 students (80 per cent) were able to connect the process of meiosis with, reproduction and inheritance, and to explain this relationship correctly. Especially in group work we saw that some students were able to relate the different processes very quickly, whereas other students still experienced difficulties. The advantage of co-operative learning was that students who understood it well could help the other students in the group discussions and assignments. Nevertheless, we think that we should add a kind of support for the students who get stuck, or are not able to keep up with the other group members.

Another problem that occurred during this first case study, was a cut back on the reflection time by the teacher. In a co-operative learning situation it is important to discuss the task with the whole class. Reflection is crucial in the learning process, because students get answers to questions that came up during their group work, and are helped to integrate new concepts into a biological framework. Learning activities were often time consuming, because they were relatively new to the teacher, and students had to fill in their personal logbooks at the end of every lesson, resulting in less or sometimes no time for reflection.

The strategy to descend from the organismic to the cellular level (and molecular level) was made clear to the teacher in the first case study. However, the levels of biological organisation themselves were not made explicit to the students and for a coherent understanding, students should also be able to ascend a level. It was our implicit assumption that when students were able to descend a level of biological organisation and to understand and relate the genetic concepts on these levels, they 'automatically' were able to ascend these levels and explain the corresponding heredity phenomena.

The written test at the end of the lessons showed that students were able to descend a level in their explanation, but they experienced difficulties in explaining heredity phenomena when they had to ascend. Students were asked to describe how the genetic trait 'eye colour' will pass on to a child of the parents and which processes are involved in the appearance of this trait in the child. They had to describe the processes on the molecular, cellular and organismic level. The test showed that most students were able to relate the process of meiosis with sexual reproduction. They correctly explained fertilisation and the new chromosome combination that was formed in the zygote. Also the allele combination that would determine the eye colour in the child was not a major problem to the students. However, they were not able to explain how these alleles gave rise to for instance brown eyes. So, the formation of proteins out of the DNA code, that could serve as enzymes in a the process of pigment formation, was a step most students were unable to make. The next transcript of the answer of a student on the written test will illustrate that she was able to descend the levels and relate the genetic concepts on these levels, but she could not explain how from the molecular level of the allele the pigment for the eye colour is formed.

St.: 'A man and a woman would like to have children. In their bodies gametes are formed by the process of meiosis. The sperm of the man fertilises the egg of *the woman after sexual intercourse. In the gametes 23 chromosomes are present with one gene for eye colour. Imagine that the man has blue eyes (bb) and the woman brown eyes (Bb). The allele for brown is dominant, so she has brown eyes. The possibilities after fertilisation are: BB, Bb, bb. The child has a 25% chance to get blue eyes (the alleles are divided in the process of meiosis). The combination of Bb is passed on to the child after fertilisation, and now the zygote contains this information. The zygote will divide and after 9 months a child with blue eyes will be born'.*

Summarising, the levels of biological organisation were not made explicit enough to the students and our assumption that when students were able to descend a level they also could automatically ascend one, was incorrect. Therefore, we concluded that students should be made more aware of the change in levels and these changes have to be logical and meaningful to them. The scenario has to be refined and adjusted in order to make the transition from one level of biological organisation to the other more explicit and effective for students.

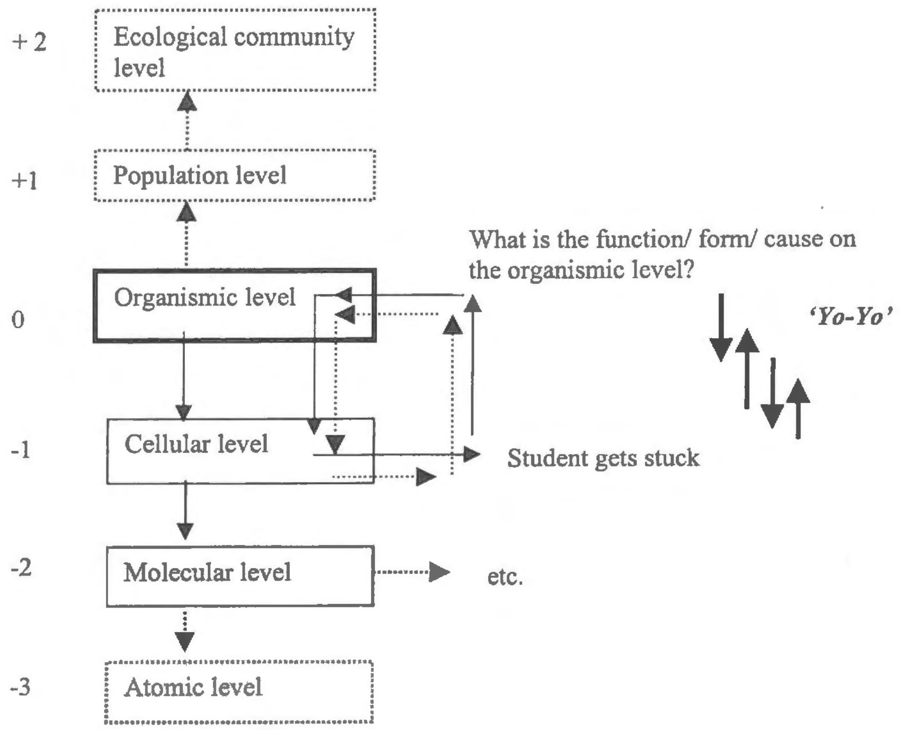
7 'Yo-yo learning'

The first case study gave rise to a new idea and revision of the learning and teaching outline. Most design criteria still seem adequate, like the emphasis on the relationship between meiosis and inheritance, the use of an active learning approach, and to start genetics education on the concrete organismic level. The sequence of the subject matter seems suitable too, but could be refined in favour of the students that still had some difficulties, and in order to make the levels of biological organisation more explicit for students.

So, the main idea risen after the experiences with the first case study, is that students should not only be able and willing to *descend* a level of biological organisation, they also should be able to *ascend* a level. The essence of this strategy might be indicated as *'yo-yo learning'*, because students are invited to think up and down between levels of biological organisation. The toy yo-yo also goes up and down guided by the person who handles the yo-yo. The yo-yo strategy could help students to solve their problems when they get stuck. Secondly, descending and ascending levels of biological organisation will help students to gain this 'biological thinking skill' step by step. Emphasis is on real understanding of genetics concepts on different levels of biological organisation and their interrelations.

The intended sequence of learning and teaching activities will not change drastically and the yo-yo strategy can be outlined as follows. Students should start on the concrete organismic level, i.e. the level they are already familiar with. Then they gradually *descend* to the next levels, switching to another level only after understanding what is going on on the level under consideration (figure 4).

Figure 4. The 'yo-yo' learning and teaching strategy



However, when students get stuck, they have to *ascend* one level and ask themselves what is the function (and/or form, cause) of the subject, item, process on that higher level, i.e. the level which they are already familiar with, but still have some difficulties with. An example of getting stuck is, when a student can't figure out whether homologue chromosomes are identical to one another or not. Ascending one level includes questions like, are children identical to their parents? Do they 'get' their genetic information from their father or from their mother, or from both? What process determines the genetic make up of the offspring? What causes the formation of pairs of chromosomes? Having answered these questions, they can descend again. When students are familiar with the cellular level, i.e. they can use the genetic concepts meaningfully on the cellular level, they can descend further to the molecular level by the same strategy. Some students may need to go 'up and down' more often then others due to differences in prior knowledge, genetic understanding and thinking skills.

At first, students should be stimulated to ascend a level, and try to answer their questions on that level. This should be guided by the teacher and/ or a learning activity. In the course of time students hopefully will be able to do this single-handed.
Ultimately, when students can use the main processes, functions, terminology and concepts on all those levels (from organismic to molecular) by means of this strategy, they also can think backward-and-forward between those levels. The desired learning outcome would be established, i.e. they are competent to use genetic concepts on the different biological organisation levels and see the relationships between reproduction and heredity.
Based on the insights and evaluation of the first case study, it is reasonable to expect that the second case study will give even more insight into what an adequate learning and teaching strategy to cope with the abstract and complex nature of genetics could be.

Acknowledgement

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INTERACTIONS BETWEEN STUDENTS' CONCEPTIONS OF THE DIGESTIVE SYSTEM AND THE TEACHING PROCESS

Xavier Muñoz Bàguena[1] & Manuel Puigcerver Oliván[2]
[1]Escola Pia Sant Antoni. Barcelona. [2]Universitat de Barcelona.

1 Introduction

The structure and composition of the digestive system is, probably, one of the subjects in which secondary school students have more misconceptions. This finding is mainly due to the popularity of the subject and also to its late introduction into the curricula. Pérez de Eulate et al. (1996) report that students in Spain are first introduced to the digestive system at 8-9 years old, but this subject can be delayed until 9-10 years old.

Usually, the digestive process is taught from an anatomical point of view, as it is the basis and starting-point from which to teach how nutrients are transformed. Therefore, we cannot consider the anatomy of the digestive system as just an isolated and purely memorizable aspect of this unit. With this regard, Banet and Núñez (1989) consider that the learning difficulties and knowledge gaps associated with the digestive anatomy hinder the learning study of the digestive process.

Previous research has shown many conceptual errors involving not only the anatomy but, consistently, the digestive process. For example, Banet and Núñez (1988, 1992) highlight that 10-11 years olds consider that, "good" food is separated from "bad" food during digestion (thereby generating, according to Benlloch 1984, a "rubbish bag"), and that the liver and pancreas are connected with the digestive system through the stomach. In their sample, 10 % of the students established links between the lungs and digestive system, and 10-20 % (depending of the course) were unaware of the liver. Moreover, 14 year-old children usually order the small and large intestines incorrectly. According to Giordan's findings (1982), liquids and solids are thought to follow separate pathways, the stomach being the center of the digestive process. This observation has been confirmed by other studies (De Vecchi and Giordan, Gené 1986, Giordan 1987, Giordan and Martinand 1988, Cubero 1988, Banet and

Núñez 1988, 1989, Sauvageot-Skibine 1991 and Pérez de Eulate 1992). In general, it seems that schools are unable to establish alternative learning frameworks for students.
Moreover, Giordan and de Vecchi (1988) show that the alternative anatomic digestive systems described by students show increasing complexity which is not associated with their age. These authors suggest that the complexity of the students' models depend on their degree of understanding.
This study aims to examine the interactions between students' conceptions of the anatomy of the digestive system and the teaching process as an evaluation study. We used a sample of 111 students aged 14, and analysed three variables: a) the degree of complexity of the models of the digestive system; b) the degree of correctness of the models; and c) the diversity of the models. This approach allowed us to test whether complexity is associated with a degree of correctness or, alternatively, whether the teaching process allows an increase in complexity but not in correctness.

2 Material and Methods

This study used a sample of 111 students aged 14 from a school in Barcelona (Spain). Students were monitored during the academic years 1997-98 and 1998-99. They had previously studied the digestive system at 10 and at 13 years old.
Students were required to draw a model of the digestive system, and give a brief written explanation, at three points in time:
Stage I: before teaching, to detect students' misconceptions.
Stage II: after teaching, to evaluate the efficiency of teaching.
Stage III: one year later, to evaluate the evolution of learning.
With regard to the teaching, five one-hour sessions were given. During this time, students acquired information on the topic, either by using resources available in the classroom or by using their own resources. They then prepared an individual report on the most relevant aspects of the anatomy and physiology of the digestive system; communication of the main issues of the topic was made in some cases, stimulating students to make suggestions and comments. Finally, a summary of the reports and the lectures was made by the teacher.
Drawings are "open" tests, in which students are not forced to answer in a certain way, and are therefore not influenced by the teacher's opinion. We have developed a method to codify these drawings (Muñoz and Puigcerver, *in prep.*). In brief, each structure (i.e. bag structures, tubular structures...) and topological relationships between them (i.e. continuity, ramification or other) have been represented by a character of a string which shows the full model (see Table 1).

Table 1. Codes used to resume drawings of the digestive system in a string of characters.

Communication with exterior:		**Topological relationships:**	
Way in	E	Continuity	
Exit	S	Ramification	[ ]
Bag-like structures:		Other	{ }
Simple bag	B	**Organ connections:**	
Complex bag	V	Connection	( )
Tubular structures:		Liver	f
Simple tube	T	Pancreas	p
Zigzag tube	C	Kidney	r
Spiral or bent tubes	@	Lungs	l
Labyrinthine tubes	L	Heart	c
Simple tubular handle	A	Unidentified organ	?
Isolated tubular structures	U, O, Q		
Appendix	X		

This coding system encompasses all the topological information from the drawings in a variable constituted by a string of characters. This allowed us to calculate indexes of complexity and correctness for each model of the digestive system, together with a diversity index of the models in each of the three stages mentioned.
The complexity index, Ic, was designed to show not only the number of elements integrating the system, but also the number of connections between them. To calculate this index, we arbitrarily associated the basic component of the system with a score (Table 2). Thus, if a simple rectilinear tube has a score of 1 in terms of complexity, a zigzag tube (a more complex structure) has a score of 2. Therefore, the value of Ic is obtained by adding the indexes of each component of the string which summarizes it.

Table 2. Value of complexity associated with each component of the system

Ic_n	Components
1	E, S, T, A, U, O, Q, X, B, (, [
2	C, @
3	L
4	V
0	All other components

$Ic = \Sigma\, Icn$

The correctness index, A, is calculated by comparing the string of characters of each model with that of the correct model. To obtain the correct string from an incorrect one, the number of translocations (changes in the position of one or more elements), additions (new elements to add to the string) and omissions (suppression of elements) is considered. The algorithm to calculate the correctness index is shown in Figure 1.

Figure 1. Algorithm to calculate correctness index, A

Translocation	ABCED	$\Rightarrow$	ABCDE	At
Addition	ABDE	$\Rightarrow$	ABCDE	Aa
Omission	ABCFDE	$\Rightarrow$	ABCDE	Ad

$$A = 10^2 \sqrt{At^2 + (2 * (Ad + Aa))^2}$$

The diversity index of the models was calculated by applying Simpson's index (Margalef 1981), which was applyied to study the diversity of ecosystems. This index (see algorithm) calculates the probability of non-coincidence of the models of two randomly chosen students. When the population is homogeneous, the value of the index is zero, and when diversity is absolute, the value is 1.

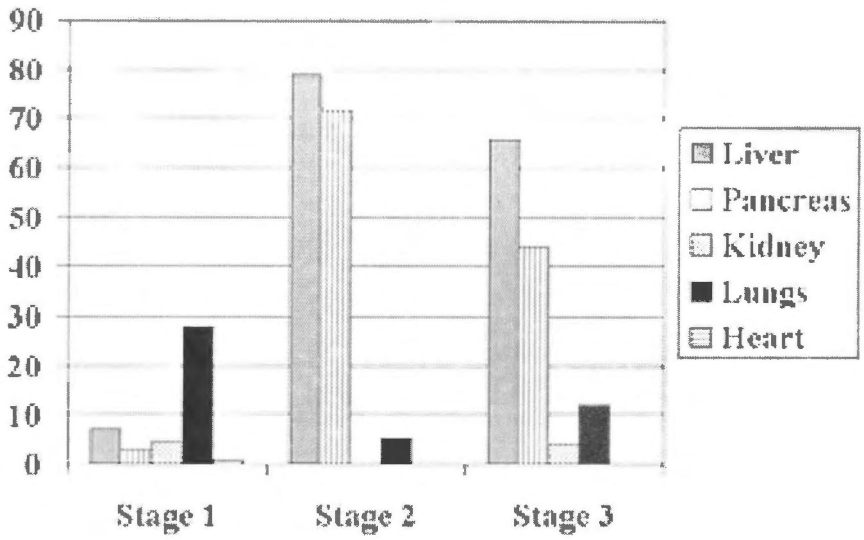
Figure 2: Algorithm to calculate the diversity index

$$k = \frac{\sum N_i(N_i - 1)}{N(N-1)}$$
$$D = 1 - k$$

3.- Results and Discussion

In Stage I, we detected an extremely high diversity of digestive system models (76); subsequently, the diversity index, D, was close to one (0.9814). A large number of models in this stage showed no exit (21 %), whereas other models showed more than one. The structure mouth-oesophagus-stomach appeared in almost all the drawings, whilst a high diversity of structures after the stomach was observed, strongly suggesting that diversification occurs at intestinal level. The liver and pancreas were poorly drawn but, in contrast, 28 % of the students connected lungs to the digestive system (Figure 3).

Figure 3. Percentage of students connecting distinct organs (liver, pancreas, kidney, lungs and heart) to the digestive system throughout the three stages of the study. At Stage I, the liver and pancreas were poorly drawn, whereas surprisingly, lungs were depicted quite well.



Complexity was clearly lower than that of the correct model (Correct Ic= 12; mean Ic at Stage I=8) (Figure 4). Similarly, the correctness of the models was clearly lower than that of the correct model (Correct A=0; mean A at the Stage I = 1140) (Figure 5).
At Stage II, after teaching, we found that the diversity of models slightly decreased, although it was still high (diversity index D = 0.9557); 61 distinct models were detected, and all the former models had been altered. Correctness and complexity increased, reaching the latter the levels of complexity of the correct model; however, few students drew an accurate diagram of the correct model (Figures 6 and 7).
In this stage, the number of "closed" models decreases (5.4 %), and there were no models with a double exit. The stomach was clearly a basic structure for almost all the students (only 4.5 % of the students drew models without this organ), the liver and pancreas were present in a high number of models, while the connection of lungs to the digestive system decreased remarkably (Figure 3). However, we found that new errors appeared at intestinal level.

Figure 4. The complexity index of the digestive models drawn by the students at Stage I. The correct model has an Ic value of 12.

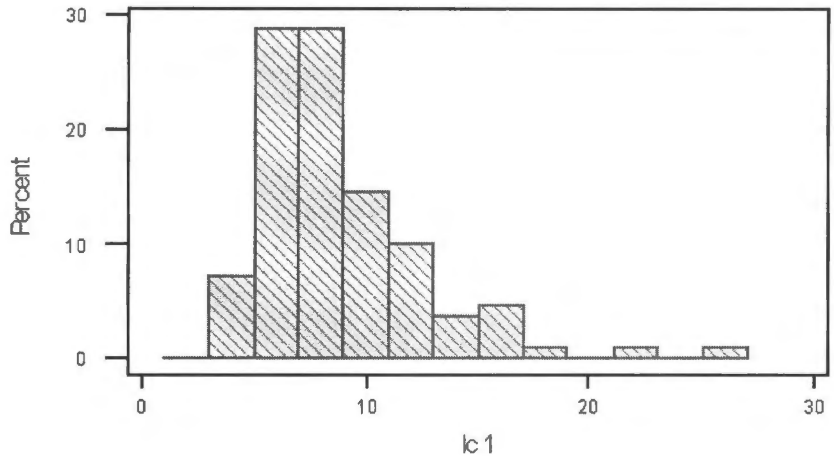


Figure 5: The correctness index of the digestive models drawn by the students at Stage I. The correct model has an A value of zero.

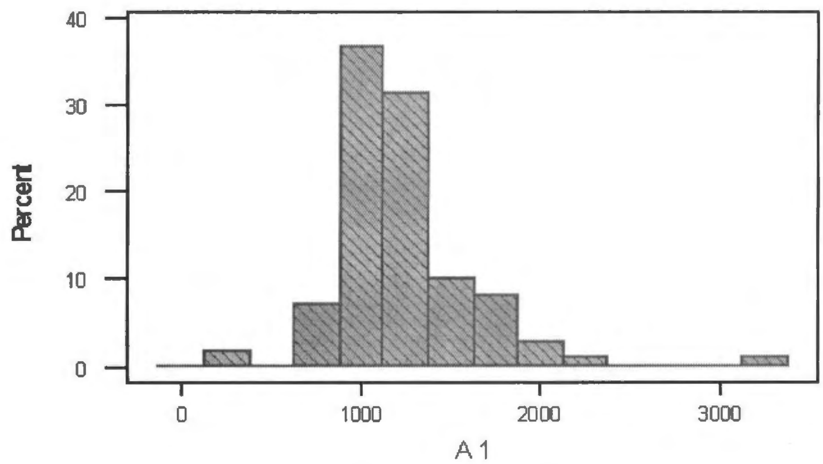


Figure 6. The complexity index of the digestive models drawn by the students at Stage II. The correct model has an Ic value of 12.

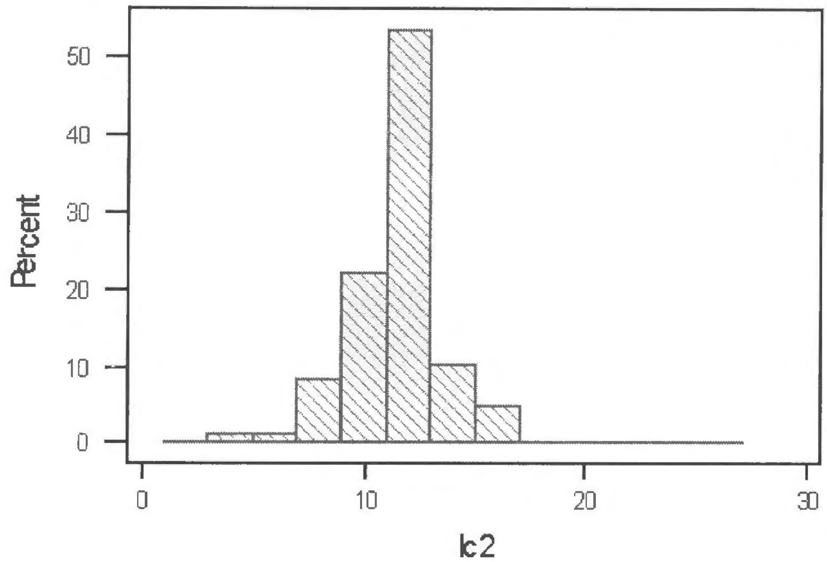
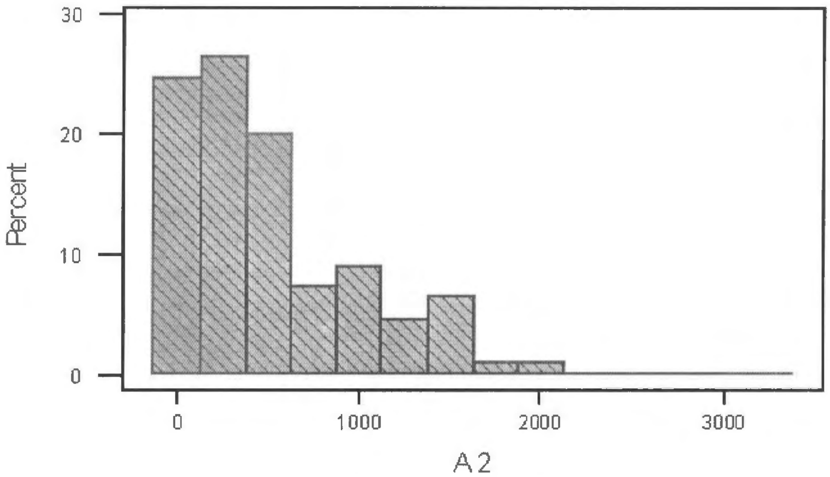


Figure 7. The correctness index of the digestive models drawn by the students at Stage II. The correct model has an A value of zero.



By comparing the evolution of the models of each student, we can affirm that individual correctness and complexity of Stage I do not determine those of Stage II.

In Stage III, one year later after teaching, we found that diversity was greater than that observed in Stage I, with 47 distinct models from 49 students. The diversity index in this stage was: D= 0.9974. Complexity levels were quite similar to those of Stage II, suggesting that teaching produced an increase in the complexity of the models. (Figure 8). However, we found that the correctness index decreased in Stage III, although it did not reach the levels observed in Stage I (Figure 9).

Figure 8. The complexity index of the digestive models drawn by the students at Stage III. The correct model has an Ic value of 12.

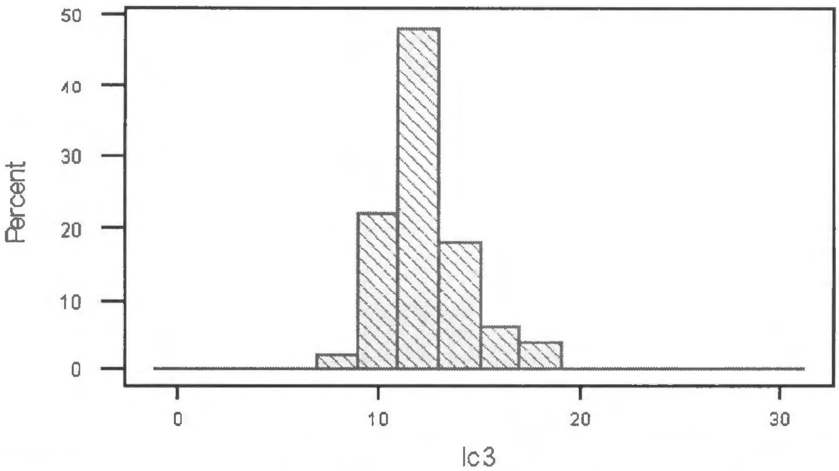
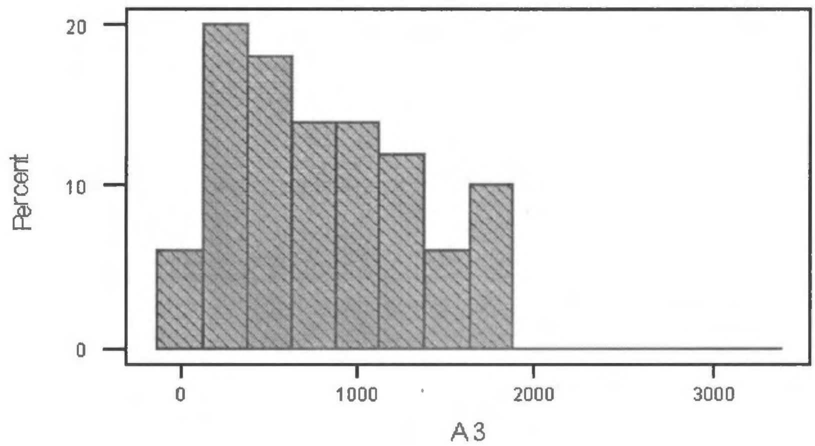


Figure 9. The correctness index of the digestive models drawn by the students at Stage III. The correct model has an A value of zero.



In Stage III there were no "closed" models (models without exit), and models with more than one exit were repeated (6 %); however, these latter were new models, that is to say, they appeared "ex-novo" and cannot be considered a regression towards incorrect old models. Moreover, we detected that the initial structure mouth-oesophagus-stomach consolidated (76-84 %) and that structures at an intestinal level remained unclear, with labyrinthine structures, ramifications of the duodenum-colon section, and other mistakes.

Figure 10. Evolution of the complexity index (Y axis) in the three stages (X axis). Horizontal line inside the box indicates the median value, the top of the box indicates the percentile 75 (Q3) and the bottom the percentile 25 (Q1). The upper limit, at the end of the vertical line is calculated as: Q1-1.5 (Q3-Q1), whereas the lower limit is calculated as Q3+1.5 (Q3-Q1). Asterisks represent values over the upper and lower limits.

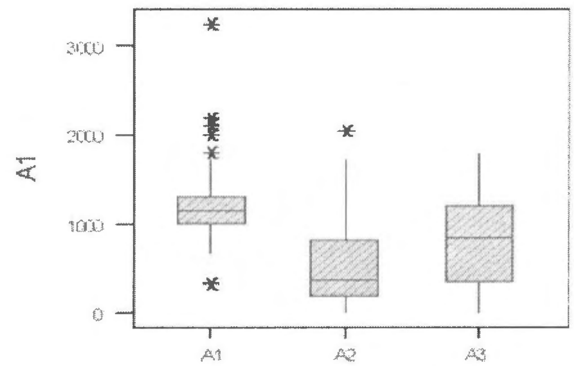
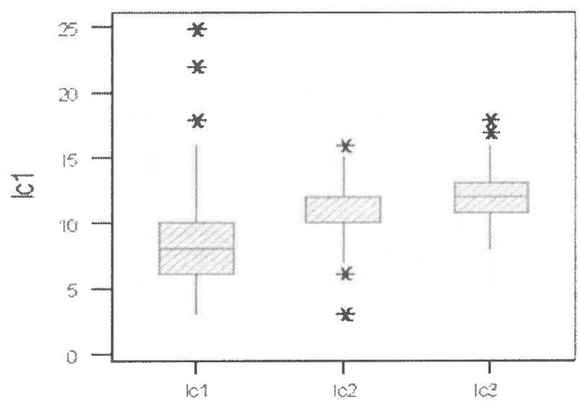


Figure 11. Evolution of the correctness index (Y axis) in the three stages (X axis). See caption of figure 10 for legend.



The liver and pancreas were, unfortunately, less drawn in the models of this stage and moreover, connections of lungs to the digestive system once again increased (12 % of the students) (Figure 3).

From a global perspective (Figures 10 and 11), we conclude that the teaching process produced an increase in the complexity of the models drawn by students, because new elements were incorporated; however, this increase does not imply a rise in correctness. In fact, correct models of Stage II rapidly derivate in Stage III to other incorrect models that have a similar degree of complexity, thus producing an increase in diversity. Therefore teaching seems to produces more complex but incorrect models. As we have exposed above, correctness improved from stage I to stage II, but this correctness evolved rapidly to lower levels due to the loose of relationships previously acquired, to the disappearance of elements like liver and pancreas and to the introduction of errors "ex novo".

Our results show that teaching does not produce homogeneity in the students' understanding of the digestive system, as shown by the high diversity of models in Stage III and, subsequently, the lack of common models, apart from the consolidated macro-structure mouth-oesophagus-stomach.

The main problems in students' concepts of the digestive system appear at the intestinal level, as they drew double pathways, there was a lack of connection between the small and large intestines, and other mistakes were detected. Moreover, because of the evolution showed in Figure 3, which indicates that the understanding of annex organs is still not consolidated, special attention should be paid by the teacher on this point. The surprising association between lungs and the digestive system did not disappear after teaching. Therefore we suggest that it is necessary to teach not only the topological aspects of the anatomy related to the digestive system, but also the functional aspects concerning the system, its annex organs and the function of other organs, especially the lungs.

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STUDENTS' UNDERSTANDINGS ABOUT ORGANS AND ORGAN SYSTEMS IN DIFFERENT ANIMALS

Michael Reiss & Sue Dale Tunnicliffe
Homerton College, Cambridge CB2 2PH, UK

Abstract
A number of studies have looked at children's understanding of human organs and organ systems. However, almost nothing is known about what, if any, differences there are between what children know about human organs and organ systems and those of other animals. In this study, a cross-sectional approach was used involving a total of 193 students from six different age groups (ranging from 5 year-olds to undergraduates - adults mostly aged about 20 years). Students were presented, on separate occasions, with dead specimens of a brown rat (*Rattus norvegicus*), a starling (*Sturnus vulgaris*) and a herring (*Clupea harengus*) and asked to draw what they thought was inside each specimen. On a final occasion, they were also asked to draw what they thought was inside themselves.
Repeated inspections of the completed drawings allowed us to construct a seven point scale with levels ranging from level 1 (no representation of internal structure) to level 7 (comprehensive representation with four or more organ systems indicated out of eight: skeletal, gaseous exchange, nervous, digestive, endocrine, urinogenital, muscular and circulatory). Our analysis shows such things as the degree to which students know more about human organs and organ systems than other animals. Our findings are interpreted with reference to the current English Science National Curriculum and we are interested in seeing how studies in other countries would compare.

1 Background and Context

As is widely acknowledged, there are many ways of gathering information about students' understandings of scientific phenomena (White & Gunstone, 1992; Tunnicliffe & Reiss, 1999a). However, despite the richness and variety of the methods used by science educators, it remains the fact that most of these methods rely on students either talking or writing about science. Such approaches have their own particular advantages and disadvantages but we wanted in this study to use an approach which relied less on words. We hope that the approach adopted here is less likely than approaches that rely solely on words to disadvantage students who are very shy in conversation, students who lack certain linguistic skills and students who speak a language (or languages) other than that used by the researcher. This last point means that drawings should be of especial value for international comparative studies.

It may be that different methodologies reveal different things about the multi-dimensional complexity usually labelled 'understanding' but better recognised as 'understandings'. On this argument, the appropriateness of drawing as the eliciting device used here is partly this provides a particular view of certain distinctive aspects of each student's understandings.

In this study we report on students' understandings of the internal structures of themselves and of three other vertebrate animals (another mammal, a bird and a fish). We decided on a cross-sectional approach in which students of different ages would simply be asked to draw what they thought was inside themselves. While we do not wish to imply that drawings are necessarily superior to other ways of elucidating understandings, they do have certain worthwhile features in addition to their lower reliance on the use of language.

In particular, there is perhaps a certain appropriateness in asking subjects to represent (albeit in two dimensions) anatomically their own anatomy. In the language of Buckley, Boulter & Gilbert (1997) and Gilbert, Boulter & Elmer (in press), such representations can be viewed as the expressed models - that is, representations of phenomena placed in the public domain - of the students. These expressed models relate to (but do not equate with) the mental models - i.e. the private and personal cognitive representations - held by the same students.

By now a considerable literature exists about the use of drawings as a research technique in education. As far as students' knowledge, as revealed by drawings, of what is inside themselves goes, perhaps the most thoroughly studied organ system is the skeleton (Caravita & Tonucci, 1987; Guichard, 1995; Cox, 1997; Tunnicliffe & Reiss, 1999a). Those research reports and papers that have looked at other human organ systems have often reported valuable data (notably Gellert, 1962; Carey, 1985; Osborne, Wadsworth & Black, 1992; Teixeira, 1998; Selles & Ayres, 1999) but we are unaware of any work that looks at what students' know is inside themselves compared to what they know is inside other animals.

2 Methodology

Fieldwork was carried out in the South of England in a primary school, a secondary school and a college of higher education. The primary school (for 4/5 to 11 year-olds) is a state Church of England aided school and is in a New Town (established after the Second World War); the secondary school (for 11 to 16 year-olds) is a state comprehensive in a rural setting; the College of Higher Education contains mainly four year Bachelor of

Education students training to be primary teachers. SDT carried out the primary fieldwork; MJR carried out the secondary and undergraduate fieldwork.

On separate occasions, the students were presented with a single dead specimen of a brown rat (*Rattus norvegicus*) (stuffed), a starling (*Sturnus vulgaris*) (stuffed) and a herring (*Clupea harengus*) (fresh). On each occasion the students were then asked to draw what they thought was inside the specimen when it was alive. The precise words used depended on the age of the students but were along the lines of 'What I'd like you to do is to draw, please, what you think is inside this animal'. A few students checked whether we meant that they should draw what was inside the animal when it was alive or now that it was dead. In these cases, we assured them that we were interested in what they thought was inside the animal when it was alive.

Students were not examined under formal examination conditions but were told not to copy each other's work. On the final occasion, the students were asked to draw what they thought was inside themselves. Students were given about 10 minutes to complete each drawing and also asked to write their name on it. A note was also made by us of the sex of each student. Many of the students labelled their drawings. Students who asked us if they could/should label their drawings were told by us that they certainly could if they wanted to and that it was up to them. The teacher wrote labels on the drawings for children if they requested it; this was particularly the case with the 4 and 5 year-olds. In these cases the teacher only wrote words said by the child. Two of the youngest (Reception) children asked the researcher to draw the outline of a presented animal and the researcher did so.

The fieldwork was conducted in whole class settings. Because the specimens were presented on separate occasions (typically about a week after the previous presentation) sample sizes vary within each age group across the four species drawn. In all, data were obtained from 21 Reception children (aged 4 or 5), 38 Yr. 2 children (aged 6 or 7), 36 Yr. 3 children (aged 7 or 8), 35 Yr. 6 children (aged 10 or 11), 25 Yr. 9 children (aged 13 or 14) and 38 undergraduates (mostly aged 18 to 22 but with a few significantly older). In the primary and the secondary school, all pupils were in mixed ability groups. The undergraduates were from a teacher training institution which, of the 52 institutions in the sector, has the highest average academic qualifications of its intake in England (Barnard, 1998). The undergraduates who participated came from two separate student groups. One group of 18 were all English specialists, none of whom had studied biology after the age of 16. The other group of 20 were all biology specialists, all of whom had studied biology after the age of 16. (In England and Wales it has been compulsory since 1989 for students to study science, including biology, up to the age of 16.) The biology undergraduates all knew MJR as their lecturer; the other students in the study knew MJR or SDT only slightly if at all.

3 Analysis

The students made a total of 617 drawings. After we had collected all the drawings, we jointly and repeatedly sorted through them, attempting to arrange them in a ranked order which we felt reflected different levels of biological understanding. We were also extremely keen to provide a scoring system which gave as little credit as possible to the 'artistic' quality of the drawing and was as unambiguous as possible to score. Some of the older students professed an inability to draw well and we assured them that this did not matter. No notice was taken of the student's ages in determining the scoring system.

Eventually, we agreed on the following order for the biological quality of each drawing:

Level 1	No representation of internal structure
Level 2	One or more internal organs (e.g. bones and blood) placed at random
Level 3	One internal organ (e.g. brain or heart) in appropriate position
Level 4	Two or more internal organs (e.g. stomach and a bone 'unit' such as the ribs) in appropriate positions but no extensive relationships indicated between them
Level 5	One organ system indicated (e.g. gut connecting head to anus)
Level 6	Two or three major organ systems indicated out of skeletal, gaseous exchange, nervous, digestive, endocrine, urinogenital, muscular and circulatory
Level 7	Comprehensive representation with four or more organ systems indicated out of skeletal, gaseous exchange, nervous, digestive, endocrine, urinogenital, muscular and circulatory.

This scoring system requires a definition of organ systems. We used the following definitions for the eight organ systems:

Skeletal system	Skull, spine, ribs and limbs.
Gaseous exchange system	Two lungs, two bronchi, windpipe which joins to mouth and/or nose.
Nervous system	Brain, spinal cord, some peripheral nerve (e.g. optic nerve).
Digestive system	Through tube from mouth to anus and indication of convolutions and/or compartmentalisation.
Endocrine system	Two endocrine organs (e.g. thyroid, adrenals, pituitary) other than pancreas [scored within digestive system] or gonads [scored within urinogenital system].

Urinogenital system	Two kidneys, two ureters, bladder and urethra *or* two ovaries, two fallopian tubes and uterus *or* two testes, two epididymes and penis.
Muscular system	Two muscle groups (e.g. lower arm and thigh) with attached points of origin.
Circulatory system	Heart, arteries and veins into and/or leaving heart and, at least to some extent, all round the body.

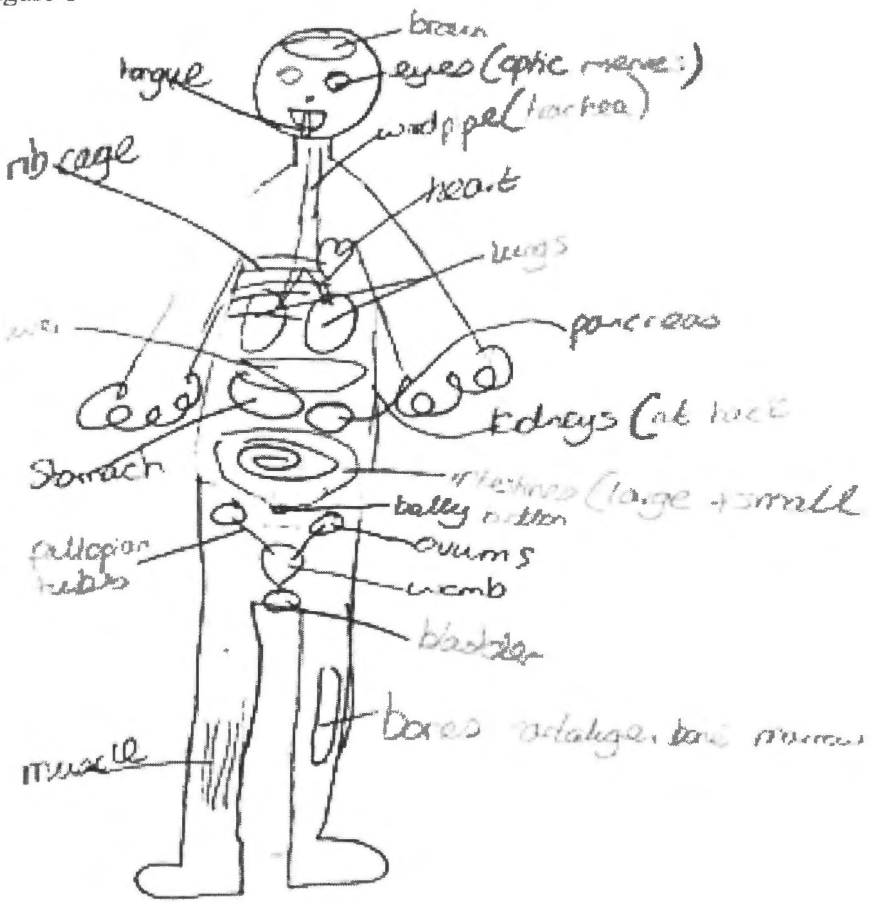
As is apparent, we therefore used the same, human definitions for organ systems when scoring each drawing, whether it was of a human, a rat, a starling or a herring. Our reasoning was that had we chosen to score each drawing on species-specific criteria (for example, air sacs in the starling), we would simply have shown that students know less about what is inside non-humans that they know about what is inside humans. Given the almost complete absence in current English biology curricula of any non-human anatomy, this finding is an obvious one. Instead, what we are looking at in part is the extent to which students presented their knowledge of internal human anatomy within their drawings of a rat, a starling or a herring. At the same time, we also made a complete list of every occasion on which a drawing showed some non-human internal feature.

The two of us then separately and independently scored all the drawings. Having agreed on the level (i.e. 1, 2, 3, 4, 5, 6 or 7), we then, for each of the eight organ systems, decided whether or not the drawing met the criterion for that organ system. If it did, we recorded the appropriate capital letter (S for skeletal, G for gaseous exchange, etc.). If it did not, we then decided whether or not at least one organ was present on the drawing for that organ system. If one was, we recorded the appropriate lower case letter (s for skeletal, g for gaseous exchange, etc.). Each drawing was therefore effectively scored a total of 17 times, once for the overall level, once for the presence or absence of each organ system and once for the presence or absence of at least one organ in each organ system. We agreed on in excess of 95% of scorings. In those cases where our views differed, we discussed each such case until we agreed.

To illustrate our analysis, Figure 1 shows the drawing done by a Year 9 girl (aged 14 years) of what she thought was inside herself. The drawing is scored 6GUsgndumc. In other words, the drawing shows two satisfactory organ systems - namely, the gaseous exchange and urinogenital systems - and seven of the eight possible organ systems - skeletal, gaseous exchange, nervous, digestive, urinogenital, muscular and circulatory - omitting only the endocrine system.

Data were entered into Minitab and Excel for analysis. All statistical tests are 2-tailed.

Figure 1



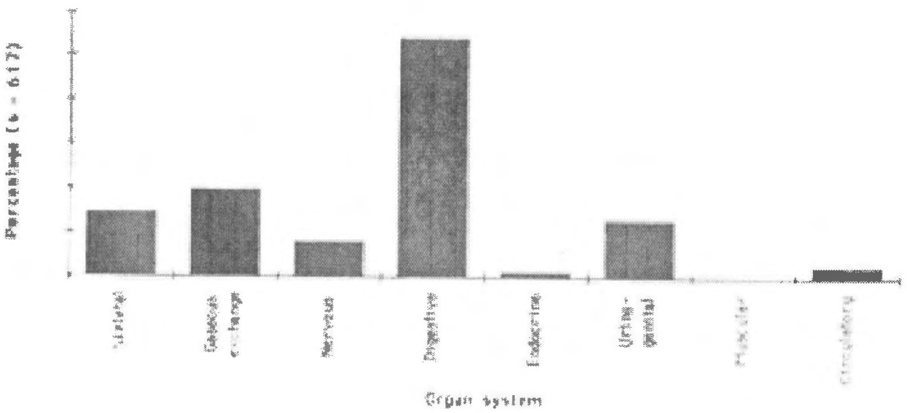
4 Results

Students' Understandings of Organ Systems

Lumping together all the data, and thus ignoring differences between the drawings resulting from student age, gender, degree of biology specialism or the species being drawn, Figure 2 shows for each organ system the percentage of students whose drawing displayed an organ system as defined above in the Analysis section above. Two main findings are clear. First of all, for each of the eight organ systems, only a small minority of drawings show the organ system drawn sufficiently completely to be classified by us as an organ system. By way of illustration, in Figure 1 –one of the better drawings done by the 14 year-olds– just two of the eight organ systems are shown sufficiently to be classified as organ systems.

Secondly, there are statistically significant differences between the eight organ systems in terms of how well they are represented ($c^2 = 192$; 7 df; $p << 0.001$). The best drawn organ systems is the digestive system represented in 11% of the drawings. At the other extreme, none of the drawings represented the muscular system, only 0.2% the endocrine system and only 0.5% the circulatory system as defined by us.

Figure 2

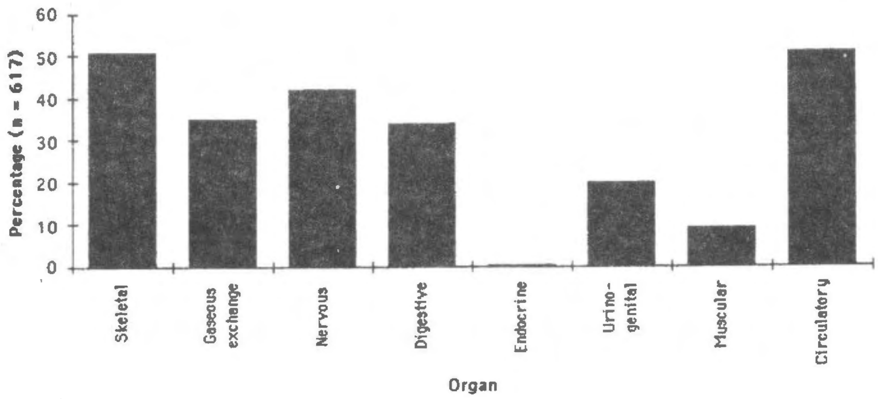


Students' Understandings of Organs

Again lumping together all the data, and thus ignoring differences between the drawings resulting from student age, gender, degree of biology specialism or the species being drawn, Figure 3 shows for each organ system the percentage of students whose drawing represented an organ (rather than the entire organ system) as defined above in the Analysis section.

Not surprisingly, students do much better at this than at representing whole organ systems. For example, 51% of the drawings showed some portion of the skeletal system and 51% showed an organ (nearly always the heart) in the circulatory system. At the other extreme, only 0.5% of the drawings showed a part of the endocrine system. However, we do acknowledge that this last result is undoubtedly largely caused by our very narrow definition of what counted as being part of the endocrine system. In particular, we excluded the pancreas (which we classified as belonging to the digestive system) and the ovaries and testes (classified as belonging to the urinogenital system).

Figure 3



As was the case with whole organ systems, there are highly statistically significant differences between the likelihood of students drawing organs from the different organ systems ($c^2 = 505$; 7 df; $p \ll 0.001$). There are also certain clear differences between the rankings in Figures 2 and 3, notably with respect to the circulatory system which is poorly represented as a whole system (Figure 2), yet components of which are very frequently drawn (Figure 3). Indeed, there is no significant correlation between the rankings of how well represented whole organ systems and partial organ systems are ($r_S = 0.38$; $0.2 < p < 0.5$).

The Levels at which the Drawings are Drawn and Species-specific Differences

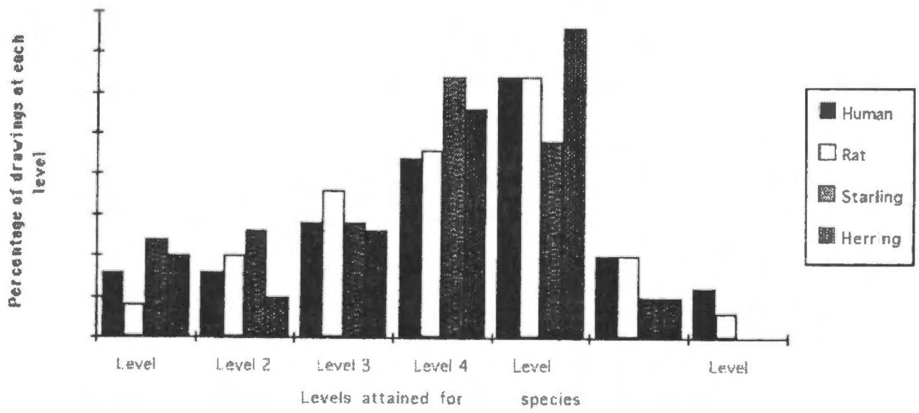
The data below show the percentage of drawings at each level, differentiated by the species being drawn:

Level	Human (n = 158)	Rat (n = 158)	Starling (n = 165)	Herring (n = 136)
1	1%	1%	4%	0%
2	9%	9%	12%	16%
3	5%	14%	10%	8%
4	50%	53%	51%	62%
5	16%	14%	18%	12%
6	13%	8%	5%	1%
7	6%	1%	0%	0%

Two main things are apparent from the above data. First, the modal level for each of the four species drawn is level 4. Secondly, any differences between species are probably small, with a suggestion that, as might be expected, the highest levels (levels 6 and 7) are more likely when pupils are drawings themselves. However, this conclusion is rendered problematic by the fact that different students were present on different occasions.

For this reason, Figure 4 shows the data just for the 78 students who were present on every occasion. (The proportion of drawings at levels 5, 6 and 7 is larger than in the overall sample as the biology undergraduates were particularly likely to be present on all four occasions and, obviously, produced many of the best drawings.) There is still a suggestion that drawings of humans (and perhaps rats) are more likely to be awarded levels 6 and 7 than the other taxa. If a c^2 test is applied to the raw data, the distribution of 6s and 7s across the four taxa (human = 16%; rat = 13%, starling = 5%; herring = 5%) is just significantly non-random ($c^2 = 7.84$; 3 df; $0.025 < p < 0.05$).

Figure 4



Closer examination of the drawings reveals much of interest with respect to what the students drew about the non-human animal. For instance, if we concentrate on just the drawings done by the Yr. 6 pupils - that is, 10 and 11 year-olds in their last year of primary schooling, Figure 5 shows a boy's drawing of the rat. The boy has successfully drawn bones in the rat's tail in addition to showing a range of organs found in the same places in humans and rats. Other Yr. 6 pupils had rat drawings with bones, nerves or muscles in the tail.

Figure 5

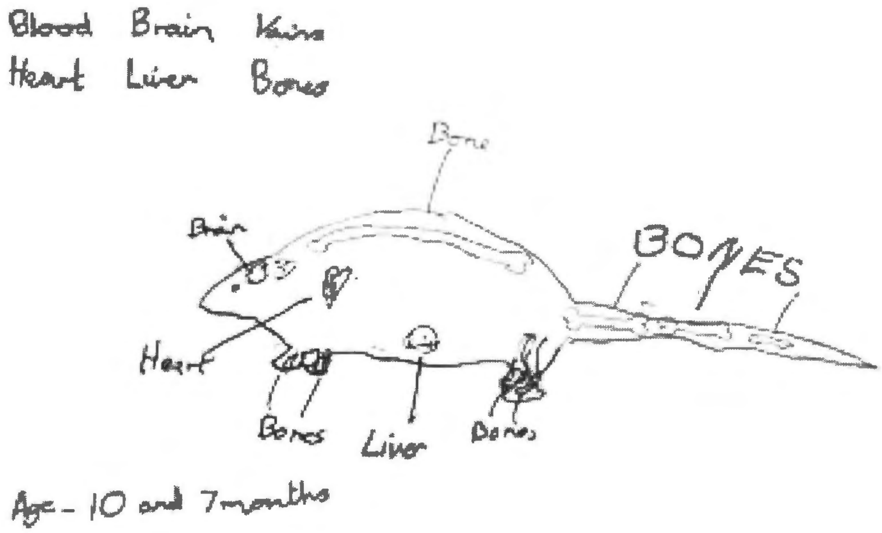
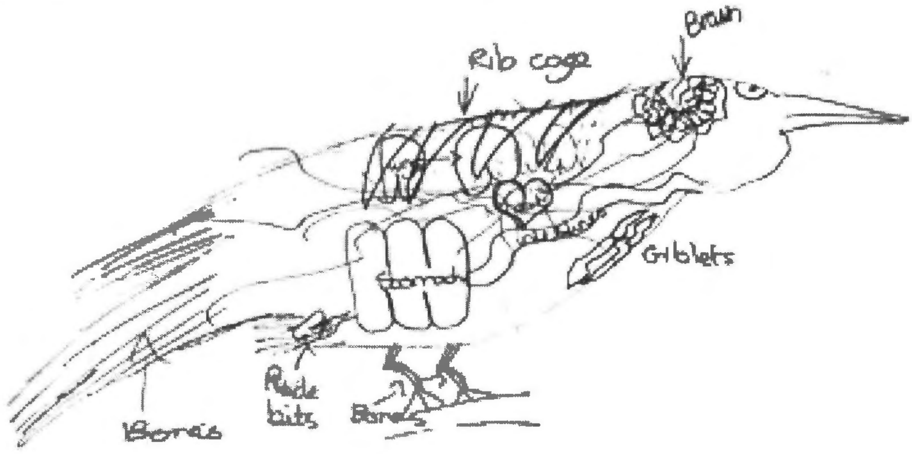


Figure 6 shows a drawing of the starling by a Yr. 6 girl. Noteworthy non-human features include the labelling of bones in the tail and the presence of giblets - presumably learned from domestic birds such as chicken. The genital area is labelled 'Rude bits'. (Elsewhere we have shown from an analysis of the drawings done by the Yr. 6 children of themselves, that 44% (eight in all) of the boys drew and/or labelled reproductive organs, in every case male reproductive organs. About the same proportion or possibly more, 64% (nine in all), of the Yr. 6 girls drew and/or labelled reproductive organs but strikingly most of these (seven out of nine) drew or labelled *male* reproductive organs (Reiss & Tunnicliffe, submitted).) Other Yr. 6 starling drawings portrayed tail feather muscles and showed a worm that had been eaten.

Finally, a drawing of a herring by a Yr. 6 girl shows that she knows that there are muscles in the tail ('tail mucciel') and that the herring has 'Gills'. However, she also includes 'Lungs'. Many other Yr. 6 fish drawings showed gills. Three pupils drew and labelled 'egg dispenser' and two pupils clearly thought little of a fish's mental abilities. One boy drew and labelled 'small brain' and one girl wrote next to the brain the brain 'memory of two seconds'.

Figure 6



5 Discussion

We acknowledge that a more intensive methodology, for example one that combined drawings with subsequent interviews, would allow students more fully to demonstrate their understanding. For example, in some cases it was difficult for us to identify certain of the internal organs drawn. Interviewing would have allowed us to resolve at least some such uncertainties. At the same time, we were extremely keen not to cue students into those aspects of their drawings that were of particular interest to us. As drawings were done on a number of separate occasions, any interviews about the drawings would have had to have been undertaken after the last of the drawings had been obtained from each child. This would have been difficult given the number of students not present on every occasion.

We believe that there is continued value in researchers identifying the sources of student's knowledge and understanding of animals. A particular concern of ours is the increasing loss of knowledge among UK pupils of organisms other than humans. In a related study (Tunnicliffe and Reiss, 1999b) we have shown that schools are significantly less likely to be cited by English pupils as sources of biological knowledge about the identity and taxonomic position of a range of animals than are other sources such as home, television and direct observation.

We found it noteworthy how few of the drawings reached level 6. And yet all that was required for level 6 was to produce a drawing with two of the major organ systems indicated (e.g. Figure 1). We strongly suspect that far too many students, however well they do on formal biology examinations, have only an atomistic knowledge of internal anatomy. Regrettably, English 'developments' in the biology curriculum and its assessment over the last ten years across the 5 to 16 age range have almost certainly reduced the chances of many students achieving a holistic understanding of much of what they study. Our belief is that too few of the students in this study, whatever their age, had any overall genuine understanding of internal anatomy, even their own.

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TEACHING AND LEARNING ABOUT THE BIOLOGICAL EVOLUTION: CONCEPTUAL UNDERSTANDING BEFORE, DURING AND AFTER TEACHING

Anita Wallin, Mats Hagman & Clas Olander
Göteborg University, Sweden

Abstract
This study is part of a project with the main purpose of developing a teaching-learning sequence that enables the students to construct a scientific model of the biological evolution. Another purpose is to document the students' conceptual development. Our theoretical background is the model of conceptual change initially proposed by Posner et al (1982). Here we focused on two key concepts in evolution – "variation" and "natural selection". The development and the long-term retention of these concepts among Swedish students (16 – 19 years old) were studied. The students' prior knowledge was investigated by a pre-test before teaching. During the teaching period some students were interviewed about these concepts, and small group discussions about the same concepts were videotaped. Approximately a year after teaching the students was given a delayed post-test. The majority of the students abandoned their prior ideas of strive and need, and adopted a more scientific view of these concepts. This was evident both in the interviews and in the post-test. The conceptual development of the interviewed students is discussed in the paper.

1 Background

During the last two decades several studies have shown that students of different ages, from different cultures and different educational systems, have difficulties understanding the theory of biological evolution (Deadman and Kelly, 1978; Brumby, 1984; Clough and Wood-Robinson, 1985; Lawson and Thompson, 1988; Greene, 1990; Pedersen, 1992), and that the students' understanding did not improve much after traditional teaching (Halldén, 1988; Bishop and Anderson, 1990; Bizzo, 1994; Demastes, Settlage and Good, 1995). Some specially designed teaching strategies gave better results, e.g. the explicit comparison of different evolutionary ideas in group-discussions (Jiménez-Aleixandre, 1992), teaching with a historical approach (Jensen and Finley, 1995; 1996) and the use of certain reading materials (Peled, Barnholz and Tamir, 1998). However, the long-term effect of these strategies has not yet been investigated.

The conceptual change model for learning, initially proposed by Posner, Strike, Hewson and Gertzog (1982), has been widely used not only to describe learning in science but also as a guideline for designing teaching (Hewson, Beeth and Thorley, 1998). According to the original formulation of the model, learning is described as a rationally driven and logical process. There are four prerequisites for conceptual change to occur. The learners must experience dissatisfaction with their existing conception, and any new conception must be intelligible, plausible and fruitful. After criticism of being overly rational, the model has been revised and extended, so that the importance of social and affective aspects now is recognised (Strike and Posner, 1992, Duit and Treagust, 1998). We place the construction of knowledge in the mind of the individual, but this construction can be positively promoted in different social interactions. Demastes, Good and Peebles studied students' conceptual change in the content area of evolution (1995, 1996). They described some patterns of conceptual restructuring that, according to their opinion, do not conform to the conceptual change model, and concluded that further research in this field is needed.

2 Purpose and Questions

The study presented in this paper is part of a project with the main purpose of developing a teaching-learning sequence that enables the students to construct a scientific understanding of the biological evolution. The aim of this study is to document the students' conceptual development, by investigating their understanding before, during and after teaching. Special attention is paid to the way students articulate their understanding in different situations, orally or in writing. We focus on two key concepts in evolution, namely "variation" and "natural selection". A number of frequently occurring alternative understandings of these concepts are known, e.g. the ideas of need and strive as forces in evolution, the idea of individual adaptation in the context of evolution and the inability to see the importance of the variation within a population. This paper pays attention to tests, small group discussions and interviews around two multiple-choice problems concerning the origin of variation and natural selection and is designed to assess the effect of instruction both in a short and a long perspective.
The research questions addressed in this paper are:

- How do the students understand "the origin of variation" and "natural selection"?
- How does the students' understanding of these concepts change during teaching?
- Will these changes persist for a longer period?
- Are the students aware of any conceptual change themselves?

3 Methods

Design of the study

The overall design of the study is shown in figure 1. A pre-test was performed prior to a four week teaching-learning sequence on biological evolution. During the teaching-learning sequence data was collected by interviews and videotaped small group discussions. Almost a year after the teaching the students were given a delayed post-test.

Figure 1. The design of this study.

February 1999	March 1999	April 1999	February-March 2000
	Teaching-learning sequence		
Pre-test	Small group discussion 1 Interview 1 Small group discussion 2 Interview 2	Written exam	Delayed post-test

The teaching-learning sequence

Our teaching-learning sequence of biological evolution is intended for students in the upper secondary school, taking a high-level biology course (Biology A). This course comprises 50 hours of teaching and covers mainly ecology, ethology and evolution. Evolution is strongly emphasised in the syllabus of this course (Skolverket, 1994), and we used 15 out of 50 hours exclusively for evolution. By the use of a pre-test, the teacher was made aware of the preconceptions held by his students. These preconceptions were also presented, at a group level, to the students, and served as a starting point for discussions. The purpose of these strategies was to allow the students to develop a metacognitive perspective on their understanding of evolutionary concepts and to elicit cognitive conflicts. In order to further facilitate conceptual change, the teaching-learning sequence gave the students the possibility to talk and discuss a lot, both in small groups with appropriate problems and in full class with the teacher as scientific leader.

The students

The participants in this study were grade 11 students attending the Natural Science Programme. The school is located in a municipality close to Göteborg, where the vast majority of the population are middle class ethnical Swedes. The Natural Science Programme has a reputation of being highly demanding, so the students in this study can be described as well motivated and gifted. Two groups with a total of 49 students (16-19 years old), who were taught by one of the authors (MH), were followed during the teaching-learning sequence on biological evolution.

The tests

Prior to the teaching-learning sequence the students were given an unprepared pre-test about evolution. This test consisted of nine problems, some open-ended but mostly multiple-choice. The authors of this paper designed the two test items, which are discussed here. The alternatives were chosen according to common alternative conceptions held by students (figure 2). The pre-test was distributed over the Internet, so the students answered the test on computers and their answers were submitted directly to our database.
Since we are particularly interested in long-term retention, the students were given a post-test approximately one year after the teaching sequence. This delayed post-test was essentially identical to the pre-test.

Figure 2. The two multiple-choice problems in the pre-test, which were discussed in the interviews, and also used in the delayed post-test.

Problem 4

Throughout time living organisms have developed a variety of different traits. What is the origin of this enormous variation?

1. The traits arose when they where needed.
2. Random changes in the gene pool of the organisms.
3. Living organisms strive to develop.
4. Great variation is needed in order to get balance in nature.

Problem 5

Which one of the following alternatives does best explain changes in a population with time?

1. Some individuals are better at reproducing than others.
2. Some individuals starve to death, while others survive by moving to new places.
3. Organs and structures that are needed evolve.
4. Individuals can adapt to survive.

The interviews

In order to follow the students' conceptual development during the teaching period, some students were interviewed about the concepts "variation" and "natural selection". One of the main issues that were brought up during the interviews was the students' thoughts about the different alternatives in the test problems (no. 4 and 5 respectively). About a week before the first interviews the teaching dealt with mutations and other random changes in the gene pool. Twelve students were interviewed about variation and were chosen according to their answers to one of the pre-test problems (no. 4) in a way that all alternatives were represented. Two weeks later 35 students were interviewed about the concept of natural selection. On this occasion all available students in the two groups were interviewed. The interviews were performed with one student at a time, they were structured and followed an interview guide. All interviews were audio taped and transcribed word for word.

In addition, small group discussions, with 4-5 students, regarding the same concepts were performed before corresponding interview. In these discussions the students were left without any teacher or researcher, but the discussions were videotaped and transcribed.

4 Results

The origin of variation

During the interviews on the origin of variation the students (n=12) were asked to comment on the four different alternatives that were given in problem 4 in the pre-test (se figure 2). The comments were categorised in three levels; agree, partly agree and disagree (table 1).

Table 1. Categorisation of the students' comments, to problem 4 in the pre-test. (n=12, some students did not comment on all alternatives.)

Alternative	Agree	Partly agree	Disagree
1. "Need"	0	8	2
2. "Mutation"	7	4	0
3. "Strive"	4	2	6
4. "Purpose"	8	0	4

Alternative 1: "The traits arose when they where needed"
A majority of the students (8 of 12) agreed partly and expressed different reasons in favour to this alternative. Some of these students clearly distinguished between the origin and the survival of new traits, but still considered "need" to be an acceptable explanation to the origin of variation e.g.:

> *S7: ... they arise, not exactly because they were needed but those who were needed were preserved, and that is a bit the same thing.*

Alternative 2: "Random changes in the gene pool of the organisms"
Seven agreed totally and four students partly agreed, e.g.:

> *S16: I think it is a bit like number two with random change ... if webbed feet arose as a trait and then was needed, it was preserved.*

Here the student referred to the survival of the trait, which he called "need".

Alternative 3: " Living organisms strive to develop."
Six students agreed with this with two different ways of arguing. Four used anthropomorphic reasoning while referring to man as example (e.g. S34) and two used the concept of adaptation in the sense of individual adaptation.

> *S34: Of course you strive to develop; you don't want to stand on the same spot all your life.*

Alternative 4: "Great variation is needed in order to get balance in nature."
Most students agreed, eight of the interviewed. It is likely that most of these accept the statement that nature needs variation.
At the end of the interview the students were asked to choose which of the four alternatives they preferred this time. Eight of the students had changed their alternative from the pre-test, seven of those to the more scientific view (random genetic change). The reasons they claimed for change was the teaching (7 students), the textbook (3 students) and/or own thoughts (3 students). Most of those who articulated reason did not show any difficulty in changing opinion; it was simply due to teaching.

The concept of natural selection
About a week before these interviews about natural selection (n=35), the students had been taught about natural selection and had discussed this concept in small groups. During these interviews the students were asked to comment on the four different alternatives to problem 5 (figure 1). The comments were categorised in three levels; agree, partly agree and disagree (table 2).

Table 2. Categorisation of the students' comments, to problem 5 in the pre-test (n=35).

Alternative	Agree	Partly agree	Disagree
1. "Reproduce"	20	12	3
2. "Move"	24	9	2
3. "Need"	7	9	19
4. "Adapt"	14	5	16

Alternative 1: "Some individuals are better at reproducing than others"
The majority of the students agreed or at least partly agreed to this alternative. Most students could see the connection between success in reproduction and population change. The other eight students did not:

> *S28: "Some individuals are better at reproducing than others" ... perhaps they are, but ...reproduction has nothing to do with change, I think.*

Alternative 2: "Some individuals starve to death, while others survive by moving to new places"
All except two students agreed to some extent to this alternative. Many also showed that they realise that this is not the major explanation to evolutionary changes.

Alternative 3: "Organs and structures that are needed evolve"
Seven students agreed with the statement. However, four of them used the term "need" in a way that suggests that they understood that evolution is not need-driven. The same thoughts were expressed among several of the students who partly agreed.

> *S31: ... Number three I think fits well. ... Yes. "Organs and structures that are needed evolve". But a mutation has to occur for it to develop, it is nothing they have any influence on.*

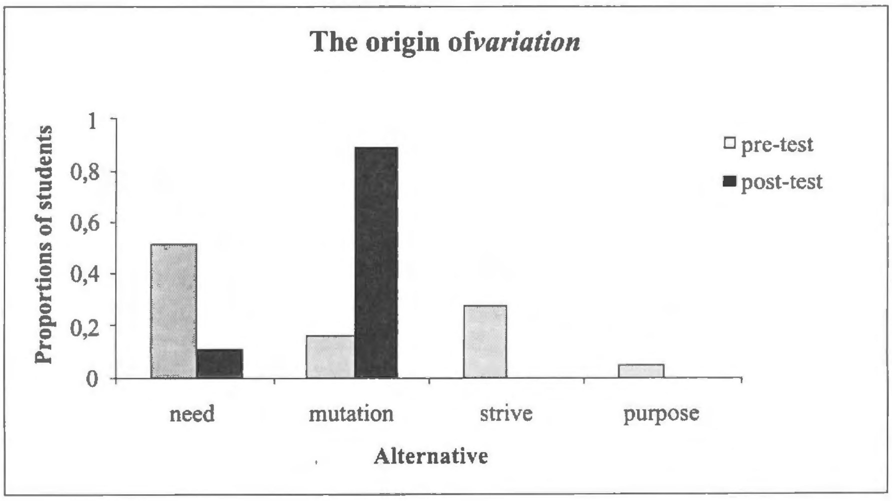
Alternative 4: "Individuals can adapt to survive"
About half of the students agreed or partly agreed to this alternative. The majority of them had not, at the time of interviews, understood the significance of the concept of adaptation. Several students still expressed their belief in individual adaptation as an evolutionary process. Only four students discussed adaptation in an evolutionary correct way.
At the end of the interview the students were asked to choose which of the four alternatives they thought was best this time. In the pre-test the

majority of the interviewed students (75%) had chosen the alternative "adapt", but during the interviews many students showed a more scientific view of the concept, i.e. they choose the alternatives "reproduce" (47%) or "move" (26%).
The majority of the interviewed students had changed alternatives since the pre-test. Nine of them were aware of their change, and offered an explanation how their thoughts had changed. Another ten students could give some kind of explanation to their change, after being confronted with their choice in the pre-test. These 19 students were analysed especially regarding any signs of conceptual change of natural selection. Eleven of them seemed to be rearranging their conception of adaptation and three students remembered that they before teaching saw evolution as a need-driven process. The other five discussed their changed views about mutations, acquired traits and the enormously long time of biological evolution.

The long termed retention

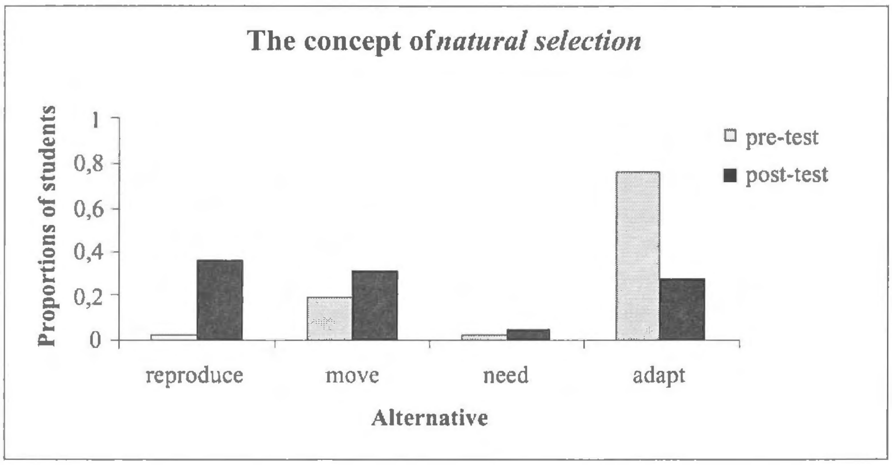
Approximately one year after the end of the teaching-learning sequence the students performed a delayed post-test. The problems concerning the origin of variation and change in populations with time appeared in both pre- and post-tests.
On problem 4 the students had totally abandoned the alternatives "strive" and "purpose" and almost everyone (89%) chose the "mutation" alternative (figure 3).

Figure 3. The proportion of students (n_{pre}=43; n_{post}=47) choosing the different alternatives to problem 4.



In the post-test 28% of the students chose the "adapt" alternative in problem 5 (figure 4). The alternative that teaching tried to support ("reproduce") increased in proportion to 36% compared to 2% in the pre-test.
As judged by the results in the delayed post-test, the long-term retention of the teaching on students' conceptions of "the origin of variation" and "natural selection" was good.

Figure 4. The proportion of students (n_{pre}=42; n_{post}=49) choosing the different alternatives to problem 5.



5 Discussion

This study confirms the results from several other studies, that there are a number of common alternative understandings regarding biological evolution. One of the major obstacles for a scientific understanding is the failure to recognise the existence of two separate processes in evolution (Bishop and Anderson 1985, 1990):

1. The appearance of traits in a population
2. The survival of such traits in a population over time

When it comes to the first of these processes, the students in this study seem to accept mutations as the ultimate source for new traits rather easily. And, as seen in figure 3, most students still accepted random mutations a year after teaching. In the interviews, several students expressed their doubts about the randomness in evolution. However, we also got the impression that when the students understood that evolution consists of several processes, of which only one is random, they accepted the randomness more easily.

The students in this study did not seem to have any problems with connecting natural selection to enhanced survival or to differences in survival, but a few students had difficulties in seeing reproduction success as necessary for population change. They saw variation in reproduction ability as a completely separate trait that had nothing to do with population change.

The understanding of need and adaptation

In several studies students' use of the term "need", in the context of evolution, has been interpreted as if the students believe evolution to be a need-driven process (e.g. Bishop and Anderson, 1985; Demastes, Settlage and Good, 1995). This investigation shows, both in interviews and small group discussions, that some students can use this term and still have a sound understanding of the processes of evolution.

Using the term "need" this way does not contradict an understanding of the processes of evolution. It is used almost synonymous to "advantageous" or "beneficial". One could say that these students see the origin of variation as mutations but the survival of traits as a need-driven process, which is very close to the scientific view. This is an important finding, which must be paid attention to when studying students' conceptions of evolution.

It seems to be quite hard for the students to understand adaptation in the evolutionary manner. In spite of the fact that many students understood the word "adaptation" as something concerning the theory of evolution, few had acquired the evolutionary meaning of the word. This is obvious in this study and has also been shown in other studies (e.g. Bishop & Anderson, 1985; 1990; Bizzo, 1994).

Signs of conceptual change

During the interviews it became clear that many students were struggling with capturing new concepts. Although most students chose the more scientific alternatives when they were forced to select, they were not so sure in their choices. As table 1 and 2 show many students could also see advantages in the less scientific alternatives. This is not only a sign of the ambivalence students experience when rearranging their concepts, but also illuminates the problem with making conclusions of students understanding on basis of multiple-choice problems.

Obviously the teaching made some students feel dissatisfaction with their existing concepts, for example adaptation, need-driven evolution and mutations. One of the students, who were rearranging her understanding of adaptation, explained that the evolutionary significance of the adaptation concept was more plausible than her old understanding. Another student talked of his prior understanding of evolution as a need-driven process and could give an example on what he thought would have happened if his prior thinking had been plausible.

> *S38: ... if they needed a longer neck, they would get one.*

Later during the interview he was asked about why he had changed opinion:

> *S38: ... after we have read about Darwin and talked about everything.*
>
> *I: Do you think it works only in school or do you think it is more plausible?*
>
> *S38: Yes, it actually is. ... for otherwise I think we ought to have wings nowadays or something.*

These examples fit rather well with the conceptual change model (Posner et. al., 1982).

6 Implications for Teaching

We consider the conceptual change model to be a fruitful theoretical background for designing teaching. The results in this study are promising, especially regarding the long-term retention. However further research is desirable for comparing the outcome from this approach with "traditional" teaching.

Many students enter teaching with an understanding of evolution as one entity, a gradual adaptation process. We suggest that if teaching starts with separating the theory of evolution into two or more processes, it might become easier for the students to understand the randomness of mutations, the importance of reproductive success and the evolutionary significance of adaptation. Later on the teaching should help the students to capture a new entity of the theory of evolution, as natural selection working on inherited variation of traits in a population over time.

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Section Two: TEACHING BIOLOGY

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CONSTRUCTING AND USING TYPOLOGIES OF MODELS IN SCIENCE EDUCATION: THE CASE OF MODELS OF DECAY IN AN ECOLOGY COURSE.

Carolyn J. Boulter & Barbara C. Buckley
School of Education, University of Reading, England, RG6 1HY

Abstract

Expressed models are those which learners represent for others and which are therefore available. A typology of expressed models is developed here using a two dimensional array with the aim of providing a reflective tool for examining the range and development of models in particular contexts. The use of the typology is illustrated through the mapping and discussion of the models used to represent decay by a student from a group of initial trainees who were part of a Soils and Habitats course investigating a woodland and stream in the field. To simplify the complexity of the ecology of soils and habitats a system of eight levels is proposed which would allow a complete scientific understanding and interconnectivity in understanding soils and living things. The data show the student's models for decay changing according to the task presented and the mode of representation she chose. They remain a fragmented collection of models but at the end of the course the student is starting to develop intentional model building which may lead to a coherent synthesis of models. The possibilities for using such typologies are briefly discussed.

1 Introduction: Some background on the approach to models

It is through models and representations that we come to understand the phenomena of the world as we appreciate them through our senses. These may be apparently simple objects like a human heart or a time bounded interaction, an event, such as a heart attack, or a series of events making a process such as decay, or a complex interacting system operating at many levels, such as a woodland habitat. The mental models which we form in our minds as we encounter these objects, events, systems and processes of the world are not available to others until expressed either in a concrete or symbolic form (Gilbert and Boulter, 2000). Often these expressed models are mixed and include say both material objects and symbolic textual labels as in the case of the labelled plaster model of the heart .The symbolic may be visual, verbal or mathematical text or gestural. These concrete and symbolic modes of representation are the ways that mental models can be expressed. When any representation is formed it expresses the behaviour of the mental model shown in the particular behavioural aspects of the representation which may be dynamic or static, deterministic or stochastic and also the numerical precision of the model which may be either qualitative or quantitative. These two parameters of models, the modes of representation and the attributes of the representation form the two axes of our constructed typology of models (Boulter and Buckley, 2000).

2 Working with models: expressed models and phenomena

The work of the Models In Science and Technology Research in Education (MISTRE) group deals with models as representations of the phenomena of the world (Gilbert and Boulter, 2000). The work reported in this paper forms part of the on-going research of this group which aims to produce a substantive theoretical base within which the teaching and learning of the classroom and out of school contexts can be investigated within a model-based framework. This framework is described elsewhere (Gilbert and Boulter 1998,2000, Gilbert, Boulter and Rutherford, 1998a and b, Buckley and Boulter,1999). Its first essential element is that the individual forms mental models of phenomena that are perceived through the senses and these mental models have particular features (Franco *et al.*in Gilbert and Boulter (eds) 2000) one of the most vital being that they are personal and can only become available to others when they are expressed. These expressed models of particular phenomena are the raw material of our empirical research across a number of contexts. In classroom situations where there is interaction between learners and teachers the expressed models of many individuals (and texts) may enter a single session and interact with each other. These expressed models may be idiosyncratic to the individual or they may be some form of consensus model in a small group working together or they may be one that many people would agree with who work within that field. Those that appear in the agreed curriculum for science are consensus curriculum models. Those that teachers use to help children understand a particular scientific model are teaching models. Those that scientists would accept in their specialist field are scientific consensus models. In collaborative discussions between learners to solve problems and explain phenomena individuals may argue to reach some sort of temporary consensus about an agreed model after discussing their personal models (Boulter et al 1998).

The second element is that phenomena are of different kinds. They may be objects which are concrete entities, they may be time-bounded events within which objects interact with each other in particular ways, they may be processes within which events interact or they may be complex systems of interacting processes. Work on the aspects of these phenomena (their structure, behaviour and mechanisms) that are used to produce representations in school texts based on the work of the group is described in work presented in these papers on the heart and circulation (Selles, 2000) and in other work (Oversby,1998).

We considered that this set of understandings that we had developed might be a useful tool for the analysis of model building and teaching and learning in the classroom. Viewed in this way sense can be made of the features of the phenomena under study and the types of models that are being presented to learners and those that they express. It is also probable that for effective learning students need to have access to a range of models to explain any phenomenon (Marsh et al.1999). The need for a classification of the representations used in the classroom was therefore apparent and we choose to use a typology with two dimensions to show our classification. In this typology we can chart the range of models of particular phenomena and so provide a tool for comparing the range used in different contexts or by different students, a tool to facilitate teacher reflection on the models available to students, and a means through which we might add to the understanding of developmental patterns in pupils expressed models as they move towards a scientific consensus view.

3 The construction of typologies of models

The axes of the two dimensional typological array are based on the work of Mirham (1989). The criteria for one dimension are the extent to which the models are material or symbolic, whether they are static or dynamic and whether they have a fixed or stochastic outcome. We call this dimension the "attributes of representation". The other dimension we have chosen is based upon the importance that the visual, spatial , mathematical, gestural and verbal presentation has upon learners. We call this dimension the "mode of representation". We recognise that modes of representation are often mixed in our typology. The typology that we propose is therefore presented as a set of cells within a two dimensional chart which if filled provide the range of expressed models possible for a given phenomenon We first made an array of the types of representations generally thus any cell can contain entities such as diagrams, and 3D models (figure 1).

Figure 1. Typology of expressed models and kinds of representations.

Modes of representation

Single mode

Attributes of representation		Concrete *material*	Visual *pictorial*	Verbal *Written/oral*	Mathematical *formulaic*	Gestural *bodily*
Qualitative	Static	3D model	Diagram Drawing	Analogy Description Metaphor		Showing positions
Qualitative	Dynamic: Deterministic	3D models that move	Sequenced diagrams Animations			Acting out set movements
Qualitative	Dynamic: Stochastic	Physical simulations				Hand gestures
Quantitative	Dynamic: Stochastic		Graphical displays		Formulae	
Quantitative	Dynamic: Deterministic	Working scale replicas	Video of live phenomena		Formulae. Computer simulations	Gesturing relative behaviours
Quantitative	Static	Scale models	Photographs	Description with size or distance	Equations Chemical Formulae	Showing size

Mixed mode

Attributes of representation		Concrete	Visual	Verbal	Mathematical	Gestural
Qualitative	Static	3D model with labels	Diagram with labels	Analogy with drawing		Showing positions with talk
Qualitative	Dynamic: Deterministic		Animation with verbal explanation			Acting out with talk
Qualitative	Dynamic: Stochastic	Physical simulation/ labels				Hand gestures with talk
Quantitative	Dynamic: Stochastic		Graphical display			
Quantitative	Dynamic: Deterministic	Working scale replica with verbals	Video with verbals		Computer simulations	Gesturing behaviour with quantities described
Quantitative	Static	Being an object with verbals	Photos with labels	Description with size, and gesture	Equations with diagram	Showing size with talk

To illustrate its use and explore its effectiveness we have arrayed within the typology the expressed models we found working with a teacher trainee of the models of decay she used of woodland and freshwater habitats.

4 The data from student teachers learning about ecology

The research data upon which we draw was conducted with a group of 31 pre-service teachers comprising 13 Science specialists and 18 Geography specialists. The course they took was a Habitats and Soils course run by the authors and its focus was the interactions between soils and habitats that determines what grows in the habitats visited each week. The students devised their own areas of inquiry in the field each week with the aim of relating their findings to their developing models of ecology. Each student group of four to six individuals worked together to raise questions to investigate, collect data in the field, and report back to the whole group. Self selected pairs prepared posters to explain their model in a particular habitat to the whole group towards the end of the 10 week course. Initial representations of student understanding of the interactions between soils and habitats were collected and at the end of the course students were interviewed , if they wished, to probe their final understanding. They submitted their personal field work files required by the university for assessment purposes. Student groups were video taped in turn in the field and classroom. The data set therefore contains initial representations, posters and field work files together with video recordings of groups working together and of pairs presenting posters.
The data has been analysed previously (Boulter, Walkington and Buckley , 2000) to show some of the constraints to the model building at the collaborative level within small groups. In this analysis the following were found:

- Initial representations clearly relate to school texts
- Critical incidents arise in the field when the match between existing models and data cannot produce a coherent explanation.
- Group dynamics have a strong influence of the group model adopted through negotiation.
- Individuals seek out information following critical incidents in the field and poster presentation.
- When producing the poster students try very hard to integrate and reconcile their models.
- In both poster discussions and in writing files students tend to revert to their individual models.
- In final interview students had all revised their models although they were still very incomplete.

- Students gained a stronger appreciation of the scope and range of models and the value of collaborative working.

The task of mapping the data on students individual models into a typology thus is contextualised by this previous work

5 Producing a typology of models of decay from a student

Ecological phenomena are complex and involve organisms (microbial objects), events such as death , processes such as decay , and systems such as the stream. Ecological processes involve not only the biological entities but also those of the soil. For us the soil/biology interface is very important as our course (Habitats and Soils) is aiming to help students to integrate their knowledge of soils and biology. We position decay as a process phenomenon, a series of events including death and the different phases of decomposition. These events involve a number of concrete entities interacting and these vary according to which level of organisation we choose to examine. The central level entities on the scales we have devised are organisms for the biological levels and pedons for the soils. Both range in 8 levels from geosphere to atom (Figures 2: Levels of organisation in biology and 3: levels of organisation in soils). Any student learner may represent decay at any level and in either the soil or biology levels or in both.

Figure 2. Levels of biological organisation in ecosystems

Level	Structures	Examples of behaviour
+2	Geosphere	Diffusion and movement of air, soil, water
+1	Ecosystems	Population dynamics
1	Organisms	Food webs & chains, feeding, dying, reproducing
-1	Organ systems	Digestion, respiration
-2	Cells	Microbes, cells within organs processing food constituents
-3	Organelles	Mitochondria, lysosomes processing molecules & energy
-4	Molecules	Biochemical cycles
-5	Atoms	Chemical reactions

- Correspond approximately to physical scale
- The lower level embedded in the next higher level
- When unicellular organisms are considered the cellular level slides up to the organism level and organelles replace organ systems.

Figure 3. Levels of organisation in soils

Levels	Structures	Examples of behaviour
+2	Geosphere	Diffusion and movement of air , soil and water
+1	Ecosystems	Mineral and water movement, gas exchange
1	Pedons	Horizon formation and destruction, bioturbation, humification
-1	Horizons	Ion concentrations, Cutans forming round peds
-2	Peds and pores	Shrinkage and swelling in clay peds
-3	Minerals	Weathering, hydration and hydrolysis, complexing
-4	Molecules	Leaching
-5	Atoms	Chemical reactions

The typology framework for categorising models in this way could be used with several sets of data from our work as mentioned earlier. We could compare groups of students at particular points in the course or compare those investigating different habitats. We could take the text books and resources that students use and classify all the representations available for them to learn from. We could focus on one level such as the ecosystem level in soils and biology and array the models which emerged during the whole course from all its participants and the texts with which they interacted to assess the potential of the course in providing a range of models.

However, as we are concerned in our work here with how individual students build mental and collaborative models during enquiry based field work (Boulter and Walkington, 2000) we have taken the data from one student called Sally.

6 The analysis of Sally's models of decay

Sally is a Geography specialist who has had previous experience but not in the field:

"...most of what I learnt was done in my A level (at age 18) when we did work on ecosystems particularly like a woodland and we did nutrient cycles. I learnt a lot then because I had to do a module so I had to do a lot of reading up...."

Like other students she experienced the different habitats and group experiences outside. Like other students she wrote a field notebook of her reflections on what she had seen.

At the start of the course all the students were asked to represent their understandings of the relationships between soil and ecosystem in a woodland. These initial representations provide the first indications of Sally's model of decay. About half way through the course students in pairs were asked to produce a poster showing the inter-relationships in one of the habitats they had studied. Sally chose to present the stream with Lisa another Geographer who was part of the collaborative group described earlier, but who had worked in a different group in the field. The poster provides evidence of Sally and Lisa's model of decay half way through the course. This poster was presented to all the other students and the lecturers who assessed them and devised questions for the presenters, to probe their understanding. These videotaped sessions, in which the poster representations were probed, allow us as researchers to see Sally's individual models of decay being challenged and defended.
At the end of the course each student was interviewed with a sheet of paper with the words 'Leaf' and 'Soil' and an arrow connecting them on it and asked to explain the relationship. This provides evidence of Sally's final model of decay. From this data we can show how Sally's model of decay changed over the length of the course and gain some insight into the extent to which this can be described as individual model building. All of this data provides representations of the student's mental models through visual and spoken material.

7 The analysis of Sally's initial representation

Sally initially chose to represent her model of decay as a linear flow diagram of a food chain with general definitions. She drew a bacterial organism level model of decay and a numerical population model of community. The task only allowed her to draw and write and she used an ecosystem level and organism level to explain her understanding. She mentions soil as a non-living component of the ecosystem but does not explain any structural or behavioural features.

8 The analysis of Sally and Lisa's poster of the river and its discussion during the presentation to the class

Lisa and Sally describe their poster during the presentation as "a map that's really about food webs and food chains". The poster is in fact very crowded and when analysed shows several different models that have been superimposed in Sally's words,
" We sort of tried to put our understanding down onto paper and that was our way of doing it. It was a sort of logical cycle for us - all the different bits".
It shows cycles rather than systems through a collection of diagrams,

photos, charts drawings and text boxes all connected together by lines of coloured tape. There is little sign here of the population approach of the initial representation and it is the habitat and ecosystem approaches which dominate. The soil interactions are only sparsely and obliquely mentioned in terms of their direct effects on the mineral content of the water and the size of the substratum of the stream. Perhaps this is the influence of the field experience in the stream where the focus of the tasks was on the adaptations of organisms to the microhabitats. In her final interview Sally explained the influence of the field work as,
"Being in the field has helped me sort of picture it more and see how, it (works) in action rather than just in a book."
The models connected to decay are very incomplete. There are a number of levels involved in a full explanation of a process. A complete explanation also requires coherence between models at each level from the atomic to the geosphere. In Sally's explanation in the poster we find two levels involved in explaining decomposition. The first is an energy flow model consisting of a number of unnamed stages during which some energy is transferred and some is lost. There is also an explanation of decomposition at the molecular level involving a breakdown model so that molecules such as protein are broken down by micro-organisms to give rise to ammonium at the bottom of the stream. These two are at different levels of organisation and Sally does not attempt to make them as coherent as she could have done by making nutrient flows explicit. At the bottom of the poster there is a little flap which tantalisingly reads "Did you know?" and inside is the statement that calcium facilitates decomposition. This statement was questioned during the presentation and revealed interesting understandings of decay. The students both struggle to explain why calcium should speed up decay and suggest it is because calcium is acidic. Then they suggest that it would also involve oxygen because oxygen is important in speeding up decay. Then they recall that peat is acid and that stops decay so they suggest that the calcium in leaves is present as calcium carbonate and that may provide the oxygen for the acceleration. The behaviour and mechanism for calcium affecting the speed of decay remains unresolved as the discussion passes on to deal with matters of adaptation.

9 The analysis of Sally's final interview

In her final interview although Sally draws linear diagrams to show her understanding of the leaf falling to the soil she talks about cycles. Talking about the skeleton of the leaf she said
" It goes into the soil, the organisms may eat it but then eventually it goes back into the soil again so it's the whole cycle of events. Everything gets used actually (that was) within that leaf."

Despite this she described photosynthesis but not respiration, the reciprocal process. She is concerned mainly with the organisms and organs in the biota and what they do and with the structure of the horizons of the soil. At the molecular level she identifies lignin, cellulose and protein leaching out of the leaf in water as shown on the poster. She is unsure of the nature of decomposition and what the scale differences are between atoms of nitrogen and molecules of protein. The molecules are represented as words and small circles. The use of the word soil in the probe may have been more difficult for her because the poster showed so little soil content and the question was never asked about the differences between decomposition of the leaf in water and soil.

10 Sally's models of decay mapped in the typology

Placing Sally's models into the typology we used *italic script* to show her models in the initial representation, Times script to show her models in the poster task and Helvetica script for her models in the final interview (figure 4). Looking at Sally's models we see that she is using a limited range of models and that for any one sample they do not cover the same levels. The task effects the models that are expressed, the poster and its subsequent discussion allowing the widest range of models, both in representational form and level.

The tasks do not allow some types of model to be expressed at all, in particular there is little opportunity except for hand movements for the dynamic aspects of ecology of soils and habitats to be expressed. This suggests to us that we might revise the course to provide tasks that would require the use of dynamic representations.

When we examine the development of Sally's models of decay we see Sally's models for decay changing according to the task presented and the mode of representation she chose. They are always fragmented and the main theme throughout Sally's struggle to understand is the need for a synthesis of these cyclical models into a coherent system. Sally has only just begun the process of intentional individual model building and the integration of soils and habitats. Sally has not yet challenged her original models although she has learnt new things. For instance the way the role of fungi in decomposition has been added onto her existing collection of models but without change and synthesis taking place.

This analysis makes us as course developers face the questions of how we can change the course so that a more effective development of models takes place. In particular we need to provide for more integration of knowledge of soils and habitats to take place. For this we are asking ourselves.

What might we expect of a student with a complete scientific model?

Figure 4. Sally' s models of decay placed in the typology

Modes of representation

Single mode

Attributes of representation		Concrete	Visual	Verbal	Mathematical	Gestural
Qualitative	Static		Organisms level: drawings of organisms			
Qualitative	Dynamic: Deterministic		Organ level: Secuence of diagrams showing leaching *Organism level:Explosion*			
Qualitative	Dynamic: Stochastic					
Quantitative	Dynamic: Stochastic					
Quantitative	Dynamic: Deterministic					
Quantitative	Static		Ecosystem level: Photos of habitats			

Mixed mode

Attributes of representation		Concrete	Visual	Verbal	Mathematical	Gestural
Qualitative	Static		Horizon level in soil: diagram with labels. Organ level: Leaf and worms	Geosphere level: river structure described		
Qualitative	Dynamic: Deterministic		*Ecosystem level: linear flow diagram with labels and pictures of decay and food chains. Organism level: bacteria*			
Qualitative	Dynamic: Stochastic					Ecosystem level: hand cycles with talk
Quantitative	Dynamic: Stochastic					
Quantitative	Dynamic: Deterministic			Molecular level: Discussion abou effect of calcium on decay		
Quantitative	Static		Molecular level: simple equation for growth		Molecular level: Equation for photosynthesis	

What might we expect a student to understand of the inter-relationships of habitats and soils?
How can we change the provision on the course to enhance more effective and coherent model building?

11 Using typologies

We feel that producing typologies of particular phenomena such as decay is useful.

- As a tool for teacher reflection on the Soils and Ecology course the typologies have enabled us as teacher trainers to identify the range of models used and the missing parts of the range. Although model development in this student was weak we hope that from further analysis we shall be able to identify more fully patterns of development as student teachers use of models.
- In school models of air resistance have been studied showing the differences in range between the imposed curriculum of the national prescription, the intended curriculum of the teacher and the experience curriculum of the pupils (Simpson, 1999).The typology could be used to analyse such ranges of models in other subject araes.
- In the classroom models are presented through four main avenues, through objects, by discourse, by print-based means and through screen based resources. Our typologies enable a discussion of the effectiveness of these avenues to present a range of models of particular phenomena and the design of investigations. Where a particular avenues are used the range of models in each can be placed into a typology and comparisons made.

The development of the framework for the typology of expressed models and representations has necessitated deep analysis of the nature of models and modelling. Its use has opened the door to making sense of what may be happening when students learn about complex processes such as decay and prompted us to ask questions about how our course could be improved.

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THE BIOLOGICAL ADAPTATION MODEL: OBSTACLE OR A DIDACTIC RECOURSE?

Milagros de la Gándara Gómez*, María José Gil Quílez* & Neus Sanmartí i Puig**
*University of Zaragoza. **University Autònoma of Barcelona

Abstract
With this work, we seek to show some of the difficulties that the transmission of scientific models in Biology presents about the notion of *biological adaptation*. These difficulties can be considered real obstacles for didactic transposition and therefore an active source of ways of interpreting Biology. The study deduced a model of biological adaptation that may work as a scientific reference for its transposition to other contexts. Attributing a meaning to the term 'adaptation' requires the interactive application of different underlying models. Certain elements and relations that play a decisive role in this interaction are transmitted in an ambiguous way and we must understand them to be implicit in most of the cases. Difficulties found in the interpretation of the adaptation model correlate to the ones found at the identification of the adaptation model that emanates from the books of obligatory education.

1 Introduction
This work is a summary of the contents of the PhD, about the transposition of the biological adaptation concept from scientific texts to the books of Secondary Education (12-16 years old) (De la Gándara,1999). Biologists warn that adaptation is a difficult term to define (Dobzhansky, 1980; Mayr, 1983). The adaptation is a concept difficult to be taught and learnt, and interfered with the learning of other concepts, specially those related to the idea of biological change (Ferrari and Chi, 1998; Moody, 1996; De Miguel and Grau, 1996; Jeffery, 1994; Swarts et al., 1994; Jiménez et al., 1992; Clough and Wood-Robinson, 1985; Lucas 1971). To this effect, we talk about alternative conceptions

distant from the concept scientifically accepted. However, both scientists and teachers in their classrooms and students in their projects allude to adaptation to explain and to describe biological phenomena of a very different nature (De la Gándara and Gil, 1995).
From the point of view of Didactic Transposition, the valuation of the ideas observed inside an institution entails bearing in mind the model components and the relations established between them, within the institution concerned (Chevallard, 1985). We are thus interested in knowing what model of adaptation is being transposed to the text books that students of Secondary Education use in relation to the model of biological adaptation transmitted by specialised literature on biology.

2 Methodology

To answer these questions we started two parallel studies, carried out in different phases.
The first phase consisted of a *previous study*, aimed at the configuration of the model of adaptation transmitted by scientists through specialised literature. At the same time, it pretends to be a source of criteria to guide the decisions to be taken in the phase of the *study of transposition in the strict sense of the word, of the adaptation model in the textbooks of Obligatory Secondary Education.*
The whole *previous study* was submitted for a process of validation by triangulation in which we counted on the intervention of three experts: two biologists and a palaeontologist.
Following the procedimental model posed by Miles and Huberman (1994) for qualitative researches, in each phase, the work develops in four stages: (1) Selection of texts and remarks through quotations. (2) Categorisation of the data in a network. (3) Analysis of the network. (4) Conclusions or partial results.
In order to shape the scientific referent we resorted to the terminology used in several works from the *specialised literature*. The selection criteria applied we summed up in the following: 1· Diversity of authors and contexts. 2· Keeping ourselves to the content remitted by the index (thematic and terminological ones) that appears in the different works (except in the two papers that we registerd entirely). The sample remained composed initially by 12 works to which we added one more (general biology), after the process of *external validation*. Its inclusion was also used as an instrument of *internal validation*, after we checked that it altered neither the analitical elements we were considering, nor the results we had obtained in the initial previous study (Annex 1).
As to the *textbooks of Secondary education* we resorted to the four books used in the four years of Secondary education that represent each one of

the three best selling publishers. Twelve books, so in this case, we took into account the whole content on Biology.
As a system of data categorisation we chose the *network* (Sanmartí, 1989; Bliss et al.1979), because it was an instrument that showed hidden more clearly, as well, giving others readers the possibility to evaluate the network.
In its most reduced form, we obtain a "*global-science net* ", where only what is said by the whole of the sample of scientific books about adaptation is shown. In the case of books for Secondary education, we establish an analogous network for each cycle (*"global-ESO-first cycle net"* and *"global-ESO-second cycle net"*), starting with the network that we created previously for scientific literature. We are interested in showing what aspects of "adaptation" the different publishers share in each cycle (Annex 1).

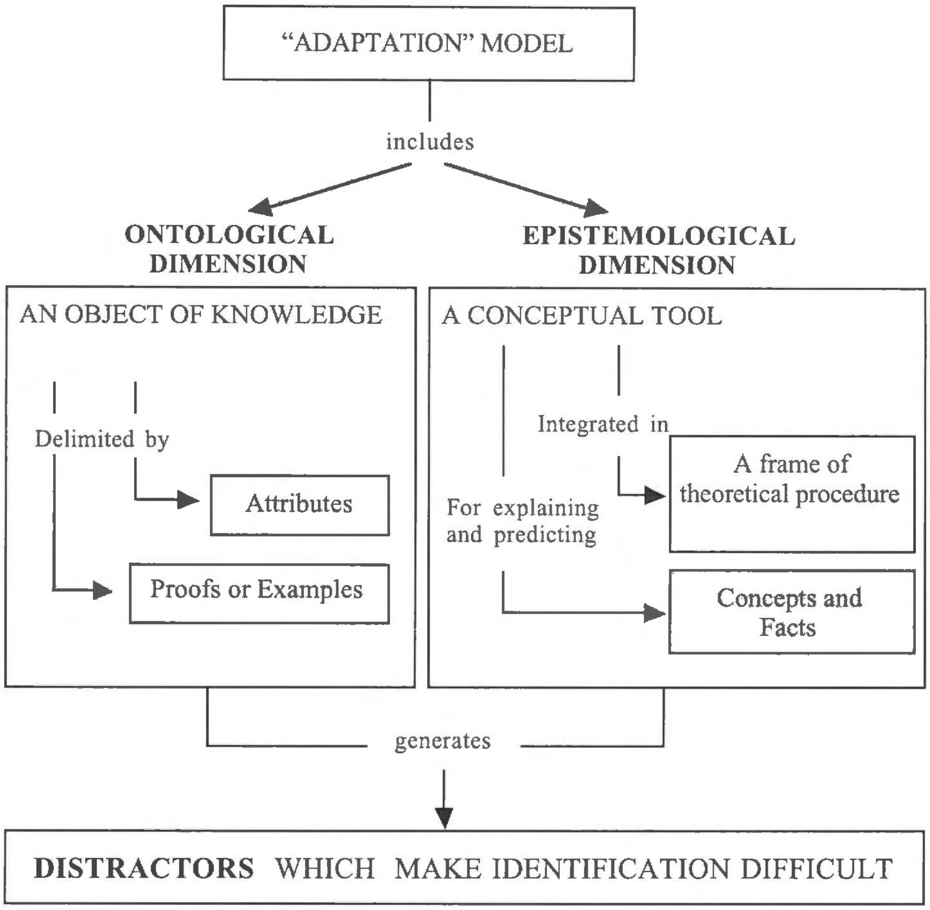
3 Results

Because of the way in which they are made, the networks represent something more than simple systems of categorisation, as they constitute a first step in the data analysis. Each one of them allows us to appreciate different points of view, giving rise to a model of the concept of adaptation (Figure 1), both for the scientific texts as well as for the Secondary education books:

- The *ontological dimension* is built up from those statements where "adaptation", of an empirical nature, works as an object of knowledge. As such, it can be outlined by the explicitation of some *attributes* and made evident by the contribution of examples. It corresponds to the network items that we included in the "object" category ("features" and "process") (de la Gándara, 1999).
- In the *epistemological dimension* the adaptation works as a *conceptual tool*. It takes in those statements that show how "adaptation" is integrated in a theorical-procedimental framework a how it is used to explain other concepts and phenomena and to predict facts. It corresponds to the analysis of the category "epistemology value" and, in the case of the Secondary textbooks, also to the category "didactic value" (de la Gándara, 1999).
- Abiding by the language used by the authors, a third dimension of the concept called "*distracters*" is configured, as long as they *obstruct the identification of de model* and therefore its *transposition to didactic contexts in non-university levels.* It corresponds to the "ambiguities" and "contradictions" that appear in a dispersed way in all the categories of the networks (de la Gándara 1999).

Comparing the models that emerge from the network, in their three dimensions, we obtain the following results.

Figure 1. Dimensions of the adaptation model on the specialised literature and the textbooks of Secondary Education



3.1 Ontological dimension transposition

The adaptation is a concept easier to be used than defined in both scientific and secondary textbooks.

The transposition to the first Secondary cycle (12-14 years) produces an adaptation model very different from the scientific one and closer to the ordinary sense of the term:

> (1) '*Adaptation*' is every feature needed for survival (2). *'To be adapted'* is equivalent to "live in a place". (3) *'How they adapt themselves' is* equivalent to "now they live".

A sudden change happens in the Second cycle (14-16), the double sense is transposed: both as a *feature* and as a *process*. The *adaptation-feature* *model* is, almost, a transcription from the inferred model from the specialised literature (Table 1).

The *adaptation-process model* inferred from the specialised literature is implicitly integrated into two submodels -the *physiological* and the *evolutionary* ones-:

(a) From the specialised literature, we infer that all the descriptive and all the *explanatory tools* of de model of *physiological process* of adaptation are implicit in most of the cases. This implicit model is transposed in an inconspicuous way to the Second cycle, substituting "life function" for "adaptation" (Table 2)

(b) The model of *evolutionary process* of adaptation is the only one transposed in an explicit way to the second cycle (Tables 3a and 3b).

Table 1. Model of *Adaptation as a Feature.*

Spezialized literature	*transcription* →	**ESO -2nd cycle**
Adaptation is a structure that supplies "profit" to its possessors:	For survival: consensus with some ambiguity	*Shared* (it means that it is equally transferred to all the publishing houses)
	For reproduction: with some discussions and refinements, among specialized literature.	*Shared without discussion*
	For evolution: stated by few authors and object of controversy for others.	*Not shared*
The status of adaptation is relative to either an environment or a way of life, or a function (functional efficiency).		*Shared*
An adaptation itself may characterise to either one species or more, even if it lacks of any taxonomic value.		*Shared*
The *evidences* or *examples of* 'adaptation'	The proof consists of showing the correlation between the feature and one or more environmental factors.	*Shared*
	The proof consists of showing the efficiency of that adaptation in the defence that it supplies to its possessor against the damaging action of environment (or any environmental factor).	*Shared*

Table 2. Inferred Model of Physiological Process of Adaptation

Spezialized literature —— *transposition* →	**ESO -2nd cycle**
Small changes with little novelties.	This sort of biological changes are transposed under the denomination "living functions", but not "adaptation".
Generation change	
Recurrent change	
Reversible change	
Predictable change in most of the cases	
Omission of the model's explicative tools: • Participation of genetic information • Participation of the reproduction • Participation of the ontegenic development • Participation of the natural selection	
It is to be presupposed that the entity who carries out the process is the individual, when they quote different types of biological systems.	

Table 3a. Inferred Model of *Evolutive Process* of Adaptation (the model's *descriptive tools)*

Spezialized literature —— *transposition* →	**ESO -2nd cycle**
Controversy: small novelty / big novelty	• Use to be implicit • Elude controversies
Transgeneration change	
Unique change	
Irreversible change	
Controversy: Predictable change / Unpredictable	

Table 3b. Inferred Model of *Evolutive Process* of Adaptation (the model's *explanatory tools*)

Spezialized literature — *transposition* →	**ESO -2nd cycle**
Role of genetic information: • New information is required. • Several terms employed: "genetic variability", "genetic change", "new genotypes"	Role of genetic information: • "Genotype" and "phenotype" are quite often used at the same level. • "Genetic variability", "genetic change", "new genotypes" are indistinctly applied.
Change requires reproduction	Insistence on "adaptations are inherited" but "not acquired". "It is very difficult to distinguish between "inherited" and "acquired".
Controversy: Normal development / Anomalous (treated by very few authors)	Ontogenesis breaks with Adaptation.
Role of Natural Selection: • Controversy: Previous / after biologic change. • Selection is employed to explain Adaptation. • Selection has value as a proof of empirical object to be an adaptation • Selection is employed to explain the restrictions of adaptation: neither every biological change is possible, nor everything produced by selection is an adaptation.	Role of Natural Selection: • Ambiguity about the sequence Selection-Evolutive change. • Adaptation is employed to explain Selection. • Adaptation has a value as an evidence; an empirical object that does not need to be demonstrated. • Ambiguity about the adaptatative restrictions. It could be interpreted that everything produced by selection is an adaptation.
Ambiguity on causal relationships: (a) Between Adaptation and Random. (b) Between Adaptation and Natural Selection (c) Between Adaptation and Isolation (d) Between Adaptation and Competition	The same ambiguities are transferred
Difficulties on distinguish between "process of Adaptation" and "process of Evolution".	The process of Adaptation is identified with the process of Evolution.
It is to be presupposed that the entity that realises the process is the population, or lineage, when quoting the different types of biological systems.	They allude indistinctly to terms that represent taxonomic or ecological groups.

The *descriptive tools*, which are implicit in most of scientific literature, are transferred in the same way or even in a confused way to the books of Secondary education. Basically the *explanatory tools* are transposed in the same way, even though some of them work in a different manner:

- The *causal relations* between adaptation and selection are reversed: the adaptation is used to explain the Selection.
- The relations between adaptation, genetic information and heredity are ambiguous.
- The ambiguity shown by scientists when relating the adaptation with random competition and isolation is completely transcribed.
- The *entity* object of adaptation must also be inferred, although the lack in precision related to it are marked in the secondary books, when taxonomic and ecological groups are placed at the same level.

3.2 Epistemological dimension transposition

- The reference *paradigm* is the Darwinian one, with some ambiguities in the framework as well as in the methods used to study the adaptation.
- Sometimes scientists point out the role of the Darwinian theory in the refutation of creationism. However all the books refute Lamarckism.
- Among evolutionists, gradualism is object of discussion, however this aspect into the Secondary textbooks is transposed in a very ambiguously way.
- The biggest difference between *specialised literature and Secondary textbooks*, takes place in the procedures. About the methods employed to study the adaptation is possible to point up the role of *examples*. Among biologists, the examples are based on isolating and contrasting hypothesis. In the Secondary textbooks the examples are used as an opportunity to make theory using two kinds of strategies for it: Sometimes analogy is used as a resort, so some "reading codes" are introduced which will show the reader both similarities and differences among the situations that have been created. Other times some facts "ad hoc" are presented, introducing a high level of interpretation, from the framework this is trying to be reconstructed in the description, for example, analogous and homologous organs like evidences of Evolution and Adaptation (Table 4).

Table 4. Transposition of the *Epistemological Dimension* of the Adaptation model

Spezialized literature — *transposition* →	**ESO -2nd cycle**
Theoretical frame: • Darwinism versus Creationism • Controversy: Gradualism versus Saltationism, to explain some biological changes.	Theoretical frame: • Darwinism versus Lamarckism • The Gradualist-Saltationist controversy is mentioned apart from adaptation and the theory of natural selection.
Proceeding frame is based on experimentation: • Mere allusion to isolation of biological and environmental variables, followed by contrasting of hypothesis.	Proceeding frame is based on exemplifying: • First Cycle: Choosing real and imaginary examples, liable to be compared by analogy. • Second Cycle: Showing theoretic constructs (interpretations) as observable objets.

3.3 Adaptation model identification: Distracters or difficulties

The texts analysed contribute to perceive an *speculative image of biology*, because the lack of argumentative consensus, even harder in Secondary textbooks:

- Substitution of selectionist criteria by utilitarian ones and this make everything able to be adaptation.
- Absence of homogeneity when stating the tools of the model, so that ones, which were useful for some authors for explaining the adaptation, are just omitted by others
- The adaptive status of some "evidences" is questionable. For example, organism colours sometimes are mimetic adaptation or a mechanism to conserve temperature body.

In the Secondary textbooks, the arguments against external teleology of creationism and against internal teleology of Lamarckism become insufficient, contributing to this:

- The *finalism* associated to the argument of benefit brought off, leaving out the evolutive model, in the physiological context in Secondary.
- The *anthropomorphic* image of selection (as selection "opts" "chooses", "decides").
- Solid arguments against Lamarckism lack.
- Abuse of problem-situations, without a previous negotiation about the meaning of the terms to be used.

The concept of adaptation is transmitted as a term *empty of any contents*, because of some reasons most of which have been quoted yet.

- Because of an argumentative circularity, as adaptation is utilised for explaining the adaptation.
- Because of the ambiguity shown at the definition of some terms, "adaptation" among them. Others are "ambient" and "time".
- Because of explicitation of a demarcation criteria between the phenomenon of evolution and the adaptation one lack, especially in Secondary education books.
- Because to explain the same phenomenon some times omitting the term "adaptation" and in others expliciting it.

4 Discussion

When we enquire what sense do the different publications give to the term "adaptation", we find several expressions, arguments, value judgements about what other authors do or say difficult to reconcile. Carrying all these expressions, without exclusion, into a network, they point to the existence of such a diversity of perspectives and ways of describing them that contribute to forge a *speculative image of biology*. At the ontological level, the term of "adaptation" can be tackled as an object that hardly designates anything empirical. We can say it an entelechy, since it is not enough for explaining the global state of adaptation attributed to their owners.

At the epistemological level can be an active obstacle, when there is not a shaped causal relationship between the concepts and methods that have been mentioned to interpret the phenomena of the biological change. It results an idea empty of any contents, when its description gives of the idea that practically any biological system (at any level) can be considered an adaptation. However, some authors tell not to understand the adaptation in that way. The adaptation is a mere rhetorical resource when is used for explaining what others deny or just question.

The majority allusions to the mediation of the Evolution made us think that the inferred physiological and evolutive models must be integrated into an only one. Nevertheless, that integration requires taking account of the interaction within the different levels of biological integration at the same time, from the individuals genetic level to the populations phenotypic one. That also obliges to consider simultaneously both the changes that happen in space and those that occur in time.

We miss a higher precision in two questions: one the one hand, an explicitation of criteria for differentiating from one state of adaptation to the following one; on the other, interaction mechanism between genotype and environment. We have not found the first one in this study. The second one only appears very superficially mentioned by

some of the authors of the sample. We believe that a higher attention to the ontogenic model of adaptation (absent in the studied samples), might help to fill these blanks as well as to integrate the inferred submodels.
If you will pardon the irony: it is possible to think that the didactic success of adaptation lies in the ambiguous way it can be used. Although it seems to be an irony, it is not. The adaptation can be a challenge to question the spontaneous thought both teachers and pupils.
For all this, arises a fundamental question for the teaching: how to control the meaning of "adaptation", indispensable for its didactic transposition. This question is even more important when teaching experience confirms that the adaptation compete in the classroom with many other meanings proceeding of the social-cultural environment, in a margin of the instruction. We cannot be astonished at how the students transmit their biological models, show such degree of confusion. We defend a major clarity in language and, on top of everything, a major rigour in the line of argumentation.

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Moody,D.E. (1996): Evolution and the texbook structure of biology. *Science Education* 80 (4), 395-418

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ANEXES

I: Composition of the sample "specialised literature"

[AO]: ALBERTS, B. et al. (1990). Biología molecular de la célula. Barcelona: Omega.

[CB]: CURTIS, H. y BARNES, N.S.(1997) Invitación a la biología. Madrid. ed. Médica pannamericana.

[CL]: CLARKE, G.L. (1971): Elementos de Ecología. Barcelona. Omega.

[DC]: DEVILLERS, C. y CHALINE, J. (1993). La teoría de la evolución. Estado del tema a la luz de los actuales conocimientos científicos. Madrid. Akal.

[DO]: DOBZHANSKY,T; AYALA,F.J.; STEBBINS,G.L.; VALENTINE, J.W. (1980): Evolución. Barcelona. Omega.

[GA]: GANONG, W.F. (1971): Fisiología médica. México. El manual moderno.

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[LE]: LEWONTIN, RICHARD, C. (1978): La adaptación, en Libros de Investigación y Ciencia (Scientific American): Evolución, , pp. 141-155. Barcelona, ed. Labor.

[MR]: MARGALEF, R. (1991): Teoría de los sistemas ecológicos. Barcelona. Ed. Publicaciones Universitat de Barcelona.

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[SC]: SCHMIDT-NIELSEN, K.(1976): Fisiología animal. Barcelona. Ed. Omega.

[ST]: STRASBURGER, E.(1984): Tratado de botánica. Barcelona. Ed. Omega.

[WE]: WEISZ, P.B.(1971): La Ciencia de la Biología. Barcelona. Ed. Omega.

II. Textbooks of "Secundary Obligatory"

[A1]: CARRION,F.; GIL,C.; SATOCA,J.; VISQUERT,J.J. (1996): *Ciencias de la Naturaleza 1*. Madrid. Ed. **Anaya**.

[A2]: CARRION,F.; GIL,C.; SATOCA,J.; VISQUERT,J.J. (1997): *Ciencias de la Naturaleza 2*. Madrid. Ed. Anaya

[A3]: BERGES,T.; CARRION,F.; GIL,C.; MARTINEZ,J. (1995): *Ciencias de la Naturaleza. Biología y Geología 3*. Madrid. Ed. Anaya.

[A4]: BERGES,T.; CARRION,F.; GIL,C.; MARTINEZ,J. (1995): *Ciencias de la Naturaleza. Biología y Geología 4*. Madrid. Ed. Anaya.

[M1]: DEL CARMEN,L.; PEDRINACI, E.; CAÑAS,A.; FERNANDEZ,M. (1996): *Ciencias de la Naturaleza. Secundaria*

1. Explora. Madrid. Ed. sm.

[M2]: DEL CARMEN,L.; PEDRINACI, E.; CAÑAS,A.; FERNANDEZ,M. (1997): *Ciencias de la Naturaleza. Secundaria 2. Explora*. Madrid. Ed. sm.

[M3]: DEL CARMEN,L.; PEDRINACI, E. (1994): *Ciencias de la Naturaleza: Biología y Geología. Secundaria 3*. Madrid. Ed. sm.

[M4]: DEL CARMEN,L.; PEDRINACI, E. (1995): *Ciencias de la Naturaleza: Biología y Geología. Secundaria 4*. Madrid. Ed. sm.

[S1]: BRINCONES,I.; CEREZO,J.M.; CUERVA,J.; SANCHEZ,D.; ZARZUELO,C. (1996): *Ciencias de la Naturaleza, 1º*. Madrid. Ed. Santillana.

[S2]: ARRIBAS,E.; BRINCONES,I.; CEREZO,J.M.; CUERVA,J.; SANCHEZ,D.; ZARZUELO,C. (1997): *Ciencias de la Naturaleza, 2º*. Madrid. Ed. Santillana.

[S3]: ALVAREZ,M.I.; CEREZO,J.M.; ESCARRE,A.; ESTELLER,A.; MULAS,J.; ZARZUELO,C. (1995): *Ciencias de la Naturaleza. Biología y Geología 3º*. Madrid. Ed. Santillana.

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BIODIVERSITY AND THE COMPARATIVE METHOD A TEACHING INTERVENTION AT AGE 11-12

Marcus Hammann & Horst Bayrhuber
Institute of Science Education (IPN), Kiel, Germany

Abstract

In the didactic literature, comparisons are attributed two main functions in the teaching of biology: On the one hand, they can be used as a source of information in order to develop the students' knowledge and comprehension of the subject matter, for example the students' knowledge of adaptations. On the other hand, the comparative method is an alternative to experimentation and can be used to familiarize students with basic ways of thinking and operating in science. Intending to clarify the dual role of comparisons in the teaching of Biology, a pilot study investigated, which aims teachers consider important when they engage their students (age 11-19) in anatomical and morphological comparisons. The teacher's responses (n= 351) showed that the contours of comparisons as a mode of scientific inquiry become sharper the more advanced the learning level of the students is. In particular, the older the students the more important the teachers consider promoting analytical skills that are necessary for scientific inquiry, for example differentiating between different types of biological similarity. The findings of this study of teachers' aims in comparisons will be reported and discussed in this paper.

Also, the theory and design of the main study on comparisons in the teaching of biology will be presented. Its main focus is on knowledge prerequisites necessary for noticing and interpreting similarities and differences in comparisons. The two research questions posed by this study are whether or not the ability to compare organisms improves if students possess multiple knowledge precedents in the domain and whether or not multi-dimensional knowledge structures are advantageous over one-dimensional knowledge structures in comparisons in which students have to distinguish between the ecological and the evolutionary perspective. This paper also provides background information about the

comparative method as a mode of scientific inquiry, gives a survey of studies pertinent to this study, and describes the theoretical underpinnings of the research questions and hypotheses. The teaching intervention described in this paper aims at 11-12 year-old students and attempts to improve the students' ability to discern and interpret differences and similarities in comparisons.

1 Introduction

The comparative method is a major mode of scientific inquiry in Biology. Important monographs (e.g., Ridley 1983, Rieppel 1988, Harvey & Pagel 1991) and science theorists of comparative biology (e.g., Nelson 1970, Osche 1975, Wuketits 1977, Janich 1993, Janich & Weingarten 1999) testify to the role of the comparative method in the growth of biological knowledge. Recognizing its importance, however, has long been rendered difficult by a wide-spread belief in the primacy of the experiment in the sciences. Mayr (1982) clearly addresses the misrepresentation of the comparative method: "In the theory of science, the experiment is often treated as *the* method of scientific inquiry. This is incorrect because in some disciplines, as for example evolutionary biology, other modes of inquiry are important which are strictly scientific. It is above all important to underline the legitimacy of the comparative method, because the experimental method cannot be applied to many scientific problems." As an alternative to experimentation, the comparative method is a mode of scientific inquiry in its own right that contributed to understanding the history and diversity of organisms. Mayr (1982) even estimates that it has brought forth "more insights than all experiments combined" (32).

From a theoretical perspective, comparisons establish a relationship between objects or organisms by using a criterion (a feature), the selection of which depends upon the specific purpose of the comparison (Janich & Weingarten 1999). Comparisons, thus, are never theory-neutral and the purpose of the comparison determines feature selection and feature weighting. Ecologists, for example, classify organisms according to common way of life and use the organisms' adaptation to the environment as the basis of their comparisons. They form the "guild school" and can be clearly set off from the "descent school," the other major tradition in comparative biology, which is constituted by evolutionary biologists (Harvey & Pagel 1991). The latter base their comparisons on completely different sets of criteria. Intending to establish groups that reflect our knowledge of the evolutionary past, they select criteria which are indicative of common descent and arrive at evolutionary—not ecological—classifications. Major advances in classification were possible by distinguishing between structural and

functional similarities that have their origin either in common descent (homologies) or in adaptation to comparable environments (analogies).
When students are confronted with the diversity of organisms in classification tasks, for example, they have to deal with the concept of similarity, a concept that similarity theorists have described as "relative and variable" and "hopelessly ambiguous" if not confined by context (Goodman 1972, 444). Without reference to the two causal mechanisms that inform biological similarity—common descent and adaptation to similar environments—similarity is hopelessly ambiguous indeed because any two organisms can be found similar or dissimilar depending on the features that are selected. A fish and a whale, for example, can be found similar if the shape of their bodies is considered. They can also be found dissimilar because the former is cold-blooded and the latter warm-blooded and also because they reproduce differently. Empirical studies, unsurprisingly, reveal that distinguishing between different types of biological similarity is particularly problematic for students who often misjudge superficial similarity (similar locomotion, similar adaptation to the environment) as indicators of kinship (Kattmann & Schmitt 1996). Thereby, they disregard that evolutionary and ecological factors figure in the concept of similarity and that it is necessary to take them both into account by reflecting upon the criteria that serve as the basis for the comparison.
Comparisons can provide students with opportunities to engage in processes of investigation and inquiry, for example, by placing functional and structural similarities in ecological and evolutionary contexts and teaching students to distinguish between them. Comparisons, thus, allow students to gain insights not only into science concepts and principles, but also into the ways in which scientists think and operate when they acquire knowledge about nature. Classifications of the goals for laboratory instruction clearly reflect these two aspects of practical work in science education, listing among other areas "the promotion of scientific thinking and the scientific method" and "the development of conceptual understanding" (e.g., Shulman & Tamir 1973, Anderson 1976). These classifications have contributed significantly to clarifying the role of practical experimental work in science education. In addition, studies investigating the aims that teachers pursue in experiments have provided precise empirical information so that it is possible, as Hofstein and Lunetta (1982) have argued, "to identify optimal activities and experiences from all modes of instruction that will best facilitate these goals" (213). Similar information is lacking for the comparative method in biology education so that it is impossible to say for which purposes teachers engage their students in comparative biology.

2 Pilot Study: Teachers' Aims in Anatomical and Morphological Comparisons

The didactic literature lists a broad range of goals for comparisons in biology education. Eschenhagen, Kattmann & Rodi (1998, 222-228) and Stephan-Brameyer (1985, 110-118) provide comprehensive synopses of the literature. In contrast to the objectives for experimentation, these have not been systematized yet. For the purposes of this study, a classification was created that focuses on two main aspects: Comparisons as an opportunity for teaching students factual and conceptual knowledge (*Set I: Knowledge and Comprehension of Science Contents*) and comparisons as an opportunity for familiarizing students with basic ways of thinking and operating in science (*Set II: Processes of Scientific Inquiry*). Klopfer's (1971) categories "Knowledge and Comprehension" and "Processes of Scientific Inquiry" were adapted for this purpose. The items in parentheses concretize these categories and can be found in Tab. 1 and Tab. 2.

Set I: Knowledge and Comprehension of Science Contents
- Knowledge of concepts .... (items 1, 2 and 3 in Tab. 1)
- Knowledge of specific facts .... (items 4 and 5 in Tab. 1)
- Knowledge of classifications, categories, criteria .... (item 6 in Tab. 1)
- Knowledge of scientific terminology ...... (item 7 in Tab. 1)

Set II: Processes of Scientific Inquiry
- Observation of objects and phenomena .. (item 1 in Tab.2)
- Formulation of generalizations warranted by relationships found .... (item 2 in Tab. 2)
- Interpretation of observations/ scientific argumentation .... (items 3,4, 6, and 7 in Tab. 2)
- Knowledge of scientific techniques and procedures.. (items 5,8, and 9 in Tab. 2)

2.1 Research Questions and Hypotheses

This study was designed to find out which aims teachers consider important when they engage their students in anatomical and morphological comparisons. In particular, it is of interest if teachers consider comparisons equally as a source of knowledge of science content and of ways of thinking and operating in science. Also, this study investigates if certain aims shift in importance at different learning levels.

It was expected, roughly, that at the lower learning stages teachers (ages 11-12) consider the development of knowledge of science contents as more important than providing insights into scientific inquiry because at the early grades the students need to acquire basic anatomical and morphological knowledge. Once this knowledge base is established, it was expected that this relationship be reversed, with knowledge about ways of thinking and operating in science becoming increasingly important also because at the middle (ages 13-16) and upper learning stages (ages 17-19) the national curricula assign the topic of evolution greater importance.

2.2 Methodology

The aims teachers consider important in anatomical and morphological comparisons were assessed with a questionnaire that was pre-tested and sent to 180 schools. Since this research project is part of the national quality development program "BLK Modellversuchprogramm: Steigerung der Effizienz des mathematisch-naturwissenschaftlichen Unterrichts" ("Increasing the Efficiency of Science and Mathematics Education") schools participating in the program were asked to answer the questions. Not all biology teachers were enrolled in the program, however, and participation in the survey was voluntary for all teachers. The return rate was 32,5% (n=351).

The teachers were asked to answer a few questions about themselves: 34% of the respondents indicated that they take part in the national quality development program; 56% do not participate (10% missing data). The majority of the respondents (54%) gave the information that they possess more than 20 years of teaching experience, 23 % possess 11-20 years of teaching experience, 8 % possess 5-10 years of teaching experience, 10 % possess less than 5 years of teaching experience (missing data and teacher trainees: 5%). The majority of the respondents (53%) indicated that they teach at the Gymnasium (grades 5-13), the type of school at which students can receive the qualification for further study at a university; 19% teach at the Realschule (grades 5-10), 15% at the Hauptschule (grades 5-9) and 6% at different school types.

In the main part of the questionnaire, the teachers were asked to assess the importance of 16 pre-formulated goals which are reported in this paper. Instead of requesting the respondents to rank the goals from the most important to the least important, a scale of four possible answers ("very often," "often," "rarely," "never") was used so that it was possible to rate aims as equally important that cannot be hierarchized. This is particularly important because there is estimated to be a high degree of interdependence between the items from the two sets of objectives outlined above; comparisons can be used for teaching science and *about* science at the same time.

Additional room was provided in case the teachers wanted to add goals to the list that they consider important. However, only very few additions

were made. Also, the teachers were asked to answer the questions for one grade only and to indicate which grade they were thinking of when they filled out the questionnaire. They were advised to choose a grade in which they often use anatomical or morphological comparisons, most preferably a grade that they were teaching at that moment or not too long ago. Also, they were asked to indicate the title of the course if they had chosen grades 11-13 (ages 17-19), which are course-structured.
The data were processed using SPSS to calculate the descriptive statistics (frequencies, means, standard deviations) for the following grade groups: German grades 5-6 (early learning levels, ages 11-12), German grades 7-10 (middle learning levels, ages 13-16), and German grades 11-13 (upper learning levels, ages 17-19). Means were calculated by translating "very often" into 4, "often" into 3, "rarely" into 2, and "never" into 1 so that an objective at a mean of 2,5 is of average importance.

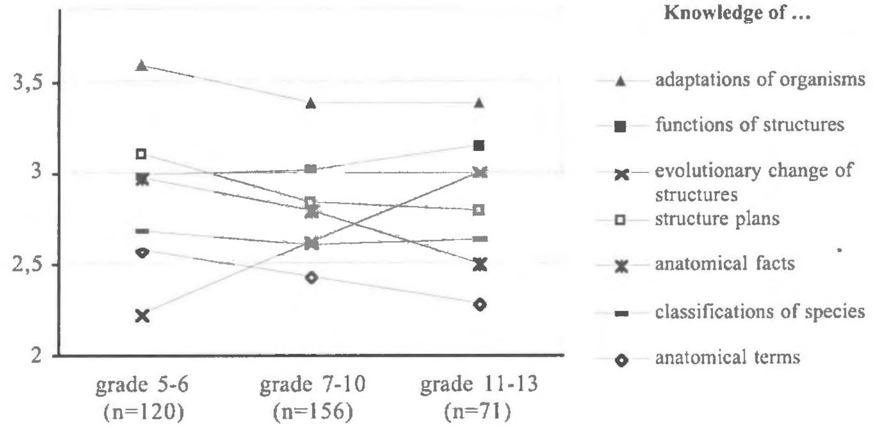
2.3 Research Findings

Table 1 reports on the means and standard deviations of the items in *Set I "Knowledge and Comprehension of Science Contents."* "Knowledge of adaptations of organisms" is clearly the leading objective in this group, while "knowledge of the evolutionary change of structures" received the lowest scores at grades 5-6 (ages 11-12) and "knowledge of anatomical terms" ranks the lowest at grades 7-10 (ages 13-16) and grades 11-13 (ages 17-19). The majority of items in this set is characterized by slight decreases in importance at the middle and upper learning stages. This is the case for "knowledge of adaptations of organisms", "knowledge of structure plans", "knowledge of anatomical facts" and "knowledge of anatomical terms." Their overall decreases in importance from grades 5-6 (ages 11-12) to grades 11-13 (ages 17-19) is 0,32 on overage. In contrast, there are two objectives in this set whose importance increases at the middle and higher learning stages: "knowledge of the functions of structures" increases only slightly, but "knowledge of the evolutionary change of structures" increases by 0,72 (cf. Fig. 1).
Teachers clearly consider conceptual knowledge—knowledge of adaptations at grades 5-13 (ages 11-19) and knowledge of functions at grades 7-13 (ages 13-19)—to be more important than other kinds of knowledge. The concept of the evolutionary change of structures is insignificant at grades 5-6 (ages 11-12), but rises in importance and ranks behind the other two concepts in the third position at grades 11-13 (ages 17-19). Knowledge of structure plans is rated higher than knowledge of anatomical facts, knowledge of classifications and knowledge of terms across the three learning stages. Knowledge of anatomical facts is still an important aim at grades 5-6 (ages 11-12), but ranks in the second lowest position at grades 11-13 (ages 17-19).

Table 1. Teachers' Aims in Anatomical / Morphological Comparisons. Set I: Knowledge and Comprehension of Science Content (means in bold letters; standard deviations in parentheses). The teachers indicated on a scale of four (4: very often, 3: often, 2: rarely, 1: never) how often they used comparisons for the indicated purpose.

Knowledge and Comprehension of Science Contents Knowledge of ...	**grades 5-6 n=120**	**grades7-10 n=156**	**grades 11-13 n=71**
1. adaptations of organisms	**3,59** (0,54)	**3,38** (0,69)	**3,38** (0,64)
2. functions of structures	**2,98** (0,75)	**3,02** (0,76)	**3,15** (0,73)
3. evolutionary change of structures	**2,22** (0,85)	**2,62** (0,83)	**3,01** (0,75)
4. structure plans	**3,11** (0,70)	**2,84** (0,80)	**2,80** (0,78)
5. anatomical facts	**2,96** (0,74)	**2,79** (0,79)	**2,49** (0,69)
6. classifications of species	**2,68** (0,70)	**2,61** (0,66)	**2,64** (0,72)
7. anatomical terms	**2,57** (0,73)	**2,42** (0,76)	**2,29** (0,69)

Figure 1. Teachers' Aims in Anatomical / Morphological Comparisons. Set I: Knowledge and Comprehension of Science Contents (lines connecting the means do not carry meaning)



The general tendency for the majority of items in *Set II "Processes of Scientific Inquiry"* is an increase in importance at the middle and higher learning stages (cf. Tab. 2). This is true for the following objectives: "analyzing anatomical structures to assess kinship," "analyzing structures to understand the ways in which organisms are adapted to their environment," "scientific argumentation", "distinguishing between different types of similarity (adaptation / common descent)",

"reconstructing the phylogeny of organisms," and "discussing research methods" (cf. Fig. 2 for this selection of objectives). Their means increase by an average of 0,16 at grades 7-10 (ages 13-16) and by an average of 0,42 at grades 11-13 (ages 17-19). "Familiarizing students with the method of classifying organisms" shows a slight decrease in importance at grades 7-10 (ages13-16), but an overall increase at grades 11-13 (ages 17-19). The other two items in this set, "close registration of similarities and differences," and "finding common features (generalizing)," stay at about the same level of importance across the three learning levels.
Teachers rate the general skills in this set of objectives (i.e. "close registration of similarities and differences" and "finding common features (generalizing)") as equally important across the three learning levels. More specific skills concerning the interpretation of perceived differences and similarities are rated higher at the advanced learning levels than at the middle learning levels and early learning levels. The same is true for objectives concerning knowledge of scientific techniques and procedures. "Discussing research methods" is considered the least important objective in this group at the three grade groups.

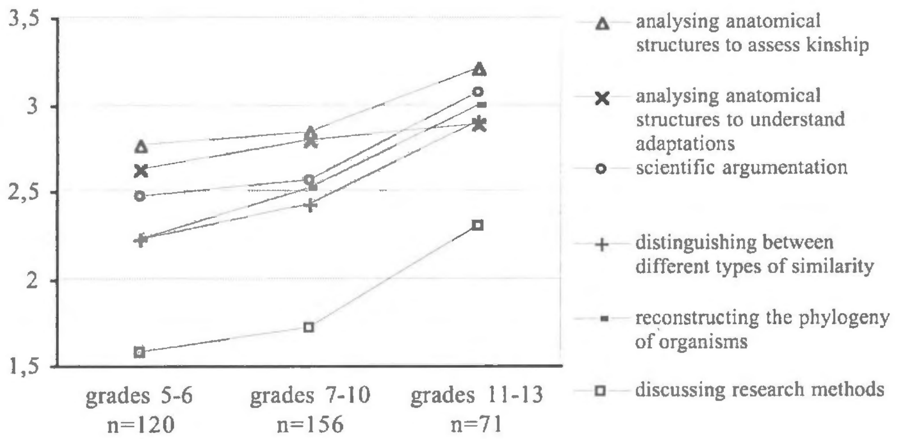
Table 2. Teachers' Aims in Anatomical / Morphological Comparisons. Set II: Processes of Scientific Inquiry (means in bold letters; standard deviations in parentheses) The teachers indicated on a scale of four (4: very often, 3: often, 2: rarely, 1: never) how often they used comparisons for the indicated purpose.

Processes of Scientific Inquiry	**grades 5-6 n=120**	**grades7-10 n=156**	**grades 11-13 n=71**
1. close registration of similarities and differences	**3,13** (0,68)	**3,09** (0,67)	**3,06** (0,72)
2. finding common features (generalising)	**2,94** (0,78)	**2,85** (0,74)	**3,02** (0,72)
3. analysing anatomical structures to assess kinship	**2,76** (0,79)	**2,84** (0,75)	**3,20** (0,65)
4. analysing structures to understand the ways in which organisms are adapted to their environment	**2,63** (0,87)	**2,79** (0,75)	**2,88** (0,63)
5. familiarising students with the method of classifying organisms	**2,54** (0,76)	**2,44** (0,69)	**2,68** (0,71)
6. scientific argumentation			
7. distinguishing between different types of similarity (adaptation / common descent)	**2,47** (0,78) **2,23** (0,85)	**2,56** (0,73) **2,42** (0,83)	**3,07** (0,60) **2,90** (0,68)
8. reconstructing the phylogeny of organisms	**2,22** (0,88)	**2,52** (0,86)	**3,00** (0,82)
9. discussing research methods	**1,58** (0,67)	**1,72** (0,61)	**2,30** (0,77)

2.4 Discussion

The findings substantiate the main hypothesis of this study. Teachers indeed rate the importance of aims in anatomical-morphological comparisons differently at different grade levels, placing less emphasis on scientific inquiry at the early grades than at the upper grades and more emphasis on knowledge and comprehension at the early grades than at the upper grades. Decreases in importance for objectives in *Set I: "Knowledge and Comprehension of Science Contents"* are however slighter than the gains in importance for objectives in Set II: "Processes of Scientific Inquiry" so that there is no complete reversal of objectives at grades 11-13 (ages 17-19). Instead, the rise in importance for objectives in *Set II: "Processes of Scientific Inquiry"* (cf. Fig. 2) indicates that the contours of comparisons as a method of scientific inquiry become sharper at the higher learning levels, though comparisons never lose their importance for developing certain kinds of factual/conceptual knowledge (cf. Fig. 1). Anatomical-morphological comparisons provide teachers with the opportunity to familiarize students with science contents and basic ways of thinking and operating in science; this potential, however, is more fully exploited at the advanced learning stages (ages 17-19) than at the earlier learning stages.

Figure 2. Teachers' Aims in Anatomical / Morphological Comparisons. Set II: Processes of Scientific Inquiry (selection of six out of nine; lines connecting the means do not carry meaning).



The findings also highlight some discrepancies. Teachers at the lower grades pursue ecological and classificatory questions in comparisons (cf. items 3, 4, and 5 in Tab. 2). However, the concept of kinship is divorced from the concept of evolution, as exemplified by the discrepancy between high scores for "analyzing anatomical structures to assess kinship" and low scores for "distinguishing between different types of similarity (adaptation / common descent)" (i.e. items 3 and 7 in Table 2; cf. also items 6 vs. 3 in Table 1, and items 5 vs. 8 in Table 2 for further discrepancies between kinship-items and evolution-items). Excluding the evolutionary perspective from comparisons in grades 5-6 is problematic because it interferes with the teachers' objective to promote methodological knowledge about classification and analytical skills geared towards classifying organisms (i.e. items 5 and 3 in Table 2). Evolutionary factors and ecological factors figure in the often problematic concept of biological similarity that students must tackle when they classify organisms. The problems referred to in the introduction, the students' deficient differentiation between ecological criteria and evolutionary criteria, can thus be related to the findings in this study. Students need to know more about different kinds of similarity and, more importantly, about the crucial role of criteria in comparative investigations because matching the aims of comparisons with appropriate criteria is at the heart of the comparative method as a mode of scientific inquiry. Enabling students to reflect upon and argue about the criteria that serve as the basis for their comparisons must be more prominent aims at grades 5-10 (ages 11-16) in order to address the problems students possess in comparisons and in order to give the comparative method a clearer profile as a method of scientific inquiry in the classroom.

3 Main Study: Comparing the diversity of organisms: A teaching intervention (ages 11-12)

3.1 Aims

The focus of this study is on the knowledge prerequisites that students should possess in order to compare organisms. Carrying out comparisons entails the two processes of perceiving and interpreting similarities and differences. Both processes are influenced by the domain-specific pre-knowledge, as studies on novices and experts' perceptions/interpretations of similarities and differences in biological and physical comparisons have shown (e.g. Chi et al. 1981, Mervis et al. 1993). The findings of these studies indicate that experts interpret similarities differently than novices and focus their attention on different details. Experts possess a larger case-based knowledge and a repertoire of internalized contrasts that

evidently enable them to perform better in comparisons in which similarities and differences need to be evaluated.
Basing their theoretical considerations on these differences between novices and experts, Bransford et al. (1989) suggested an instructional approach involving contrast sets. According to Bransford, contrast sets help students acquire a repertoire of knowledge antecedents, familiarize them with common interpretations of similarities and differences in the domain and support their abilities to recognize features and patterns of features. In the present study, the method of contrast set teaching will be applied to biology instruction. In particular, contrast set teaching is expected to enhance the students' performance in ecological and systematical comparisons. Two main research questions will be posed. First, this study investigates if a larger case-based knowledge in a domain enables students to perform better in comparisons. Second, it will be tested if multi-dimensional knowledge structures are better suited to carrying out ecological and systematical comparisons than one-dimensional knowledge structures.

3.2 Hypotheses

Two sets of hypotheses on the advantages of contrast set teaching will be tested:

1. The great diversity of organisms complicates the application of ecological and systematical knowledge in comparisons. Contrast sets familiarize students with a larger number of cases so that they can acquire a number of possible analogies for understanding new cases and applying knowledge. Against the background of Bransford's (1989) theoretical considerations, the following hypotheses will be tested: *Contrast sets facilitate the perception and interpretation of features and patterns of features in comparisons. Students possessing a large case-based knowledge will be able to notice and interpret more features and patterns of features in comparisons than students with a more limited case-based knowledge.*
2. Students easily confuse the criteria for ecological comparisons and systematical comparisons (Kattmann & Schmitt 1996) because of the different causal origins for similarity in biology (adaptation, common descent). For this reason, the following hypothesis will be tested: *If the organisms of a contrast set are presented from the two perspectives of ecology and systematics, students will perform better in classification tasks.* Spiro's et al. (1989, 1991) Cognitive Flexibility Theory serves as the theoretical background for this hypothesis, in particular their reflections on the advantages of multi-perspectival knowledge representations in situations in which knowledge must be applied to new cases.

3.3 Design

A 2x2 factorial design will be used, varying the number of perspectives from which the contrast sets are represented and the number of knowledge precedents offered.

	single knowledge precedents (no use of contrast sets)	**multiple knowledge precedents** (use of contrast sets)
one-dimensional knowledge representations (ecology)	control group	experimental group I
two-dimensional knowledge representations (ecology and systematics)	not administered	experimental group II

4 Relevance of the Study

The use of laboratory activities in science education is characterized by a shift from telling—or verifying—the story of science to inquiry, testing assertions, and practicing 'the way of the scientist.' Today, procedural knowledge is considered as important as conceptual knowledge when pupils engage in lab work (Lunetta 1998). Similarly, the goals for the comparative method need to be reconsidered. Shifts in science education theory that led to dramatic revisions in lab work have left the comparative method unaffected and important implications for curriculum and practices in the classroom have been ignored. This research project intends to stimulate a discussion of the goals of comparative investigations in the classroom by calling attention to the fact that comparisons can be used to familiarize pupils with a basic way of scientific inquiry. It also aims at providing empirical data for using multiple knowledge precedents and integrating ecological and evolutionary perspectives in the teaching of biodiversity (ages 11-12) to enhance the students' understanding of different forms of similarity and support their ability to classify and compare organisms.

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15-YEAR-OLD PUPILS' IDEAS ABOUT THE DEVELOPMENT OF THEIR OWN UNDERSTANDING OF BIOLOGICAL PROCESSES

Gustav Helldén,
Kristianstad University, Sweden

Abstract
The present study of twenty-eight pupils' thinking about their own understanding, builds upon data from a longitudinal study of pupils' conceptualisation of conditions for growth, decomposition and the role of the flower in plant reproduction. Each pupil was individually interviewed on different occasions from age 9 to 15. At the age of 15, after the previous interviews, the pupils were interviewed about their views of the development of their own understanding. The pupils listened to the tape-recorded interviews with them when they were 11years old. They were then asked to make comments on what they said in the interviews and try to describe how they thought they had developed their understanding. They were also asked to describe what they thought had been of greatest importance in the development of their understanding. They could recognise statements in the interviews as results of experiences at an early age. The majority of pupils could describe concrete experiences that had contributed to the development of their understanding. The pupils explained how their understanding had changed through the years. Conceptions developed at an early age seemed to be important for future conceptual development.

1 Background
The present study of twenty-eight pupils' thinking about the development of their own understanding builds upon data from an expansion of a longitudinal study of pupils' conceptualisation of conditions for life, decomposition and the role of the flower in plant

reproduction (Helldén, 1995; Helldén, 1998; Helldén, 2000). Longitudinal studies of individual pupils' conceptual development can provide researchers with information about the nature of the learning process, learning pathways and the influence of everyday experiences on pupils' long-term learning. Without such studies, we cannot make knowledge and value claims about pupils' long-term conceptual development (Arzi, 1988). In spite of this need, comparatively few research projects have been longitudinal in nature (White in press). Therefore, I carried out a study of the same subjects' description of the three biological processes from 9 to 16 years of age.

Even at an early stage of the research project, there appeared to be personal features in the pupils' descriptions year after year that seemed to result from personal experiences hidden from the researcher. Why not ask the pupils themselves about such features? The pupils also showed interest in what they said during earlier interviews. So, I decided to let them as 15-year-olds listen to how they had described conditions for life and decomposition during the interviews at 11 years of age.

The objectives of the present research project are as follows

- to study the pupils' views of the development of their own understanding of biological processes,
- to study what kind of experiences the pupils found to be of greatest importance for the development of their understanding
- to make a more complete description of the pupils' conceptualisation.

2 Design and Procedure

Like many other researchers in science education, I have found that clinical interviews can give in-depth information on pupils' thinking about natural phenomena (Duit, Treagust & Mansfield, 1996). Over the course of my study, I interviewed the same twenty-three pupils on 11 different occasions from grade 2 (9 years) to grade 8 (15 years) in a Swedish comprehensive school.

Prior to beginning my interviews of the pupils, I regularly visited the class of 9-year-old pupils during a six-month period. The purpose of these preliminary visits was to become familiar with the pupils and to show them that I was really interested in their thoughts about phenomena in nature. During the interviews I made it clear to them that I was interested in their thoughts per se, not whether the answer was right or wrong. To show the children that I was primarily interested in their thinking, I usually started the first question of the interview with the words: "What do you think ......?"

To challenge the pupils' ideas about the conditions needed for life, we grew plants in sealed transparent boxes. I started the interview with the question: "What do you think the plant needs to be able to grow in the box with glass lid pasted on?" Another question was: "What do you think will happen to the plant in the box if we plant it there and glue the lid on?" For my interviews about decomposition, I had soil, brown leaves and litter on a table in front of the pupils. The opening question was in this case: "What do you think will happen to the leaves on the ground in the fall?" Later during the interview about decomposition, I also asked the pupils: "What makes the leaves fall from the trees in the autumn?"

A couple of hours after the last interview at 15 years of age, each pupil listened to audiotapes of my interviews with them four years earlier. I asked them to comment on their ideas at 11 years of age and explain why they said what they did. I also asked them to describe how they thought they had developed their ideas after age 11 and what they thought had been of greatest importance in the development of their ideas.

In this report the students have been divided into three groups. One group consists of students who do not recognise a major change of their understanding. A second group of students recognised a change but expressed a more descriptive than reflective and metacognitive view of their learning. The third group consisted of students that recognised a change and could analyse how their thinking had change. Some students described themselves as active learners. Other students saw themselves as passive learners who learnt through experiencing without doing much themselves. See figure 1.

All of the interviews were audiotaped and transcribed verbatim. Ausubel's theory of meaningful learning had important implications for the analysis of the interview data and for the description of the pupils' differential conceptual development (Novak, 1998).

3 Results

3.1 No or little recognition of change

All pupils had comments on their descriptions of the phenomena as 11-year-olds compared what they thought at 15 years of age. After they had listened to what they said as 11-year-olds, Fourteen pupils only recognised a minor change in thier understanding of the processes. Sten said: "*I think the same today besides some stuff about the soil, the mice and sort of.*" The pupils did not correct their answers they gave four years earlier, rather extended their explanations like Emil explaining his view of the importance of oxygen: "*When it has come up from the ground there is soil that will help it to grow.*" Others made comments on the different tone of voice like Linda in the following interview segment. "*I think the same today but it sounded a little more childish.*"

Figure 1. The 28 pupils didvided into categories according to their recognition of change and their view of themselves as learners.

	No or little recognition of change	Recognition of change Descriptive view	Recognition of change Reflective view
Active learners	Alexander Barbara Betty Ellen Helga Linda Paul Ralf Ruth	Anders Lisa Louise Thomas Tove	Annie Hanna Johanna Oscar Sofia Sven
Passive learners	Emil Gunnar Sten Stina Sune	Eric Mary Morgan	

Five pupils in this group can be characterised as passive learners. They only talked about their learning as a result of hearing and experiencing and did not include any thinking themselves. Stina explained how she had learnt to understand: "*It's school and TV and then you look more carefully when you are in the woods. Perhaps we talked about it.*"
The other ten pupils in this group look upon themselves as active learners. Some of them talked about their thinking about the phenomena like Helga: *"Then I perhaps remember something and put some details together.* Linda talked about her earlier understanding and expressions as ' a ten-year-olds thinking'. Ellen claimed positive feelings about her learning: *"Cos when you were a child you didn't understand that much but learnt still more. You didn't understand anything and were happy to learn."* Ralf described the development of his thinking in the following way: *"Perhaps I asked my parents about what is happening. I think I went home and asked them. The biology teacher told us a lot and you reflect."* The pupils frequently described the importance of talking to parents as a help to understand. Some of them mentioned other forms of activities that they thought had contributed to their understanding. Ruth said: *"I think, I was often in the woods when I was younger. There I investigated many things together with a class-mate.* " Betty described how she had cultivated plants during different circumstances.

3.2 Recognition of change -A descriptive view

Fourteen pupils in the class expressed recognition of change in their understanding of the phenomena. Eight pupils in this group had a more descriptive than reflective view of learning. They talked more about addition of new facts than analysing their thinking. Anders belongs to this group of pupils. He was fascinated by the recognition of how he described some details about decomposition in the same way as four years earlier: *"I said the same today. It is still several years later. You don't remember what you said and although it is somewhere 'in the back of your head'."* Although he found himself use the same expressions as four years earlier, he described a change in his thinking about the decomposition of leaves on the ground: *"You know more today and think in a more complicated way. You sort of think more of details. At that time you were only thinking that they rot away. Today you think how they rot and why. You know a little more today than at that time for example about bushes and trees."*

Mary and Louise said that they had learnt a lot by being out in the natural environment. They valued experiences to be an important source of knowledge. Mary expressed this in the following way: *"You get more life experiences all the time. The brain develops all the time and you are able to comprehend and understand more, understand relationships."* Mary, Eric and Morgan constitute a group of pupils that can be characterised as a group of passive learners. They described learning as a result of having experiences.

Tove and Lisa looked upon themselves as more active learners. Tove was astonished at the development of her understanding: *"You have difficulties in thinking that there is more to be learnt. In some way, you think you are fully trained; you think you understand a lot. But when people ask certain questions, you realise that there is a lot that you don't know and that there is much more to learn."* Already at 11 years of age, she used cycle explanations when she discussed conditions for life and growth in the sealed transparent boxes. As a 15-year-old, she said: *"I walk in the woods, in nature. I see what happens. Well, I can see how cycles in nature function."* Lisa expressed a descriptive view with some reflections. She talked about the importance of school learning but always added that you must think yourself: *"You have tested sort of .... Then you have learnt from school and your own thought. You know something else and how it is. And you think a little about how it is constructed. Well, about how it ought to be."*

3.3 Recognition of change -A reflective view

Six pupils were able to more deeply analyse and reflect over the ideas that they described four years earlier and over the development of their understanding. They willingly discussed the reason why they said what they did but their conclusions sometimes ended up in incorrect descriptions of the processes. All of them made comments on their earlier use of analogies between a plant and a human being's need for resources.

Both Hanna and Sofia compared a plant's germination and development with a child's birth and development. Sofia said: *"You can often compare them even if the seed hasn't any human thoughts. You can see yourself how you develop. The seed grows too. It's like ..... the seed grows and I grow."* The pupils continued to use anthropomorphic formulations even when they made comments on their earlier descriptions. Oscar found it to be natural to talk about a plant's eating: *"Well, we as human beings eat and become bigger, don't we. Even the plants eat and grow, don't they."* Sven talked about nutrients as something that he thought necessary for both plants and humans.

When I asked the pupils to describe how they had developed their understanding, they emphasised the importance of building upon earlier experiences and knowledge. All of them described an active and constructivist view of the learning process. For them learning could start by reading a book, listening to others and catching some words. The pupils described how they worked with their impressions. This could be expressed in different ways. Hanna described the development of her understanding as another way of thinking: *"Well, the world grows all the time When I was a child my home was the world. Now the world is Bill Clinton in Washington and Boris Jeltsin in Moskow. As an adult you learn to think in new trajectories, a little more logical although I prefer to be a child. The world isn't as small as when you were a child. And there will be more anxiety."*

Johanna argued that imitation was initially important because you did not need to understand. Then she started to think for herself and because of her curiosity, she picked up what she called 'pieces of knowledge': *"At that time I only thought about things like piece by piece, but now I have put them together."* At the end of the interview, she said that the reason why she understood the processes better at the age of 15 was that she had started to think more for herself. All the six students in this group can be characterised as active learners. Sofia gave a quite positive picture of her learning and of the driving force to learn more: *"You actually learn for the rest of your life. I didn't learn in order to please my parents but I learnt for my own interest."*

Annie described her learning partly as an addition of facts but also from a more reflective perspective: *"You hear a little, don't you. Then you think yourself and form an idea."* She gave an example of such a process. At 11 years of age she said that you talk to the plants when you have them indoors like her grandmother did. She said as a 15-year-old that the growth had to do with the carbon dioxide and that she only knew that plants grow better if you talk to them.

3.4 Contribution to the development of the understanding

When I asked the pupils what had contributed to they development of their understanding, 24 pupils spontaneously mentioned school, preferably secondary school but 6 pupils referred to primary level. Even if Oscar in the interview talked about stimulating discussions with his parents, he argued that schooling was of greatest importance for the development of his understanding and ended his argument by saying: *"You think you know everything but you don't know all that ..... You go to school to learn what you didn't know what you didn't know."* The interviews were carried out in a secondary school. The influence of that context could be of great importance for the outcome of the interviews.

11 of the 28 pupils said that looking at the television had been important and 12 pupils that talking with parents or other relatives had contributed to the development of their understanding. A couple of pupils referred to talking to other people like neighbours that had stimulated their interest in biological phenomena. Garden activities of different kinds seemed to stimulate interest according to 10 pupils. More than 75% of the pupils could describe concrete experiences, often in detail, that had contributed to the development of the their understanding. Several episodes dated from the ages 5-10. Such concrete experiences could have to do with events at school but more often with out of school experiences.

Louise argued that the days she spent at her grandma's summerhouse had great importance for her interest in and understanding of processes in nature. Helga referred to pre-school experiences when she visited the woods together with playmates.

At 11 years of age, Sofia was asked what will happen with the leaves on the ground and answered: *" From those you burn there will be smoke and there can be compost heaps and sort of."* She said that the reason why she said so could have to do with the experience of a compost they had in the garden and the bonfire they had every year at the 30th of April. *"We had a lot of large trees. And we cut down a couple of them and burnt them on a bonfire out on a meadow."*

When Annie explained from where the soil came, she said with feeling that soil also consisted of sand that came from stones that rot, and were ground into sand. At 15 years of age she smiled with recognition and said: *"This depends on the fact that we had a summerhouse up there in the forest where I saw them hew stone and blast it into pieces."*

When Anders described the decomposition of the leaves on the ground, he always in someway referred to composting and described this process in a detailed way. For example, from 9 to 13 years he always mentioned that you could put eggshells on the compost as in the following segments of the interviews with Anders.

Anders at 9y: *"Quite a lot of soil comes from leaves. Eggshells ...... Soil comes also from coffee grounds and that sort of thing, it rots and becomes soil."*

Anders 11y: *"I think they rot in some way and then there is nothing left of them. Some people make a heap of the leaves and make compost and they lie there and rot. You put many other things there, you can also put eggshells and so on the compost heap. And they stay there and rot in some way. It takes a long time, it takes just about four years to get real and very nice soil. Those who have compost heaps move it over from one to the other. Then they dig away some soil and spread it out and then they move it back so it rots. That's way it works all the time. You usually move it out onto your flowerbeds and that it's very good. It is a little like fertiliser, something like that."*

Anders at 13y: *"Soil's made of mainly sticks and gravel and that sort of thing. Something else that can dry and become soil can be eggshells and the sort of things you put on the compost. That becomes soil."*

When Anders heard this he made the following comments immediately after he had listened to tape-recorded interview: *"When I was younger, my neighbour had carried out composting. And I was always there and helped him with things and sort of. Therefore, we were standing there one day talking about it and after that I knew that it takes between three and four years before it will be soil."* Anders was referring to the visits in the neighbour's garden and the discussions there became quite important for his interest in and understanding of the biological processes.

Also in the interviews with Hanna about decomposition of the leaves we can follow a characteristic feature in her descriptions. There is one theme that persists throughout the years that concerns raining and drying that continues to exist even if other perspectives are connected to this core idea.

Hanna at 9y: *"Some of them sink down into the mud when it's raining. They dry out in some way and shrivel up. Then when they are completely dry. It is enough for it to rain just once more for them to become just small bits."*

Hanna at 11y: *"I think they mould away. They will dry out ... then an animal is coming, trampling them and they become broken. It will become small, small pieces and then the real soil is pressing them down and they will be a lump and then it is raining and the sun is shining and it becomes soil."*

Hanna at 13y: *"They dry out and perhaps it rains so that they become soft. Then they dry out again. Then in the end they become .. and animals start eating them. Then you get soil from it."*

At the age of 15, Hanna argued with conviction that this description was the result of a childhood experience: *"Well, we had a lot of leaves on our ramp. There were two birch trees behind the house. In autumn and winter there were loads of small, ragged leaves. I remember I thought of them being green in summer. In winter, they always were tiny, ragged and not that funny."* The development of Anders' and Hanna's understanding show that early experiences even experiences outside school can play an important role in a child's conceptual development.

4 Discussion

All the pupils showed great interest in listening to what they had said as 11-year-olds, but they showed quite different abilities to make comments on what they heard from the earlier interviews. Fourteen pupils in the class did not recognise changes in their ideas from 11 to 15 years of age concerning conditions for life and decomposition in nature. But still changes had occurred in some cases. The pupils could describe their understanding in a way that meant that they had changed their ideas compared with what they said in the interviews as 11-year-olds, but they did not notice it.

The pupils often only paid attention to some obvious expressions that they recognised. Because of their limited metacognitive ability, they were in most cases not able to analyse their own knowledge. Shortage of basic biological knowledge can also have influenced their ability to make comments on their understanding. Four of the fourteen pupils who did not recognise any change, saw themselves as passive learners. That means that they did not describe any activity through which they tried to understand the biological processes.

Among those who recognised an obvious change of their ideas, eight out of fourteen pupils expressed a descriptive view of change. Five pupils in the group characterised themselves as active learners and the other three as passive learners. Anders is a typical representative of the group of active learners. He was astonished over some common features in his ideas as an 11 and 15 year old but also described how his thinking had changed. These students described a more additional than reflective view of their ideas. These students claimed that they knew more because of having more life experiences.

Morgan, Mary and Eric seem to see themselves as passive learners according to their description of their own understanding. If we investigate how pupils have understood the different processes through the years, we will find a quite good description of conditions for life and decomposition in nature. Morgan is a boy who does not like to talk that much. When I asked him why he did not say more about the processes, he said: *"No, I don't know. I have perhaps ...when I didn't know something, I have never been fond of talking much."* This reminds us that there are pupils that can have higher capacity but for some reason do not like to talk about their understanding.

All the six pupils who recognised changes in their understanding from a reflective view, saw themselves as active learners. They discussed in a constructive way where they had got their ideas from and why they had developed as they did. Because of their good metacognitive capacity they could to some extent analyse the nature and development of their learning. All six students could also describe concrete examples of experiences that had been of great importance for their conceptual development. They connected these experiences with a reflection that became fruitful for the development of their thinking. There seem to be a link between student's metacognitive view of learning and their ability to integrate new perspectives in their thinking.

When the students listened to what they said about the biological phenomena in earlier interviews, they could reveal particular events that they had experienced together with other persons, such as parents, playmates and neighbours. The participation in such events in childhood seems to be of great importance for the development the students' future understanding. Several of students' conceptions were traced back to social situations that had been important to the student's. The student had developed their personal biographies through which they saw in the world.

Educational research has been caught between two metaphors: the 'acquisition metaphor', representing the cognitive perspective and the 'participation metaphor', representing the situated perspective (Sfard, 1998). Sfard claims that the difference between the two perspectives is not a matter of differing opinions but rather of participating in different, mutually complementing discourses. This argument was recently accepted by researchers that a couple of years had been arguing heavily in favor of one or other of the two metaphors (Anderson, Greeno, Reder & Simon, 2000).

From my point of view learning cannot only be described as a participation in a social practice. It is also important to pay attention to what goes on in an individual's mind. My study has been carried out from both a participation metaphor as well as from an acquisition metaphor perspective. I have studied the development of the students' conceptions and what could have happened to individual students' thinking. Many students could reveal personal reasons for why they said what they did, after listening to earlier interviews with them.

The study that has been described in this paper shows that early experiences of different phenomena can play an important role in the development of children's conceptual understanding. There are possibilities for improving children's understanding of biological phenomena by creating an atmosphere that gives them opportunities to investigate and discuss their personal ideas and experiences. It may also be important to help students in the early ages to develop an ability to reflect on their ideas and on where the ideas come from. These personal ideas can then be starting points for teaching. Sofia reflected over the nature of her understanding in the following way: "*You come back to the same framework all the time. It is still there. There is a way of thinking through everything.*"

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THE TEACHING OF ECOLOGY IN THE AGRICULTURAL SECONDARY *CURRICULA* IN FRANCE: A NEW DIDACTIC APPROACH

Alexandra Magro, Laurence Simonneaux, Aurélie Navarre & Jean-Louis Hemptinne
Ecole Nationale de Formation Agronomique (Toulouse – France)

Abstract
The teaching of ecology in the agricultural secondary *curricula* in France is relatively new. The displaying of the *curricula* has been causing some problems to the teachers (general frustration and difficulties to motivate their pupils).
In order to identify the cause of the problems, analysis of *curricula*, teachers conceptions about ecology and the teaching of this discipline were performed. Main attention was paid to epistemological aspects.
The results show that the ecosystem concept is central and structures all the teaching-learning process. On the contrary individuals are never mentioned. Additionally, teaching is based on description and definitions resulting very abstract and not leading to an understanding of the processes that give rise to the patterns.
Nowadays, however, ecology follows an approach based on Darwin's theory of evolution. In this approach studies proceed from individuals to communities, in a bottom-up sequence, allying classical scientific methods.
In the light of the history of ecology we think it is necessary to establish a good relationship between teaching and the actual "scientific knowledge" and find the more effective way of doing so in terms of the learning process.
A didactic approach is proposed and its construction presented. The implementation of that approach on pupils will be assessed, the parameters subjected to evaluation being mentioned.

1 Introduction
The teaching of ecology to pupils (15 to 18 years old) taking the secondary *curricula* in schools of the French Ministry of Agriculture started in 1990 (Baradat-Bouillier-Oudot, 1999). The objective was to give future agricultural professionals a better understanding of the environmental framework within which they would be working and a better appreciation of environmental questions. This development was stimulated by European regulations favouring sustainable agriculture.

Although well intentioned the *curricula* are difficult to teach. Teachers are frequently frustrated because they found it difficult to motivate their pupils.
In order to identify the cause we analysed the *curricula,* the teachers' conceptions about ecology and how the subject is taught. This analysis mainly deals with the *epistemological* aspects. Subsequently an alternative didactic approach will be proposed and assessed from the point of view of pupils.
Ecology is a new discipline, which developed rapidly after the word "ecology" was coined by Haeckel in 1869.
During its short history two methods of study have emerged. The *ecosystem approach:* The word ecosystem was created by Tansley (1935) and championed by E.P. Odum, for whom it was the corner-stone of ecology. It is interesting to note that Tansley was engaged in a dispute over the most suitable metaphor for describing succession in plant communities. He strongly objected to a philosophical comparison and favoured an analogy with physical systems. Later, E.P. Odum tried to convince his academic colleagues that ecology was a science based on sound principles, the prominent one in his opinion being the ecosystem. As a result of E.P. Odum's publications and enthusiasm the description of ecosystems dominated ecology for 2 decades. The theory was often developed *a posteriori* to fit the observations and never by hypothesis-falsification, the classical scientific method. In addition, in the process of simplifying description there was a staggering loss of biological information about species.
The *evolutionary approach:* This follows from Darwin's theory of evolution. The fittest individuals are those that contribute most offspring to future generations, that is, selection acts on individuals. Ecology is viewed as the scientific study of the interactions that determine the distribution and abundance of organisms (Krebs, 1994). In this approach the basic units of study are individuals. Characteristics of the individuals are used to understand population processes; the later, in turn, to understand community issues. This approach was not favoured during the 2 decades when the ecosystem approach dominated. It is now widely and successfully applied to unravelling ecological problems. The fact that it is based on the theory of evolution, using fitness as the measure, means it is possible to compare individuals experiencing different living conditions.
In the *ecosystem approach* the emphasis is on representing complex communities by means of interactions between the components that make up the communities. They are described in terms of food webs, trophic levels, energy and matter flows (Golley, 1993). In contrast the *evolutionary approach* proceeds from individuals, to communities, i.e., it is a bottom up approach rather than the top down approach of the *ecosystem approach.*

It is interesting to note that two of the most widely used ecology text books do not have a chapter specifically devoted to ecosystems (Begon *et al.*, 1996, Krebs, 1994).
Chevallard (1991) represents Verret's notion of didactical transposition (1975) by the following scheme:

"Scientific knowledge" → "To be taught knowledge" → "Taught knowledge"

In the light of the history of ecology we wonder if the teaching of ecology (the "taught knowledge") evolved at the same pace as the theory (the "scientific knowledge"). We think it is necessary to establish a good relationship between teaching and the actual "scientific knowledge" and find the more effective way of doing so in terms of the learning process.

2 Research Design and Method

a) Is the teachers knowledge close to the actual "scientific knowledge" (i.e. the evolutionary approach)?
33 Biology – Ecology teachers were asked to answer a questionnaire at the beginning of their training (Table 1). They were selected at national level; 10 were recruited in 1998-1999 and the remaining 23 in 1999-2000.

Table 1. Questionnaire answered by the 33 Biology – Ecology teachers.

i. Give a definition of ecology.

ii. In which order would you list the following key-words: limits, interactions, food chains, ecosystem, population, spatial distribution?

iii. If the words "individuals" and "communities" were added to the previous list where would you insert them?

iv. Does research in ecology
❑ follow a classical scientific methodology, i.e., a question is asked, hypotheses proposed and tested, and finally accepted or rejected,
❑ follow a different methodology?

b) In order to determine whether the "to be taught knowledge", represented by the institutional *curricula,* is closely linked to the actual ecological theories, two *curricula* were analysed:

- The *Baccalauréat technologique* – gives students the scientific, technological and economical backgrounds in a certain field. It opens the way to higher education in that specific domain (Direction générale de l'Enseignement et de la Recherche, 1993).
- The *Baccalauréat professionnel* –is the training required just prior to entering a profession (Direction générale de l'Enseignement et de la Recherche, 1996).

The objectives and purposes outlined in the forewords as well as the key-words of these *curricula* were analysed.

c) To assess the similarity between the content of the lectures given by teachers (real *curricula*) and the institutional *curricula*, 20 in-service teachers, from throughout France, were each asked to make a poster explaining how they would build a sequence of teaching on ecology. Several points were then analysed:

1. When teaching the ecosystem concept do they stay within the concept or do they try to study it in terms of its component parts, i.e., starting with individuals (Bottom-up approach)?
2. Is their teaching based on a succession of definitions or an understanding of mechanisms?
3. Do they get the pupils to ask questions and make predictions?
4. Do they have a STS (Science – technology – society) approach (Robottom, 1993), that is, do they teach scientific content and skills in a meaningful context of technology and society?

3 Results

a) The teachers knowledge of ecology.

Regarding the definition of ecology (Question i), 85% of the teachers either used Haeckel's definition of ecology - "study of the relationships between organisms and their environment" – or say "ecology is the study of the relationships in an ecosystem". Of those, 61% add that ecology is a science. The remaining 15% confused ecology with environmental protection.

76% of the teachers listed the key-words (Question ii) in a way that suggests they favour a "Bottom-up" approach: they tended to start with populations and finish with ecosystems. However 44% of those that initially choose a "bottom-up" approach had problems inserting the words "communities" and "individuals" into the sequence (Question iii). Although "communities" was usually inserted after "populations" ("in a Bottom-up" approach logic), "individuals" was inserted in several different places, indicating confusion.

In addition (Question iv), 61% of the teachers stated that research in ecology was not based on scientific principles, which, for many, contradicted responses given to question i, to which they had replied ecology is a science.
b) The "to be taught knowledge".
The *Baccalauréat technologique*: The foreword states that high level technicians are trained to be critical. In the *curricula* body, the key-objectives are: to became familiar with the notion of biodiversity, ecosystem (components, biotic and abiotic factors, interactions, definition and limits), energy and matter fluxes, primary and secondary producers, niche, r and K strategies, agroecosystems (structure, functioning and dynamics). Time allowed for teaching is 89 hours.
The *Baccalauréat professionnel*: The foreword emphasises the need to understand the underlying mechanisms and acquire methodological approaches for solving practical problems. It is clearly expressed that the role of ecology is to help professionals manage environmental systems. The key-words of this *curriculum* are: the environment (components, biotic and abiotic factors), ecosystem dynamics (description of the interactions) and the role of man in ecosystem transformation. Time allowed for teaching is 75 hours.
In both *curricula* the "ecosystem" is central and individuals are never mentioned. There also seems to be a gap between the aims of the programmes and what they offer the students: the description of systems does not necessarily lead to an understanding of the processes that give rise to the patterns.
c) How the teachers proposed to teach ecology
Most teachers closely followed the institutional *curricula*. They start with the ecosystem concept and individuals are never mentioned. All their teaching is based on description and definitions. The relevance to technology and society is presented at the end of the course and is again descriptive. In addition the subjects chosen to illustrate the topics are seldom relevant to agricultural issues.
Nevertheless, most teachers tried to link their teaching to biological reality. All teachers regarded field trips as important but what they proposed to teach was more appropriate to a course on natural history than ecology.

4 Discussion

Teachers at the beginning of their training have a vague notion of what ecology is about. They see it as a science that lacks a scientific method. In addition their definition of ecology does not state that it is a science aiming at *understanding* the patterns of distribution and abundance of organisms.

Although their definition of ecology includes the word organisms, they don't know how and when to include them into the concept. The understanding of ecosystems, on the other hand, appears to be their ultimate target.

The teachers proposed courses are very similar to the institutional *curricula* in which the ecosystem concept is central to the teaching –learning process. Ecosystems come first in the teaching sequences and then its component parts and interactions are successively described. This is the way the textbook "Fundamentals of Ecology" (Odum, 1953) is organised.

"Fundamentals of Ecology" was a revolutionary text: it treated ecology in a very concise way and emphasised its supposed principles. It greatly influenced ecological research in the 15-20 years following its publication. But, the research so stimulated and the concept itself were criticised mainly because:

- The descriptive nature of the studies resulted in severe difficulties when handling complexity,
- It lacked a rigorous scientific methodology,
- Species and individuals were considered so that biological reality disappeared, and finally,
- It didn't consider the role of natural selection in the evolution of behaviour and life history, the regulation of populations and the organisation of communities.

The present study shows that the teaching of ecology in the French agricultural *curricula* can be criticised. If we go back to our representation of didactical transposition, we may say the "to be taught knowledge" and the "taught knowledge" are based in a "scientific knowledge" which is outdated. In conclusion, the "to be taught knowledge" is not changing at the same pace as the "scientific knowledge".

This is not unique to France as in both Portugal and the French-speaking part of Belgium the same approach is adopted (Magro and Hemptinne, pers. com.). In Italy the *curricula* also look very similar (Arcá & Caravita, 1998).

We believe that in this kind of teaching the concepts are divorced from reality. The subject lacks meaning. Pupils are concerned about applied problems and, as Reiss & Tunnicliffe (1999) say, "what is being learnt must be of personal meaning to the learner in order to create interest". Additionally, this approach does not encourage pupils to acquire a methodological approach to problems as is recommended in the Biology-Ecology *curricula*.

The difficulties expressed by the teachers and the finding that the institutional *curricula* are based on an out of date scientific knowledge, led us to look for a different didactic approach.

We propose an approach based on the study of individuals, inspired by an evolutionary perspective and following a rigorous scientific methodology, as used in modern research.

The approach we propose does not change fundamentally the content of *curricula* but demands a reorganisation in the emphasis placed on the different concepts.

Courses should make an appropriate composition of a context so that stimuli can be attached to an object / situation and create interest (Krapp, 1992): e.g., field observations, the analysis of an article, watching a film, *etc. Curricula* propose that the influence of human activity on the physical environment or on other species should be considered at the end of the ecology course. We think this subject would be better dealt with at the beginning of the course. This can be justified because pupils asked to state their main interests in Biology most frequently give ecology (Evrard *et al.*,1998). These authors relate this to the importance of environmental questions in our daily lives. Our choice inscribes itself in the Science-Technology-Society educational initiative (Robottom, 1993). We think this will make the subject, as Alsop (1999) says, more " germane, salient and palatable".

Coming back to our situation, a question must be raised. This is an important point that is central to the search for understanding.

The attention is focused on a species, the central character of a story. The class is stimulated to look for information about the biology and life history of this species in the library, on the internet or on CD roms. If the species is available, experiments can be carried out, certain parameters of the species life history measured and observation skills developed. We consider this an interesting step: a direct contact with living material helps developing the affective area of learning and gives a comprehensive grasp of biology, structures and processes (Heimerich, 1998). Finally it can be intellectually challenging, helping to develop the appropriate scientific methodologies.

From individuals to populations and thence to communities, the sequence proceeds by the establishment of links with other individuals (same species, other species) and the environment. At the same time the mechanisms resulting in the observed patterns are introduced.

We do not want to overburden students with knowledge but wish to stimulate them to answer basic questions. We believe the learning and application of scientific methodologies to solving specific problems will enable pupils to address other ecological questions. Teachers may relate the acquired knowledge to other problems whenever they think it is relevant or interesting.

Ten teachers will be trained using this approach (the evolutionary, bottom-up approach) and their pupils compared with those of 10 teachers that will follow a conventional method (Ecosystem approach). Both groups will be asked to teach the same *curriculum*. Evaluation of pupils interest, procedural and declarative knowledge and mobilisation of knowledge in professional activities will be assessed.

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ANIMATIONS, SELF-REGULATION, AND MOTIVATION IN A COMPUTER-BASED LEARNING ENVIRONMENT FOR NEUROBIOLOGY INSTRUCTION

Helmut Prechtl, Detlef Urhahne, Matthias von Davier & Manfred Schenzer
Institut für die Pädagogik der Naturwissenschaften (IPN) an der Universität Kiel (Germany)

Abstract

In this study, 46 11th- and 12th- graders of German Secondary Schools worked with a computer-based learning environment, in which basic functions of the nerve cell membrane were demonstrated via illustrations with explanatory texts. The aim of the study was to investigate the effects of animations and self-regulation on learning gains and motivation. Therefore, two versions of the learning environment were used, one with animated illustrations and one with still images combined with textual descriptions of the dynamic processes. Furthermore the learning conditions were varied for high and low self-regulation. In a pretest questionnaire the learners' factual knowledge was checked and their individual visual and verbal learning preferences as well as their motivational attitudes were registered as covariates. After working with the computer-based learning environment, students' knowledge gains and the motivational effects of the learning environment were checked with another questionnaire. Individual motivational attitudes of the learners were significantly correlated with knowledge gains, whereas visual or verbal learning preferences had no influence on motivation or learning success. Interestingly, there were tendencies of interactions between animations and self-regulation. Results are discussed with special respect to the need for an instructional balance of instruction and construction in multimedia learning arrangements.

1 Introduction

Neural sciences as a subject in biology instruction in schools is of growing importance. Reasons for this are the tremendous progresses made in research work as well as the strong relations between scientific insights into natural phenomena given by this discipline and students every day life. Examples for this are learning and memory, drugs, emotions and brain disorders. In neurobiology, as in allmost every topic of biology instruction, there are basic concepts to be understood by the students in order to make natural phenomena intellegible to them in terms of

scientific explanations. E.g., the generation of the membrane potential is substantial for the signal conduction along the cell membrane of a neuron. Thus, knowledge of the membrane potential is essential for the understanding of all higher level nervous functions.
From a didactic point of view teaching this basic principle therefore has a central meaning in neurobiology instruction. Knowledge of the main structures and ions involved in these processes can be acquired easily by most of the students, whereas understanding the generation of the dynamic equilibrium of these ions and its changes depends on a deeper insight in the dynamic properties of these cellular processes. It seems reasonable that this insight can be fostered by computer-based animations.
In this study we examined the effects of learning with computer-based animations on students knowledge of the nervous membrane potential as a basic concept in neurobiology. We were especially interested in motivation both as independant and dependant variable in computer-based learning. Furthermore we investigated possible interactions of technical attributes of the learning environment, the instructional method and the learners individual differences in attitude and aptitude.

2 Theoretical Background

Animations in computer –based learning environments

In modern educational technology dynamic processes are usually visualized by animations, instead of e.g. still images in combination with explanatory texts. Animations are supposed to help learners to imagine processes properly and thus to be able to build up adequate mental representations of causal relations within an investigated system (Salomon 1979; Rieber & Kini 1991; Mayer 1997; Lewalter 1997). Basically these assumptions largely rely on the dual coding theory of Paivio (Clark & Paivio 1991; Paivio 1978). E.g., Mayers generative theory of multimedia learning (Mayer 1997) has derived from this. According to these theories there are two ways of information processing and hence two kinds of mental representation in the cognitive system. In the verbal system informations of a sequential structure like written texts or spoken words are processed. In the non-verbal system informations about room like pictorial stimuli from a picture are processed. A major assumption made by the authors is that connecting these two cognitive representations in a proper way should improve learning results.
The advantage of animations in comparison to still images is attributed to the complete representation of a movement or the changing state of an object. The unequivocal representation of a dynamic process helps to avoid misinterpretations of movement indicators used in still images by the learner and allows him to use larger amounts of his cognitive capacity

for higher order learning strategies like control of understanding (Salomon 1979; Rieber & Kini 1991; Lewalter 1997).

Visual and verbal learning preferences

But according to the concept of individual visual and verbal thinking habits (Paivio & Harshman 1983) animations will possibly favor visual thinking types more than verbal thinking types of learners (Plass, Chun, Mayer, & Leutner 1998). Verbal thinking types, however, presumably profit more from the textual parts of a multimedia learning environment. As the concept of visual versus verbal learning preferences has regained attention of researchers recently in the context of multimedia learning these individual preferences should be identified in a study on computer-based learning.

Self-regulation and self-efficacy

Due to technological progress, many computer-based learning environments are designed in a highly interactive manner. Thus, modern multimedia learning tools offer the opportunity for self-regulated learning which is assumed to be more effective for motivation and understanding (Euler 1994; Haack 1995; Schnotz et al. 1998). A prerequisite for self-regulated learning, however, are motivational attitudes of the learner, such as individual concepts of self-efficacy or interest (Meece 1994; Pintrich & de Groot 1990). Theories of self-regulated learning (Zimmermann & Schunk 1989) consider cognitive as well as motivational aspects of learning processes. From a cognitive and metacognitive point of view learners control and actively influence their learning activites and their understandig. The motivational element, however, determines why und to what extent self-regulation options are taken.

In the present study it was assumed that processes of understanding are motivationally supported by so called "expectancy of understanding" and "value of understanding". "Expectancy of understaning" is derived from Banduras theory of self-efficacy (Bandura 1997) and means, whether a person believes that she can reach cognitive goals by use of learning strategies. "Value of understanding" arises from the personal significance of this process and is based on interest, mental effort, and the perception of importance and usefulness. Expectancy and value of understanding depend on personal as well as situational characteristics. Therefore experimental studies, testing learners dispositional motivational traits and controlling properties of the learning environment, are the best way to register and test the predictive power of presumed motivational bases of understanding with respect to acquisition of scientific knowledge.

At this point in time, decisions on how to design a computer-based learning environment are still on a general level. Maybe one has to change the learning environment to allow more self-regulated learning or to make it more motivating. But to what extend should students be allowed to learn in a self-regulated manner? Self-regulation could interfere with the kind of media employed in a way that learners profit the most from animations or still images only in combination with the appropriate amount of self-determination. Furthermore, using multimedia learning environments for instruction one has to take into account individual learning preferences for visual or verbal learning material.

3 Objective

To get a deeper insight into the problems mentioned above we designed an experimental study in order to test the following research questions: (a) Does learning from animations support a higher conceptual understanding than learning from still images with textual descriptions? (b) Do high visualizers improve more if learning with animations as compared to low visualizers? (c) What role plays motivation for factual and deeper knowledge acquistion? (d) Do high verbalizers improve more, if they learn from still images with verbal descriptions, as compared to learning from animations? (e) Does self-regulated learning in a computer-based learning environment prove to be more effective than heteronomous learning? (f) Do technical features of the learning environment interfere with the instructional method, i.e. high or low self-regulation?

4 Methods

In this study, 46 11^{th}- and 12^{th}- graders of German Secondary Schools worked with a computer-based learning environment, in which basic functions of the nerve cell membrane were demonstrated via illustrations with explanatory texts. Basic principles that had to be learned by the students were (i) the structure of the nerve cell membrane and its constituents, (ii) the kind and relative concentration of different ions within and whithout the nerve cell, and (iii) the dynamic interaction of membrane porperties and the concentration and current of ions, together causing the membrane potential. (Fig.1.)

The aim of the study was to investigate the effects of animations and self-regulation on learning gains and motivation. Therefore, two versions of the learning environment were used for two experimental groups of students. One group learned with animated illustrations and one with still images combined with textual descriptions of the dynamic processes. Furthermore the learning conditions were varied for high and low self-regulation. Accordingly, each experimental group was split into halves, with one half of the students learning under the condition of high self-regulation and the other under the condition of low self-regulation. Thus, there were four experimental groups with different treatment combinations of animation vs. still images and high vs. low self-regulation (Fig. 2).

Figure 1. The computer-based learning environment

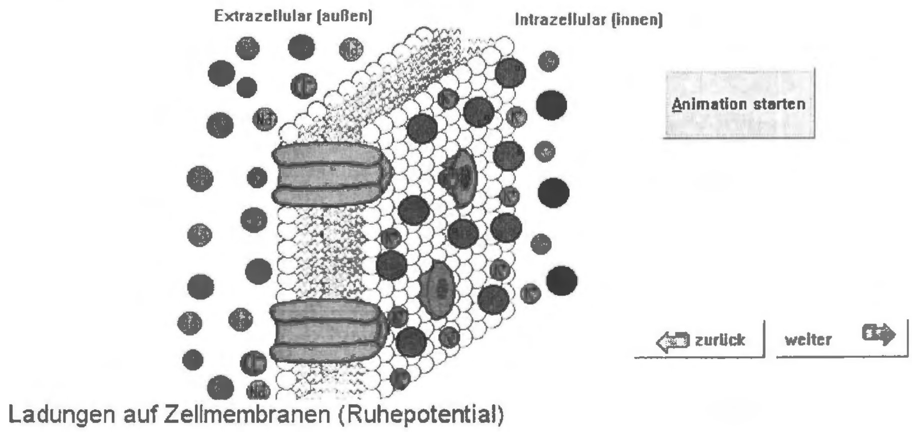
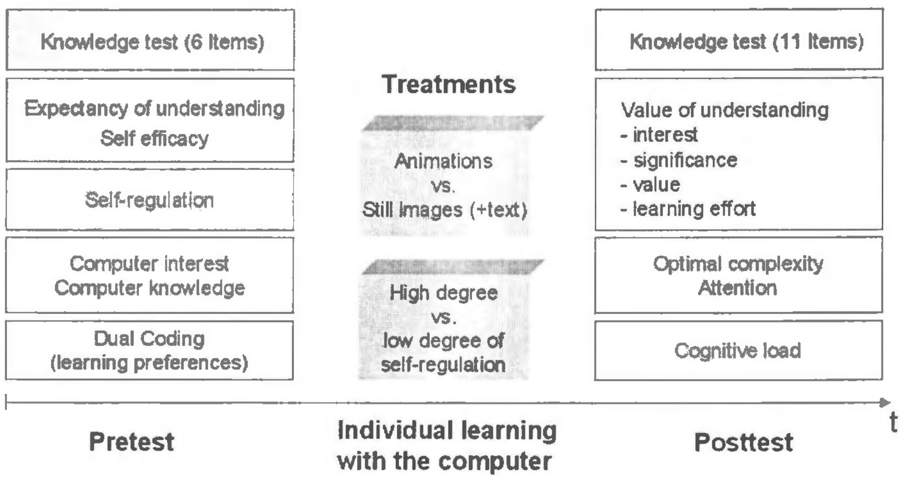


Figure 2. Research design



In a pretest questionnaire the learners' factual knowledge was checked and their individual visual and verbal learning preferences as well as their motivational attitudes –mainly "expectancy of understanding" and "self-efficacy"– were registered as covariates.
After working with the computer-based learning environment, students' knowledge gains were checked and the self-reported motivational effects –namely the "value of understanding"– were registered with another questionnaire. "Value of understanding" consisted of interest, the mental effort necessary for working with the learning environment, and the perception of its importance and usefulness (significance, value).

5 Results

Animations

In contradiction to our hypotheses there were no main effects of animations or registered learning preferences for visual or verbal material on learning gain. Likewise the learners of the different groups (animations vs. still images) neither did differ in their self-reported interest, effort or attention, nor did they differ in their perception of the value of the learning programme. On the other hand, the way of representation correlated with the personal significance in so far that information presented with still images and explanatory texts was accounted as more significant than information presented by means of animation ($p < .01$).

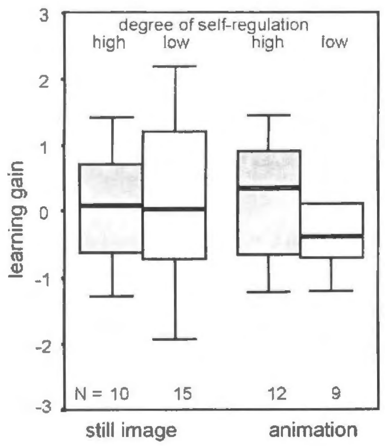
Self-regulation

Self-regulation proofed to increase attention for the programme ($p < .05$), but this was without any consequences for learning gain in comparison to the group under a heteronomous learning condition.

Interactions of animations and self-regulation

Multivariate analysis of the data yielded no significant interaction of animation and self-regulation. Nevertheless, there was at least a tendency for this interaction with regard to learning gain and self-reported effort (Fig. 3, 4). Students working with the animated version of the learning environment needed less mental effort and learned better than the group with still images and explanatory texts, but only if they could learn under the condition of self-regulation. On the other hand, students working with still images an explanatory texts felt less mental effort then those learning with animations, if they belonged to the heteronomous learning group.

Figure 3. Interaction of animation and self-regulation with regard to learning gain



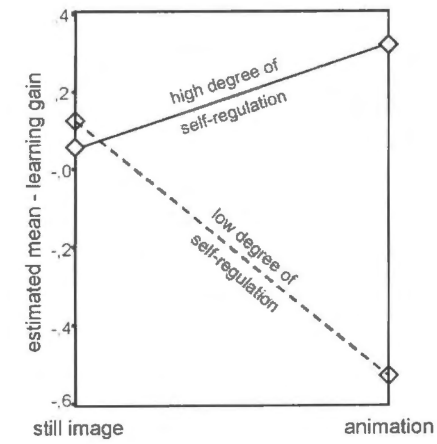
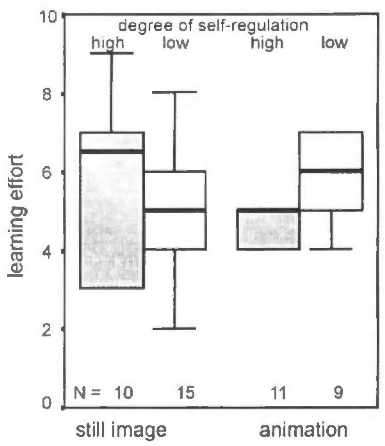
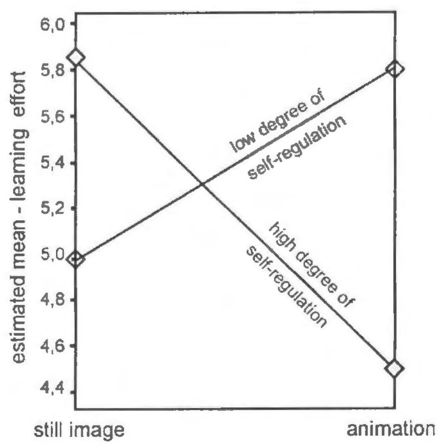


Figure 4. Interaction of animation and self-regulation with regard to learning effort





Motivational effects

Individual motivational attitudes of the learners were significantly correlated with knowledge gains. The coefficients of correlation were $r = .41$ ($p < .01$) for self-efficacy and $r = .35$ ($p < .05$) for expectancy of understanding. Among the constituents of the value of understanding only the individually ascribed usefulness correlated significantly with learning gain ($r = .36$; $p < .05$).

6 Conclusions

In this study, the effects of animations in computer-based learning environments with neurobiological topics as a subject-matter were examined under various conditions of instruction. The lack of significant influences of animations or self-regulation on learning success is not sufficient for refusing the critical role they possibly may play in computer-based learning. On the one hand this lack of results could be due to methodical reasons. The differences between the various learning conditions may have been not pronounced enough. The suggestion to the students to use a sample of important pages of the programme for a better orientation may be not to far away from the clear instruction to make sure to have worked with all of these pages. Furthermore, the number of animated sequences in the animated version of the learning programme was limited for reasons of ecological validity: Not a single specimen of commercially availabel learning software is purely animated, but rather a mixture of animations and still images, and so was our own learning programme. Finally the number of students could have been to low for more signifanct results. Clearly, twelve persons per learning group is not a big sample.

On the other hand the data analysis yielded tendencies of interaction of animation and self-regulation. Students working with the animated version of the learning environment needed less mental effort and learned better than the group with still images, but only if they could learn under the condition of self-regulation. If this result will proof to be stable in future studies, it can be regarded as a strong hint for the instructional design of computer-based learning arrangements: Animations should be combined with learning conditions fostering self-regulation. But what about very complex learning environments, such as highly interactive simulations? Several authors (Leutner 1993, Peeck 1993; Peeck 1994; Rieber 1990; Fischer & Mandl 1990) mention the danger of a cognitive overload and suggest strong instructional support for learners in complex learning environments. Further research work has to be done to check the tendency of interaction reported in this study for significance and to gain further insight in the adequate balance of instruction and construction in multimedia learning arrangements.

In general, the results of the study give further evidence to the importance of motivational influences on learning processes. Especially self-efficacy, expectancy of understanding and the percieved value of a learning environment seem to be of greater importance for learning success.

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MODELS OF THE HUMAN CIRCULATORY SYSTEM IN SCIENCE TEXTBOOKS: BUILDING A FRAMEWORK FOR REPRESENTATION ANALYSIS

Sandra Escovedo Selles, Ana Cléa Ayres & Tania Reznik
Faculdade de Educação/Universidade Federal Fluminense, Universidade do Estado do Rio de Janeiro and Centro Federal de Educação Tecnológica de Química-Rio de Janeiro, Brazil

Abstract

The basic assumption of this paper is the understanding that, epistemologically, scientific knowledge is representational and results from a modelling activity. Following the work developed on models in science and technology (Gilbert, 1997), we will analyse a number of teaching models employed by fourteen textbooks from primary to secondary level to represent the human circulatory system, using as reference the work of Buckley and Boulter (1997). For them a model is an integrated knowledge of structure, behaviour and mechanism of a phenomenon. The general idea was then, to study to what extent textbooks representations included the components of the models. We developed a mode of analysing science textbooks representations which maintained certain features of the Buckley and Boulter's work. Three representational dimensions of the human circulatory system in the textbooks were considered: *semantic-contextual dimension; correspondence dimension; and abstract dimension.* Within each dimensions a set categories were used in other to explore which components of the model (*structure, behaviour and mechanism*) are related to. The framework developed in this work grasped three elements of the data: the model components, the type of representation used and the teaching level targeted.

1 Introduction

Analogies have been widely used in all knowledge fields based upon the understanding that, epistemologically, scientific knowledge is representational and results from a modelling activity (Franco et al, 1997). Within the school context they are employed in many different ways to facilitate more abstract conceptual understanding. Particularly, in the teaching of biological themes analogies represent a basic strategy to support the comprehension of related concepts. Glynn, Duit & Thiele, R.

(1996) however, point out the limitation of the pedagogical use of analogies because they can cause confusion when not utilised properly.

In this work we are interested in the pedagogical use of analogies from the "model based teaching and learning" (MBTL) perspective as suggested by the MISTRE[1] group. For that we have taken the definition from Johnson-Laird to whom "mental models are structural world analogues". Gilbert (1997) also Gilbert et al in Gilbert and Boulter (2000) considers a model as "*a representation of an idea, an object, an event or a system.*" It is through models that we come to understand the phenomena in the world as we perceive them. Mental models are "*internal cognitive representations, used to reason about a phenomena and also to describe, explain, predict and sometimes, control a phenomena.*" (Buckley & Boulter, 1997:3). Gilbert & Boulter (1998) present a differentiation of models which includes: *mental models, expressed models, consensus models and teaching models*. The mental model that we form in our minds as soon as we "meet" objects, events, systems and world processes are not available to others until we express them in either concrete or symbolic ways (Buckley & Boulter, 1997). Those which scientists accept in their specific scientific areas (historically localised) are the scientific *consensus models*. The models which appear in the school curriculum are the consensus models used by teachers to help students to understand a particular scientific model and they are called *teaching models* (Krapas *et al, 1998* prefer to call them *"pedagogical models")*. It has been considered by these studies that in order to achieve effective learning, pupils have experience a variety of teaching models to understand a certain phenomenon.

Our focus is on the expressed teaching models used by schools to enhance pupil's understanding of the phenomena and how, potentially, they help the construction of mental models. Thus, we want to analyse a number of analogical resources[2] employed by science textbooks to represent the human circulatory system using Buckley and Boulter's (1997) elaboration. For them a model is the integrated knowledge of the *structure, behaviour* and *mechanism* of a phenomenon. In a circulatory system model Buckley (1995:1) proposes that:

> *"a model of the circulatory system begins with the structure of the circulatory system, ie the heart, blood vessels, and blood. A working model expands on the anatomy to include dynamic behaviour such as the heart pumping blood, blood vessels conducting blood, and blood carrying cells and chemicals. Together the structures and their behaviour accomplish the global function of the circulatory system of carrying cells and chemicals throughout the body".*

In the Brazilian literature, textbooks are regarded to be the most used teaching resource and indeed, guide teacher's work at school (Pretto, 1987; Fracalanza, 1989; Reznik, 1995; Selles & Ayres, 1998, among several). Therefore, we have identified the teaching models (analogical resources) employed in fourteen textbooks, most commonly used in Rio de Janeiro schools, from primary to secondary level[3] to represent the circulatory system.

2 Methodology

The general idea of this work was to study to what extent textbook representations included the components of models according to that developed by Buckley and Boulter (1997). In their work they proposed that *structure* refers to the nature of the components of the phenomenon and their spatial relationship; *behaviour* is related to changes that occur with time; and *mechanism* indicates the causes of that behaviour. These components are not mutually exclusive; they tend to be interactive in the sense that *mechanism*, in general, explains the structure and behaviour. It is also important to point out that the causes considered here are, as defined by Mayr (1982), *proximate causes* (in opposition to *ultimate* or *evolutionary causes*).

In the case of the human circulatory system, in the *structure* we have the anatomical elements. We consider *behaviour* as blood movement, transport of cells and chemicals, the heart beating (systole and diastole) and the dynamics of the blood cells in action. In all these cases we observe that the circulatory system behaviour represents the systemic functioning as a whole, in which modifications occur within a considered time span. On the other hand, we can take as *mechanism* a group of factors such as the physical or biochemical which, together, sustain the functioning of the whole system. Thus, it is possible to say that the following are examples of mechanisms of the circulatory system: i) the cardiac muscle contraction; ii) the sinuatrial (SA) node action that is responsible for the heart nervous impulses; iii) the contraction of blood vessels and its valves; iv) the osmotic and hydrostatic pressure on the blood capillary.

We have created a set of categories to analyse the data, derived from the work of Buckley and Boulter (1997) who built a framework to analyse three kinds of representations of phenomenon from different sources (an interactive multimedia resource, a book illustration of greenhouse effect and a 3D concrete model of solar system). They have used an analytical framework created by typographers to make sense of graphic images. Particularly, they have chosen what Goldmith (1984) used to examine the common value of illustration and problems in interpretation, which included semiotic levels and visual factors. For the purpose of this work we developed a simpler mode of analysing textbooks representations which maintained certain features of the Buckley and Boulter's work.

In our analytical framework we considered different dimensions of the analogical resource employed in terms of how, potentially, it would facilitate pupil's understanding of the aspects of the phenomena. In other words, which meaning could pupils take from the representations expressed in the book. Within each dimension a set categories were used in order to check which components of the model (*structure, behaviour and mechanism*) are present. The whole data were considered within two domains: i) a non-scientific domain (representations which make use of everyday elements, closer to common sense); ii) scientific domain (representations directly related to science contents). The three representational dimensions were considered as: a *semantic-contextual dimension a correspondence dimension; and an abstract dimension.* The former has been considered as a *non-scientifc domain* and the two other ones were included in the *scientific domain.* We looked in both texts and illustrations in the books analysed, selecting examples to match the categories. For each example selected we identified which components of the model were represented.

3 Categories employed

The set of categories developed are the following:

a) Semantic-contextual dimension: This dimension is related to all kinds of representations using *linguistic expressions* (such as *the heart is a pump* or *the heart is about the same size of a fist* etc.), *quantitative data* coming from the study of the phenomena which helps to understand how it functions (such as heart beating, blood pressure etc.) or, *objects from the everyday life* (such as cartoons of anthropomorphic blood cells carrying oxygen shown in figure 1 and figure 2).

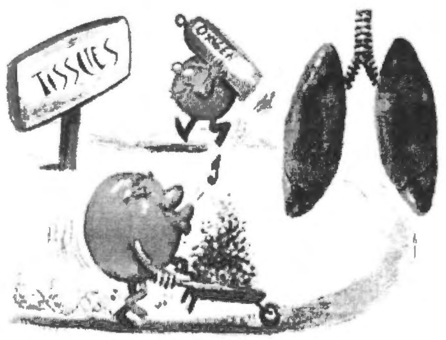

Fig 1. The red cells transport oxygen from lungs to tissues and carbon dioxide from tissues to lungs. **[Book 10]**

Fig 2. The white cells attack the microbes which invade our organism. They do fagocytosis or they produce antibodies. They are our body defence soldiers. **[Book 10]**

b) Correspondence dimension: We included in this group the representations which show a level of correspondence with 'reality' (in this case, the tangible human body). The main features of correspondence are both the structural parts immediately identifiable and ways of representing behaviour or mechanism with more proximity with ordinary facts easily observed by people (for instance, a blood pressure being taken fig. 4). The representations used by textbooks, in this case, include the use of *drawings, photographs, microscopic images or the ones taken from endoscopy* etc. [figures 3 and 4]

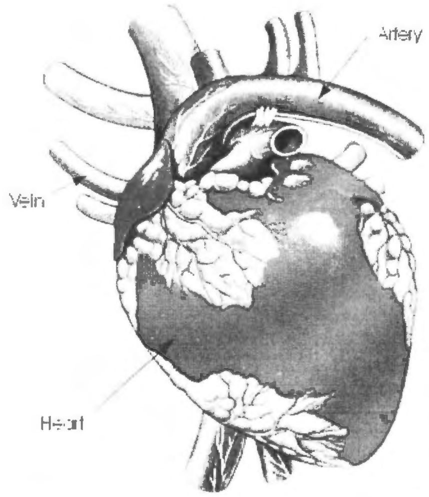

Fig 3. [Book 4]

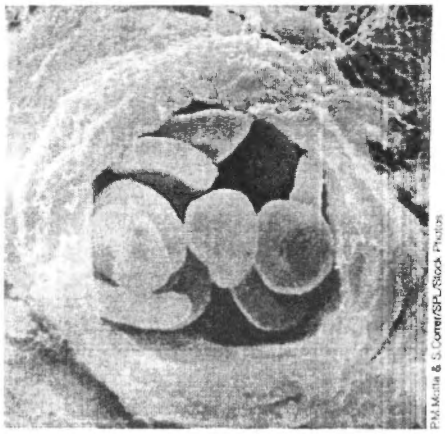

Fig 4. Red cells inside an artery. [Book 9]

c) Abstract dimension: In this category we included representations using structural body elements which have been simplified so that, the relationship with 'reality' is hardly observed or even not observed at all. So, in this group are included *schemes* and *diagrams*. The distinction we made between them is, basically, that the former relates to a *distant* association with 'reality', showing a kind of combination of anatomical structures (poorly represented), no spatial references (a viewer has to guess what is a lung or what is a liver), but it makes use of arrows to show, mainly, behaviour or mechanism. On the other hand, *diagrams* do not show any relationship with 'reality'; they are just abstract formulation of the behaviour or mechanism of the phenomena represented. [figures 5, 6 and 7]

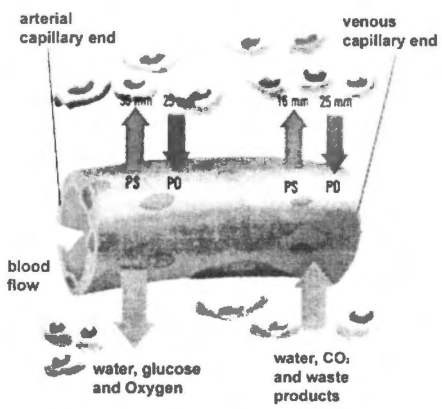

Fig 5. The difference between hydrostatic pressure (PS) and osmotic pressure (PO) promotes changes between blood and tissues. Pressure unity: mm Hg. [Book 13]

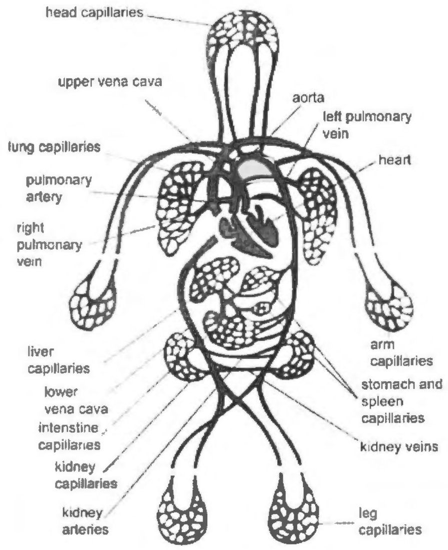

Fig 6. A more detailed scheme of the human circulatory system. [Book 13]

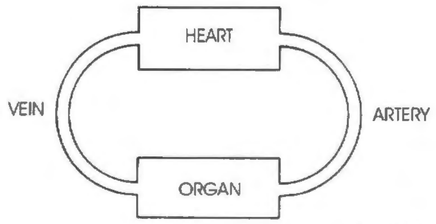

Fig 7. [Book 6]

4 Findings

The framework developed in this work dealt with three elements of the data: the model components, the type of representation used and the teaching level targeted. This methodological approach gives us a measure of how appropriate is the representation for teaching purposes.

The Table 1 shows examples of the three categories in the textbook representations and the relationship with components of the model (as proposed by Boulter and Buckley) according to the school level. Linguistic expressions are underlined.

Table 1. Examples of the three categories in the textbook representations

	Semantic-contextual Dimension	**Correspondence Dimension**	**Abstract Dimension**
Group I 1ª a 4ª years	*Structure:* "Arteries are tubes that take blood from the heart to the rest of the body" (L6, p.77) *Behaviour* "The heart works as a pump. It pumps blood to the body through the blood vessels" (L4, p.58) *Mechanism:* [absent]	*Structure:* drawing illustration of the heart showing the aorta stick and the coronaries" (L6, p. 77) *Behaviour:* [absent] *Mechanism:* [absent]	*Structure:* scheme of the heart with cavities and main vessels (L2, p.117) *Behaviour:* activity requiring the pupils to indicate the passage of the blood in the body (L.1, p.46) *Mechanism:* [absent]
Group II 5ª a 8ª years	*Structure:* "the heart is approximately the size of a closed fist size and it is hollowed (L8, p.95) *Behaviour:* "arterial blood pressure compared to the water pressure in a garden pipe"(L.8, p.99) heart valves compared to bags which open like a parachutes when blood tries to come back.(L. 11, p.111) *Mechanism:* blood cells represented using anthropomorphic images: red cells 'carrying Oxygen' or 'lymphocytes attaching a bacterium" (L.11, p.119-p.120)	*Structure:* microphotography of a red cell within an artery (without scale) (L.9, p.85) *Behaviour:* [absent] *Mechanism:* [absent]	*Structure:* scheme of comparative blood vessels (including capillary) comparative (L.7, p.91) *Behaviour:* scheme of the heart indicating flux (L.7, p.92) *Mechanism:* a general scheme presenting changes between lymphatic and circulatory systems (L.8, p.100)
Group III Upper secondary	*Structure::* "blood cells go in a queue line (one by one) at capillary level". (L11, p.241) *Behaviour:* "Blood pressure is less stronger in the veins because it has been filtered by the capillary net" Or In the arteries the blood progresses by hiccups, by heart contraction rhythm" (L11, p.239) *Mechanism:* "Thus, plasma and leukocytes run away or desert from the blood stream and go to the tissues." (L11, p.245)	*Structure:* lens photography of lymphatic vessel valve showing magnification". (L.11, p.246) *Behaviour:* measuring blood pressure illustration (L12, p.367) *Mechanism:* [absent]	*Structure:* scheme of the whole circulatory system stressing the arterial and venous blood indicating the small and large circulation (colours were used) L.13, p.319) *Behaviour*: scheme of vein valves functioning (L.13, p.320) *Mechanism:* synthetic scheme of substance interchanges in the arteries and both the blood pressure and osmotic pressure (L13, p.320)

A first attempt to analyse the textbook representations showed that the *semantic-contextual dimension* and *correspondence dimension* were predominant in all school levels. Anatomical structures of the circulatory system were more frequent too[4]. At the beginning of the work we made the assumption that as the school level progresses we would find in the books more abstract levels represented and, therefore, the components such as behaviour or mechanism would be more numerous. Indeed, representations of the mechanism of the circulatory system were seldom shown in first year books. However, when quantified, the number of abstract dimensions did not increase proportionally. In the upper secondary groups we found less abstract levels than in the intermediate group (group II). For instance, in group I we found no textbook representations of mechanisms at all; in group II there were six; and in group III, there were only five.
The Table 2 shows the number of categories employed related to the mental models components, according to the school level:

Table 2 – ***Number of the categories employed related to the models components***

Mental Models components (Buckley & Boulter, 1997)	Group I (Years 1-4)			Group II (Years 5-8)			Group III (Upper secondary)		
	Semant./ Context	Corresp.	Abstr.	Semant./ Context	Corresp.	Abstr.	Semant./ Context	Corresp.	Abstr.
STRUCTURE	4	8	3	16	11	29	5	9	25
BEHAVIOUR	4	-	6	16	-	29	10	2	14
MECHANISM	-	-	-	3	-	3	-	-	5

5 Discussion

The systemic principle of the human blood circulation is a group of physiological phenomena which occur at different organizational levels within the organism and they rely upon the relationships among several anatomical structures undertaking certain functions. In this sense the systemic dynamics of the human body can be understood by the explanation that the blood circulatory system depends on the functioning of the several other systems related to it as well as to the different levels of organisation within the system. These systems perform different functions whose interconnections produce, in their turn, a chain of relationships that maintain the life of the organism. The idea underlined here is that the understanding of the blood circulation requires an organic view as supported by modern biologists to explain life processes (see, for example Mayr, 1998).

It is important to stress that this research study tries to look at the group of blood circulatory phenomenon from their educational representations. Thus, any analytical category aims to study the representational suitability to the educational context, and takes the phenomena as a reference but differs from it. In taking into account the phenomena, it has to be considered according to the scientific consensus model which implies that this phenomena previously received an interpretative treatment. It is from this perspective that we tried to analyse whether the analogical resource represented in the textbooks, potentially enables pupils to accurately grasp the scientific meaning. We have to show the boundaries between different dimensions of the phenomenon and the different attempts to represent it for educational means, in other to clarify the investigative approach and its methodology.

In using these analytical categories for research, we have to take the model components not as isolated elements, but maintain the interactivity, since by doing so, we preserve the systemic identity. In other words, *structure, behaviour and mechanism* are indeed, considered as integrated knowledge. Thus, when we take the heart beating as behaviour it is seen within a certain organisation level. It is also possible to consider this example as mechanism it we say that heart beating is also responsible for the specific function of making blood circulate throughout the body. In other words, according to the level of organisation considered, a behaviour can explain the next level upwards and so on.

The most common pedagogical approach to teaching the human body contents seems to begin with the macroscopic level, preferably with organs taken in isolation from the systems. This approach is not always successful to grasping the systemic dimension, or, in other words, this educational strategy reinforces a fragmentary notion of the way the body functions. The other systems are introduced to pupils as units or sub-systems which merely have organs. Within this reducionistic perspective it is hard for pupils to understand the several relationships which connect the human body and its environment. There are some studies that point out the weakness of such approaches (Ramadas & Nair, 1996; Nuñez & Bannet, 1996). The analogies employed in textbooks, mainly the ones which make use of 2D images, follow this pattern and in this sense, we recognise that they do not always work for pupils.

Kearsey and Turner (1999:93) examining the usefulness of figures in biology textbooks point out *"that for illustrations to have a beneficial effect, there should be references to them in the accompanying text"*.

They mention that it is necessary to help students to develop an *"ability to read pictures"* which has been described as *"visual literacy"* (Goldsmith, 1984 and Kress & van Leewen, 1990). Moreover, *"students need to be taught about this **grammar** of scientific graphic illlustration along with picture-scanning strategies, including means of interpretation, if they are to use textbooks to support their learning effectively"*. Péres de Eulate, Llorente and Andrieu (1999) and Pérez de Eulate and Llorent (1998: 49) have reached similar conclusions when analysing biology images in textbooks. They stress that the image can teach little if students do not connect the text explanations to the images, regardless their adequacy: " ... *we should not forget that the mere presence of adequate images do not guarantee a better learning, since that there are multiple factors which interfere in this process.*"
In our work we found that a great number of figures used as analogies belonged to the *correspondence* and *abstract dimensions* and the representation showed, mainly, the physical components of the circulatory system. Therefore, in order to help students to build their mental models, as an integrated knowledge, the analogical resources in textbooks need to be well related to the text, especially when figures are employed. It is agreed that the teaching-learning process goes beyond the use of textbooks and that personal variables, linguistic interactions in the school environment and outside it, have great influence in the way students build their models. However, if analogy is to be employed in textbooks as a fruitful tool to help pupils to understand phenomenon, special care needs to be taken.

6 Conclusion

If we take for granted that models are an integrated knowledge which includes the three components; and that in the Brazilian context, textbook representations are most powerful tools both for teachers and for the pupils teaching-learning process; we understand that in order to help pupils to build them, the teaching models should be as complete as possible. From the data analysed, we conclude that textbooks, alongside schooling, inform pupils more about the structure of the circulatory system than about how it works and which mechanisms make it do so. We recognise that both behaviour and causal mechanisms are difficult to represent in a 2D illustration (Buckley & Boulter, 1997). Therefore, if we think about the relevance of this biological topic and its implication for everyday life, the absence of more abstract component in the teaching model employed in the textbooks is a matter of concern. The need to develop a pictorial language in textbook illustrations in order to achieve more abstract levels of the phenomenon seems to be needed.

Notes

[1] Models in Science and Technology Research in Education
[2] In this text we used *analogical resource* and *teaching model* interchangeably. For that we mean the expressed model used by textbooks for teaching purpose.
[3] Each book was identified from **B1 to B14**. According to the Brazilian educational system the books belonged to three school levels: group 1 (years 1-4) – **B1 to B6**; group II (years 5-8) – **B7 to B10**; group III (upper secondary or the three last school years) – **B11 to B14**.
[4] The total amount of representations identified, in all levels were: 111 structure, 63 behaviour and 17 mechanism.

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Section Three: REASONING

Proceedings of the III Conference of European Researchers in Didactic of Biology. September 27th- October1st 2000. Santiago de Compostela (Spain), pp.231-245

ROLE PLAYING IN SCIENCE: A TOOL FOR A NONVIOLENT APPROACH TO ENVIRONMENTAL CONFLICTS

Laura Colucci, Elena Camino & Anna Perazzone
University of Torino, Italy

The emergence of biophysical limits to economic growth undermines *"the famous metaphor of the growing cake that offers larger pieces for everyone without imposing smaller pieces to anybody"*. Sachs (1999) *argues* that *"it derives its attraction from the promise to achieve justice without redistribution"*.

1 Introduction

We share many authors' idea that "the essence of scientific thinking is the ability to examine problems from different perspectives, and seek explanations of natural and social phenomena and processes, constantly submitted to critical analysis" (AA.VV, 1999).
Critical and free thinking – which is essential in a democratic and peaceful world – requires that people have access to information and data: to academic as well as to traditional and local world views, to scientific knowledge intertwined with economics, ethics, philosophy. Thanks to a scientific education which promotes an active and responsible citizenship (Aikenhead, 1997; Hodson, 1993), people should become aware of the increasing interdependence within the global life-support systems and of the interconnectedness between the ecological management and equity problems (Gadgil & Guha, 1995).
Our research stems from a long lasting interest for role-plays as educational tools (Camino & Calcagno, 1995; Colucci & Camino, 1999). Our working hypothesis is that role-plays are a powerful tool to cope with complexity and interdependence, and to help students to think in terms of ecological sustainability.
In our previous researches (Forneris, 1998; Colucci, 1998) we found that students met with difficulties in assuming active roles within the classroom, in selecting information, in managing the decision process and the risk/benefits analysis.
On their side teachers – accustomed to more traditional methods of teaching – tried hard to assess students in the new teaching/learning context.
Taking the opportunity of a new role-play that we recently published (Colucci & Camino, 2000), we have decided to go deeper into some aspects of this methodology, and we have focussed our attention on:

- How participants behave when they are asked to take a stand about a controversial environmental issue: how they search data and assess their pertinence and reliability, how they organise information from various sources and from different subjects.
- How they deal with the strategies for the resolution of conflicts: the degree of competition, co-operation, empathy within and among groups, the use of argumentation (Newton, 1999) in supporting the various points of view, the creativity in searching 'positive' solutions, the ability to listen at others' reasons and to put oneself in other people's (or other living beings...) shoes.

2 The topic

The new role-play set up by the Authors (Colucci & Camino, 2000) deals with the global environmental and social issue of the production of shrimps in aquaculture ponds (FAO, 1999; P.S.B.R. James, 1999). Some of the materials used during the introduction session can be found in Appendix 1and 2.

This activity spread massively – during the last ten years – along the coasts of many tropical countries. Promoted and funded by International Institutions (FAO, IMF, WB) in order to improve proteins' input in the diet, to offer new opportunities of employment, to raise the economies of developing countries, this activity has also produced widespread damages to the coastal ecosystems, and has weakened the subsistence economy of local populations (AA.VV. 1998).

In the previous role plays two groups ('pros' and 'cons') after having collected information and documents about the problem, discuss in front of a third group of 'decision makers', who have to choice one of the alternative positions after evaluating costs and benefits. In the new role-play a further decision -making situation is offered: a round table where all the participants cooperate to reach a positive outcome by applying non-violent strategies to solve the conflict.

3 The materials

The role-play textbook includes the rules of the game, the cards of roles, the materials for the group work. In addition to it a wide selection of documents on scientific and technological aspects of the problem is included, with descriptions of the socio – cultural context, and several information related to economical aspects and the current conflict. (Some of the materials used during the game can be found in the Appendix 3and 4).

As regards biological knowledge players have to master knowledge in ecology, zoology, botany, in order to understand science-related situations occurring in the real world. For example, players are required to investigate food chains and ecological webs within the context of the global trade, as well as within the local scenery of the mangrove shrub. They have to deal with nutritional tables, with water-induced illness; they are required to evaluate the time extent of biological processes and of the consequences of human intervention.

4 The methodology

In this first stage we followed the Action - Research approach (Elliott,1993; Feldman, 1994, Sauvé, 1994), according to the typical sequence of reflection, planning, action and observation, which is repeated cyclically and allows to carry on the research along a spiral process (Dodman, 1998).
Activities were planned by researchers, who acted then during the game sessions as conductors and facilitators.
Our objective – in this stage of the research - was to investigate in which conditions players felt most confident to seize the learning opportunities offered by the role play. We focused our attention on skills in handling information, ability to sustain the role, insight of the understanding of the extent and complexity of the controversy.
We worked so far in three experimental contexts: a group of university students of the 4th year of the degree in Natural Sciences (**G1**; n=17), a group of secondary school teachers (**G2**; n=9), and a 'mixed group' of people interested in environmental education (**G3**; n= 15).
With each group the game session was introduced through the presentation of the local and global scenario of the controversy e by some methodological information.
At the end of the game participants - guided by the researchers - were involved in the Risks/Benefits analysis of the two alternative solutions.
The amount and variety of documents available to players was modified at the end of each Action-Research cycle, according to the conclusions drawn from observation and reflection.

5 Data collection

Some data were collected in written form:
Reports of the group's activity. Each group received two worksheets: in one they were asked to write down a report of the activity by the group. In the second one they had to make a list of 'strong & weak' aspects of the group's strategy, in order to facilitate the co-ordination among roles and to find out the critical aspects of the controversy.

Debate. The debate was recorded and transcript in order to analyse groups' strategies during the presentation in front of the decision – makers.

Immediate perception. As soon as the debate ended up, participants were asked to write down the feelings they had during the simulation. This activity aimed to put forward the emotional involvement, the assumption of responsibility, the degree of empathy, the dynamics of interpersonal relations.

Final evaluation. After the conclusion of the experience, participants were involved in a further activity: they were asked to point out learning opportunities, development of new attitudes and abilities they eventually ascribed to the activity.

Some more data were collected by the researchers in the form of personal notes recorded during the activities, then used in the reflection phase of Action-Research.

6 Results

The data collected were ordered and grouped according to the scheme of Table 1. Data consist of single sentences or argumentative sequences that participants wrote on the worksheets or pronounced during the debate.

Quantitative and qualitative analysis of these data allowed us to detect some of the difficulties that participants met during the game, and helped us to assess the effectiveness of the strategies we gradually introduced in the experimental setting.

Table 1.

Topic
Handling information (Dodman, 2000)
Types of strategy (Galtung, 1996; Johnson & Johnson, 1989; Kolstoe, 2000)
Personal involvement (Thomashow, 1996; Pontara, 1996)
Attitudes (Naylor & McMurdo, 1990; Hicks, 1994 & 1996)

6.1 Quantitative analysis: a global view

By comparing the course of the argumentative sequences in the three experimental situations we could draw some general observations, which we report in the following paragraphs.

First of all, we designed a map in which the different groups' strategies –used in each of the three different contexts– are represented. On this map it

is possible to recognise different types of argumentation paths: from single and isolated elements of discussion referred to the local scenario up to complete argumentative sequences in which interdisciplinary conceptual tools are used and the global scenario is taken into account.
As it is summarised in the chart below (Fig. 1), group G3 was able to extend the discussion from the specific problem of aquaculture ponds to the global scenario and to assume a critical position about the role of science and technology in solving global problems.
In the 'immediate perception' reports the three groups emphasise different elements of cognitive learning (Fig.2): G1 feels to have learned notions; G2 appreciates the acquired competencies in searching data, G3 underlines the complexity of the problem.

Figure 1.

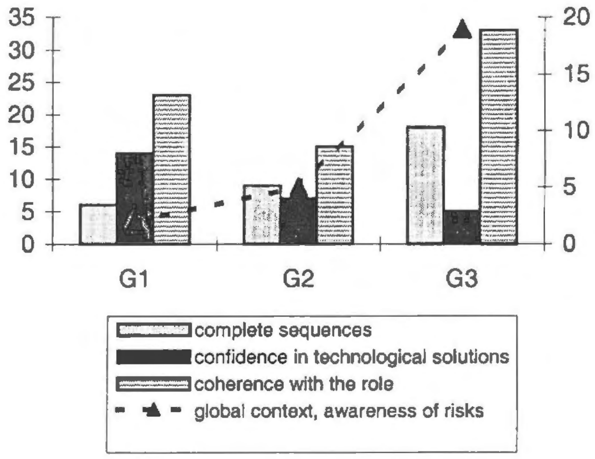
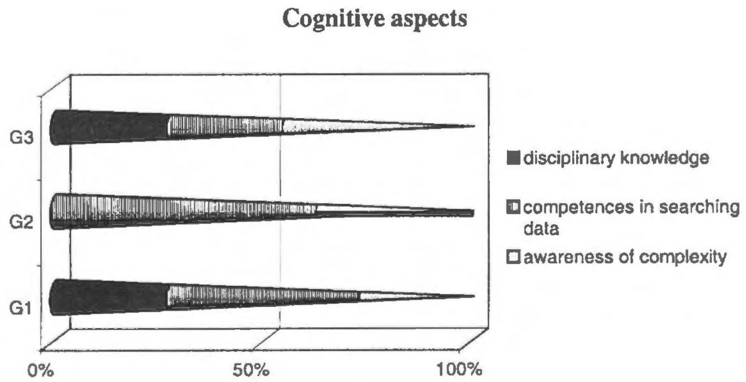


Figure 2.



The three groups express also a different degree of emotional involvement. Students (G1) put out their difficulties in 'assuming the role'. Teachers comment on the simulation as a good opportunity to acquire a deeper knowledge, while the emotional participation is higher within the third group (G3), where people still feel involved in the role after the end of the simulation.
In the final evaluation G3 offers the highest number of sentences, as regards each of the considered arguments. Only G3 explicitly suggest the need of creative solutions and of a co-operative attitude.

6.2 Analytical aspects: qualitative data
Specific remarks and comments of the participants gave us some cues on the difficulties met during the role-play, so that we were able to modify game conditions and assess their effectiveness during the following cycle of Action-Research.
We describe here some of the obstacles that we have identified, and the changes we introduced to support participants' effort.

A) The problem is complex
In order to handle the problem players have to master basic scientific knowledge more than specialised disciplinary knowledge. Bases in ecology, physiology, geology is required. Moreover it is important a system approach in order to grasp ecological process and interdependencies and to appreciate space and time dimensions of phenomena.
With the first group researchers observed that players have difficulty in selecting relevant information and in connecting various disciplinary points of view.. The argumentation is often superficial and fragmented. Awareness of the interdependence of ecological processes and of the biosphere's limits is lacking
"As regards polluting wastes of course they must be eliminated [...] dumping them for example, or isolating them from the external environment and then move where chemical and biological treatment follows... "
As much as difficult it is to recognise extent and dimensions of risks (particularly long – term risks) of human interventions on ecosystems:
"Each aquaculture system must be equipped with water softener, and every 5 years the firm must attend to the treatment of its wastes and to make sure that the ground and stratums are restored... "
Players easily tend to delegate to 'experts' the burden of searching for solutions:
"There are scientists who have seen that those aquaculture systems are well designed: there are air and water chemical treatments, which make them totally safe... "

With G2 and G3 we introduced the idea of a systemic approach to the planet (Clayton & Radcliffe, 1996), and we offered an example of other 'local' situations with intensive shrimp pond (Hawaii). Moreover we supplied evidence of the contribution of local knowledge in dealing with environmental problems.

B) Controversy is simulated, but the conflict is real

In Southern India the controversy on shrimp ponds gave rise to a conflict which assumed the form of a nonviolent protest by the local villagers. Therefore some of the players are requested to assume principles and ideas of a very different tradition (i.e. Gandhian ideals), and to manage the R/B analysis not only in terms of a win/lose model, but also according a win/win hypothesis, in search of a solution fulfilling both parties.

During the first cycle players showed difficulties to put themselves in other people's shoes. Moreover they hardly managed the chances offered by the socio-economic view based on values (equity, simplicity, frugality) quite far from the western ones. They lacked confidence in the possibility to modify an ongoing process, which looks the non-violent proposal appeared to them as utopistic and inapplicable:

"...It would not make sense to eliminate everything now, India will fall into pieces and moreover it holds already so many debts that we cannot imagine what will be if we had to give up everything now..."

In order to help players to become more involved in their role, we showed slides and videos on village life in rural India and on the protagonists of the nonviolent protest.

The R/B analysis was modified, from a scheme with two alternative solutions (Table 2), to a new one based on the search of shared needs (Table 3).

C) Taking responsibility

The controversy on shrimp aquaculture – besides Indian villagers - involves also northern consumers who can affect the market with their decisions.

Players of the first group did not consider themselves as part of a global ecosystem, nor did they take into account the biophysical limits of the planet. Technological solutions based on the model of unlimited growth did not stir up opposition (Sachs, 1999). The reflection on equity was absent (Gadgil & Cuha, 1995).

With the 2nd and the 3rd group the links between production and consumption of shrimps at the global level were openly mentioned, and the interdependence between North and South was illustrated with documentaries (Norberg-Hodge H.).

Table 2.

Pro - shrimps		**Against- shrimps**	
Costs	benefits	costs	benefits

Table 3.

Pro - shrimps			**Against-shrimps**		
Worldviews	Interests	Needs*	Needs*	Interests	Worldviews

(*) In the sense of Gandhi: *"on the Earth there is enough for the needs of all, not for everyone's wants".*

Table 4.

Topic	**Levels**		
	1	**2**	**3**
Handling information	Multi-disciplinarity	Inter-disciplinarity	Trans-disciplinarity
Types of strategy	No collaboration	Collaboration	Co-operation
Personal involvement	Individual	Team	Empathy/compassion
Attitudes	Conservation	Recourse to past	Futures vision

Table 5.

	Handling information	**Types of strategy**	**Personal involvement**	**Attitudes**
G1	2	2	2	1
G2	2	2	1	1
G3	3	3	3	3

6.3 A comprehensive view

From a global view of the experimental data, for each of the topics we have discerned three levels, according to an increasing degree of complexity (Table 4).
On the base of this scheme we ranked the performance of the three groups. The results are summarised in Table 5.

7 Conclusions

Even if they are supported with adequate information on the scientific, economical and ethical aspects of an environmental problem, and even if they receive detailed instructions about how to prepare and handle the controversy, the participants to the role–play usually do not succeed in carrying out the activity with fulfilment.
Our previous investigations had already thrown light on some critical aspects. Fragmented and incoherent patterns of information, individualistic attitudes during the collective activities, a vision of the environment as a sum of separate and isolated parts, lack of awareness of time and space dimensions during risk analysis and decision making process were identified as obstacles to the role-play activity.
Thanks to the three cycles of Action Research that we have described here, we collected evidence on the causes of such critical aspects, and - by modifying the experimental setting of the simulation – we assessed whether the participants felt more comfortable in handling data and in collaborating within groups.
We found that participants improve their performance when they are assisted in developing awareness of <u>interconnection and interdependence</u>:

- in handling knowledge,
- in dealing with other people,
- In the experience of the Self related to the biosphere.

Most of the conceptual tools which are effective in developing such awareness arise from the biological domain, and can be summarised as an ecological systems thinking, a perception of self as part of a larger system, a knowledge of the biophysical limits of the biosphere.
These considerations throw light on the relevance and responsibility of Biology education for the development of aware and responsible citizens in a sustainable society (Orr, 1992).

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Text of the role-play and the teaching materials are available in hardcopy and in CD-ROM on request to the Authors.

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APPENDIX 1 - PRESENTATION OF THE TOPIC

A controversy on shrimp farming....

... Is not it too far away?

LOCAL - GLOBAL - LOCAL ...

What happens in other places at the **LOCAL** level...

Cultural and political events (new CD, scientific discovery, political elections...)
Natural phenomena (earthquakes, typhoon...)
Individual or group actions (felling of a forest...)

The use of a particular language increases (technical terms)
The global level of CO_2 increases
Some products become more available
A species disappears
the price of some goods may change...

... has repercussions at the **GLOBAL** level...

The **GLOBAL** situation becomes the new context where the **LOCAL** people

jobs become difficult to find...
... a knowledge of the language is required
the price for pineapples and shrimps is lower
Drinking water would be better to be bought...

At the LOCAL level the single person can:

- Sometimes can choose with awareness
- Sometimes he has to suffer something in positive or in negative sense

At the LOCAL level the whole community of people:

- can be puzzled, cannot understand ...
- <u>can organise itself and take action (laws and norms, displays...)</u>

APPENDIX 2 - PRESENTATION OF THE TOPIC

"A Meal Of Shrimps: A Global Problem"

The role-play deals with the global environmental and social issue of the production of shrimps in aquaculture ponds.

80's - 90's

This activity spread massively - during the last ten years - along the coasts of many tropical countries. Promoted and funded by International Institutions (FAO, IMF, WB) in order to **improve proteins' input in the diet, to offer new opportunities of employment,** to raise the economies of developing countries...

1995 - 2000... ?

... this activity has also **produced widespread damages to the coastal ecosystems,** and has weakened the subsistence economy of local populations

---

IN INDIA:

This controversy has given rise to a conflict, which assumed the form of a non-violent protest animated by the local villagers against the local farmers and the multinational organisations.

APPENDIX 3 - WORKING MATERIALS

GAME RULES

MATERIALS FOR GROUP WORK

✔ **ROLE CARDS**

GROUP "A": World Bank, local and foreign investors, government officials

1A Sonja Kumar ex government official
My name is Sonja, I am a senior government official and I spent all of my life caring of India's problems. I had been working at the Agricultural Department since 1950.
Sustaining and promoting aquaculture industry means having a very big income of high currency and lots of jobs will be available. Aquaculture industry will lead India to such a huge economical development that everybody will be certainly able to reach his own "place under the sun". Intestine fights will definitively come up to terms. That will mean new social positions for everyone, especially for women (...).

GROUP "B": local villagers, NGO, International Organisations

9B Jegannathan, leader of the non-violent movement against shrimp farming.
I am very old now. My wife and I we spent all of our life to give voice to the weakest people. They are last ones, the ones who never see their rights to live recognised. We are carrying on a third revolution, in place of the two previous ones (the green revolution and the blue revolution), which only gave benefits to foreign companies or to whom who already were in a privileged position. People who take on action for their life and their environment make our movement.
The 11 December 1996 the Supreme Court deliberated in our favour: intensive shrimp farming must be forbidden. But there is still a lot to do. We must be careful and vigilant, if we want to see that sentence be respected. We won't stop our singing and our hunger strikes.

GROUP "D": decision-makers

D4 Shagor Goshivah, doctor
My name is Shagor, I am 40 years old and I am employed at the Tamil Nadu National Health Department. In our Department we are doing a permanent and restless work of monitoring the quality of freshwater and prevention of diseases. India is a very over-populated country, and water is often lacking in some periods during the year. Viral epidemics can easily spread all over the country. They are very strong epidemics and they can even halve the number of people in the villages. My doubts about the two alternatives that we are going to discuss today are principally related to health aspects. I would like to know if shrimp farming can be really effective in assuring a better life quality for Indian people, or if the rural people who are actually protesting have to suggest any alternatives for dealing with the current low health conditions. I will be ready to hear from both of them.

APPENDIX 4 - WORKING MATERIALS

✔DOCUMENTS ON SCIENTIFIC AND TECHNOLOGICAL ASPECTS OF THE PROBLEM, DESCRIPTIONS OF THE SOCIAL AND CULTURAL CONTEXT, HISTORICAL BACKGROUNDS OF THE CONFLICT.

- Looking at the **MEDIA COVERAGE...**

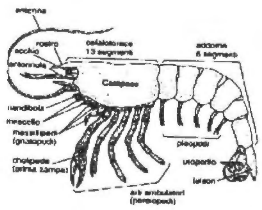
THE HINDU

" Greenpeace activists joined the movement of fishermen in Mumbai to show the problematic situation. The coomunities of local fishermen are badly damaged by the industrial development...". Fishermen protested against the l l'Aquaculture Authority Bill...

- ... Approaching the major **SCIENTIFIC JOURNALS:**

Science

Shrimp feed contains about 30% fishmeal and 3% fish oil, and intensive shrimp farming actually results in a net loss of fish protein...
So long as the full environmental costs of feed and stock inputs, effluent assimilation, and coastal land conversion are not recognised in the market...



- Selecting information from **SCHOOL TEXTBOOKS...**

- Using Internet to keep in touch with **INTERNATIONAL ORGANISATIONS**

www.fao.org
www.gaalliance.org/revi2.html
http://home1.gte.net/hosaka/ecuador/shrimpop.htm
SIERRA CLUB, www.sierraclub.ca/national/MAI/brief.html

... Accessing the major **DATABASES...**

1990 - 93	ITALY	INDIA
Population	55.226.000	994.580.000
Life span	78	62
N. of children per woman	1,2	3,2
Daily proteins' intake (g/day)	139%	101%
Access to drinking water	100 %	81%

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COMMUNICATION IN THE LABORATORY SESSIONS AND SEQUENCES OF ARGUMENTS

Joaquín Díaz de Bustamante & María Pilar Jiménez Aleixandre
Universidade de Santiago de Compostela, Spain

Abstract

This paper reports a case study about discourse and argument in the Biology laboratory (microscope). 9th grade students (14-15 years) were asked to solve a problem: to identify an unknown biological sample. The purpose was to explore the classroom discourse, the system of communication, being the focus the argumentation pattern, the relationships that the students establish among data and theoretical hypothesis, the operations by which hypothetical statements are transformed into data and the uses of justifications. Two groups of students were video and audiotaped while solving the problem. The transcriptions were analyzed using Toulmins' (1958) layout.

The focus of this paper is the methodology used through the analysis, and the inscriptions designed for reporting the paths of argument. The criteria used for deciding whether a dialogue was an argument or not and which exchanges belonged to the same argument are discussed. We designed a flow diagram to represent the sequence of arguments along the discussion. The sequence and instances of arguments are analyzed, focusing on the substantive arguments, related to relevant biological knowledge. The results show how students are able to use argumentative reasoning, to justify their claims. Implications for promoting talking and doing science in the biology laboratory are outlined.

1 Classroom discourse, communication and argument: theoretical framework and objectives of the study

The exploration of the classroom discourse, understood as the system of communication in a particular classroom (Cazden 1988) is receiving growing attention from science education. It is expected that these studies would shed light on the ways science is learned and taught, being complementary with studies focused on pupils' ideas. We need to explore the processes through which meaning is made *in* science classrooms. Classroom is a keyword, because these questions are concerned rather with situations, interactions, exchanges taking place in actual classrooms or laboratories that with studies in an out-of-school setting. From the different communication modes the focus here is on argumentation, understood as the relationships that the students are able to establish among data and theoretical hypothesis, for instance the operations by which hypothetical statements are transformed into data and the uses of justifications in them.

The framework for this study is related on the one hand to Science studies, including perspectives from Philosophy, History and Sociology of Science, and on the other hand to psychological views of learning. From the philosophical perspectives we borrow the argument layout from Toulmin (1958), working with the assumption that the goals of science education include developing the capacity of relating evidence to theory, of supporting claims with evidence. It is worth discussing the relationship between argument and reasoning. The role of logic in argumentation has been much discussed and although some view arguments as a form of logical reasoning, we assume Hintikka (1999) position in establishing a difference among, on the one side the traditional conception of formal logic and, on the other side argumentation and logic in natural discourse. As Hintikka says, for theorists of human reasoning: "*the truths of formal logic are mere tautologies or analytical truths without substantial content and hence incapable of sustaining any inferences leading to new and even surprising discoveries*" (Hintikka 1999, page 25).

For us, that means that while formal logic could be used to represent or analyze established knowledge, it is not an adequate frame to interpret discourse in situations where new knowledge is being generated. In natural discourse, for instance when solving a problem in the science classroom or laboratory, many propositions could be not correct or even be fallacious from the perspective of formal logic, while at the same time they could constitute fruitful steps in the construction of knowledge.

Informal logic is also relevant for the study of argumentation in discourse: As Walton (1989) says, to analyze argumentative discourse on controversial issues in natural language a number of questions, as careful attention to language or the ability to deal with vagueness and ambiguity, must be taken into account, and researchers must be prepared to unravel the main line of argument from long exchanges among two or more people. Walton stresses that in this dialectical approach the question-answer context of an argument is brought forward and an argument is seen as a part of an interactive dialogue of two (or more) people reasoning together.

Our understanding of the scientific enterprise has been extended by the sociological approach through study of current scientific practice (Latour & Woolgar 1986); this sociological perspective has been applied to the study of science classrooms and school labs (Kelly and Crawford 1997). Through argumentation analysis we try to identify the construction of facts and data in students' conversation, the operations through which hypothetical claims are transformed into "facts", the ways warrants are used in them.

From the psychological views of learning, when studying how the background (Biology) knowledge is used in warranting arguments, we draw on Brown, Collins & Duguid (1989) perspective, assuming that conceptual knowledge cannot be dissociated from the situations in which is learned and employed. First, this was taken into account in the design of the authentic problem which students had to solve. Second, we try to look for instances of students' conversations which could be identified as part of the scientific culture, as defined by Brown *et al.* This kind of conversation is not found in standard Biology laboratories (Jiménez and Díaz 1997).

The conceptualization of scientific thinking as argument has been proposed by Deanna Kuhn (1993) who points at the social dimension of science construction, at the ways science is connected to controversy and argument. Scientific knowledge implies choice among competing theories, analyzing the evidence, relating evidence to theories. Argumentation analysis has been applied to the study of classroom discourse, for instance by Kelly, Druker, and Chen (1998). Driver, Newton and Osborne (2000) point at the lack of opportunities offered by current pedagogical practices as the major barrier in the development of the skills of argument in young people.

This paper reports a case study about discourse and argument in the Biology (microscope) laboratory. It intends to document instances of students talking science but, as this doesn't happen often in classrooms, we have designed different units and problem-solving activities with the aim of promoting discussions about the knowledge related to data and claims. The objectives addressed are:

– To test research methods used to analyze students' arguments.

– To explore the relationships established among the data (observations through the microscope) and the biological knowledge about the cell by means of justifications.

– To analyze the argumentation path leading to a conclusion about the sample.

The next section is devoted to methodology, then the students' arguments are presented and finally they are discussed in relation to the biological knowledge involved.

2 Methodology: participants and tools for the analysis

Participants and classroom context; data collection

Participants were drawn from two groups of 3ª BUP (9th Grade, aged 14-15 years) High School students taught by their regular teacher, the sessions being part of the Natural Science course schedule. The students worked in groups of two, three or four sharing a microscope. A lab session on the topic of microscopic observation was video and audiotaped. The student were asked to solve a problem: to identify an unknown biological sample (not the same for each small group), being this task quite different from the ones which usually consist in observing and drawing a known sample (onion skin etc.). The task is discussed in detail in Jiménez, Díaz and Duschl (1999); the problem is reproduced in Appendix 1. The study focuses on the performances and discussions of two small groups, one from each school: F (four boys) and G (two girls).

The students were not expected to recognize (label) the sample –in F epidermis from the plant *Centranthus ruber* and in G osteoblasts in fish operculum–, but to match it with one option in the handout; in other words to tell whether it was plant or animal, and which one of the two choices about ir. They were asked to draw the sample.

Argumentation Analysis

The small groups were video and audiotaped while solving the problem. Their dialogue was transcribed and contrasted with the videotapes, drawings and reports, in order to include relevant information, for instance about handling the microscope. The transcripts were analyzed and coded for argument components by the two authors. The analysis were then compared and discussed until an agreement was reached.

In a second step the different arguments (which could include more than one message units, and different speakers) were identified and a sequence map of them was outlined; this was performed first independently and then comparatively as in the first step. In a third step the warranted arguments were identified and coded following the taxonomy proposed by Kelly *et al* (1998) about the range of warrants. Finally, after the identification of conditions leading to warranted arguments, a set of categories was developed for conditions and each warranted argument was coded in it. At some of the steps, reconstruction of the analysis grids and categories was needed.

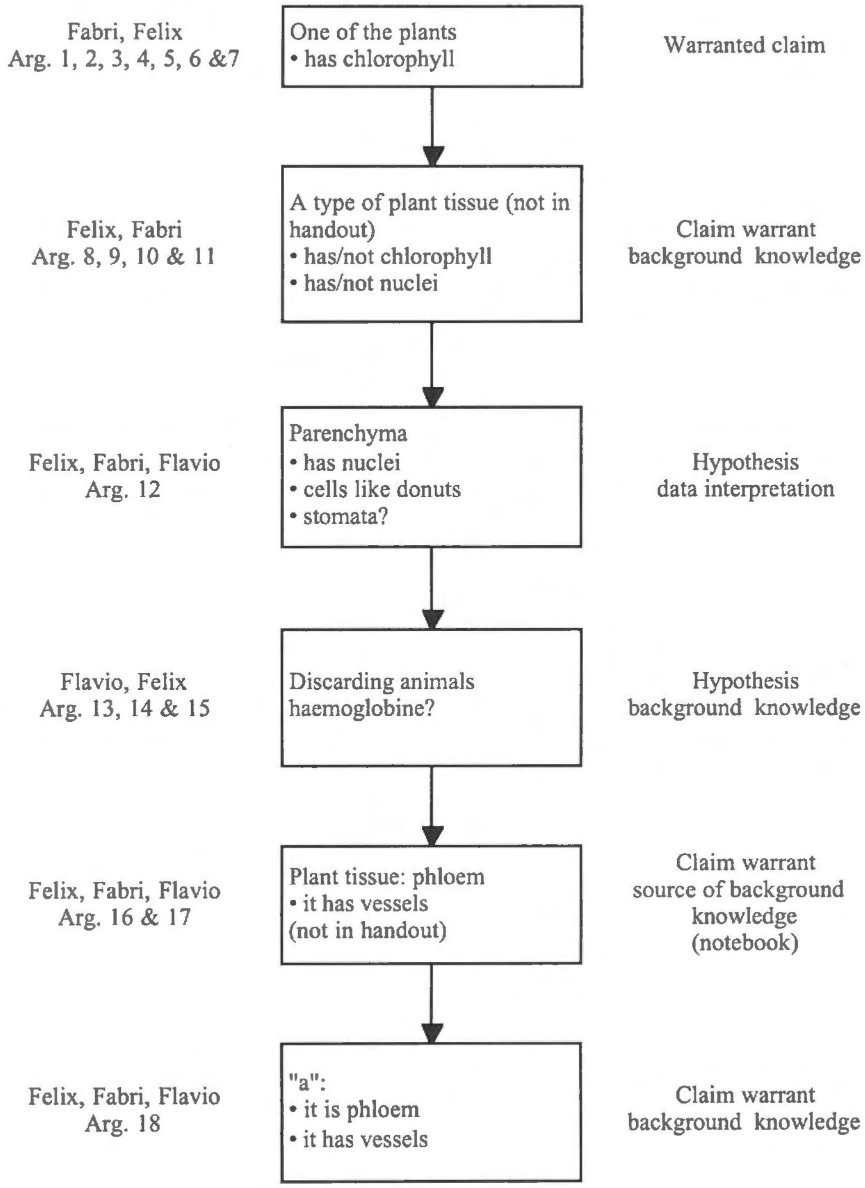
It is necessary to discuss the methodologies used through the analysis, as part of the focus of the paper. The issues raised about classroom discourse analysis are complex, ranging from how to organize the data, which tools to use in order to interpret them, to how to present and represent the results by means of inscriptions. The relevance of this analysis to the study of science classrooms is supported by research on the discourse processes of scientists. Latour and Woolgar (1986) have studied the construction of facts, the transformation of data through conversation, the processes by which scientists give meaning to their observations. They document instances of transformation of statements into facts, what they describe as efforts to introduce order in a disordered array of observations; they see inscriptions and writing as a material operations aimed to create order more than to the transfer of information. This perspective has been applied to the study of classrooms and school labs by Kelly and Crawford (1997) who explore what counts as science in

High School laboratory; and Kelly and Chen (1999). The studies by Kelly and colleagues exemplify a new way to explore students' views of science through direct study of classroom discourse, rather than through analysis of reconceptualized answers to particular instruments.
The analysis of classroom discourse could be compared to studying a sample with a microscope: different approaches and magnifications are needed. Next we will discuss two of the representations that we use in order to understand what is going on in the classroom: sequences of episodes during a session and sequences of arguments.
Sequences of episodes: during a session there are different episodes, either in terms of the tasks, or in terms of issues at the center of students' discussion. Drawing the sequence requires an interpretation: to identify relevant episodes and group the speech units into them. In the microscope sessions, the time allocated to each task or subtask is a relevant issue, for instance in order to compare the activities of different teams.
Sequences of arguments: when analyzing the students' argumentation, we are interested not only in the specific arguments, but also in the process of construction, co-construction, refinement and change that the arguments experience. Our analysis does not focus on every sentence or group of sentences, but only on these called by Toulmin substantive arguments, having as requisite a knowledge of content. The steps followed are: first to identify in each small group the substantive arguments whose *claim* (explicit or implicit) constitutes an *answer* to the problem, for instance about the sample (animal, plant, type of tissue). Several exchanges among students, whatever its length, are considered part of the *same argument* when related to the same claim; and of different arguments when the claim is modified. Then the sequence of arguments is drawn for each session and small group. A second step is to identify the warranted arguments and categories of warrants. Figure 1 is one example of a sequence of arguments from group F. The representation of sequences helps to make visible the process through which an argument changes, how different warrants are used to justify it.

3 Results: range of warranted arguments

The second research question deals with the relationships established among the data and the biological knowledge, particularly knowledge about the cell. Two types of data were considered: empirical, obtained through sample observation, and hypothetical. Some of the hypothetical data are administered, as the information in the handout, and other are obtained by the students through sources as books or notebooks. One of the differences among students working in the problem-solving context and in standard sessions was that the firsts were searching for information outside the handout, in their books and notes, while exchange between the practical activities and the regular classroom sessions is rarely seen in standard laboratories (Jiménez and Díaz 1997).

Figure 1. Sequence of arguments Group F



To show an instance of the argument analysis, below is reproduced one excerpt from the transcriptions, corresponding to part of a warranted argument (table 1).

Table 1. Argument number 3 of group G

Line	**Transcript**	**Argument & epistemic operations**
52	Fabri: What are stomata?	question on background knowledge
53	Felix: Which stomata? They are nuclei	interprets observation
56	Fabri: Don't you see that stomata is the reproduction of ... of the mushroom which throw and cross two and then...	scientific language: definition
57	Felix: They are spores	opposition
60	Flavio: (*looking notebook*) Floema ... stomata aren't in here (*classroom notes*)	relating observations to background knowledge
61	Fabri: It has no stomata so: what do you want them for?	data construction epistemological commitment
62	Felix: There is not a dictionary over there?	appeal to information sources

The students in group F spent some time discussing the term "stomata", mentioned in the handout (see Appendix 1) as one of the criteria to distinguish among the two plants. In their struggle to find out what stomata means, Fabri (line 56) offers a definition which, as Felix (57) points, refers to "spores". It has to be noted that both in Spanish and Galician the words "estomas" and "esporas" bear greater resemblance than they do in English. The students browse their notebooks in search of "stomata" and, as they cannot find them (line 60), Fabri jumps to a claim: there are no stomata in their sample (line 61), related to what we interpret as an epistemological commitment: the only knowledge needed is the one about the problem / sample. In fact the sample did have stomata, and some time later they describe them with a good analogy "They look like donuts" although they don't match them with the appropriate label. This example shows the difficulties that students experience when struggling to relate the practical tasks in the lab to the theoretical knowledge, terms and concepts learned in the classroom.

Figure 2 represents in Toulmins' layout a compound of arguments from these groups: # 10 from Group G which exemplify one of Kelly *et al* (1998) categories for warrant strategy: subsequent, as opposed to direct. Subsequent strategy means that the warrant offered is another argument; the claim about the sample, that it belongs to the "d" type, "Arañilio", is justified because it matches one of the features discussed in the handout (all the cells belong to the same type), and this first warrant is, in turn, the claim of a second argument, warranted in the interpretation of the observed differences among cells as a question of size, of being bigger or smaller, apart or close, not of intrinsic differences corresponding to two cell types. In fact the two students in this group have changed their interpretation, and will doubt again about it later.

We have coded as an argument, for the purposes of this analysis, only claims about the nature of the sample, and coded as part of the same argument all the exchanges while the claim is not changed, as discussed in the methodology. With these criteria, a total number of 18 argument were produced by group F and 21 by Group G, and from these we consider that 10 in each case are warranted. As an instance of the different claims, a summary of group F in form of a sequence of all arguments, warranted or not, is reproduced in figure 1.

Our focus are the warranted arguments: the range of them, with respect to the three dimensions explored, is wide and is summarized in table 2. It is difficult to establish a pattern about warranting, although some trends could be found, like in this case the use of empirical referents as should be expected from an experimental context.

Figure 2. Argument 10 (line 146-147) group G. Between brakets: implicit

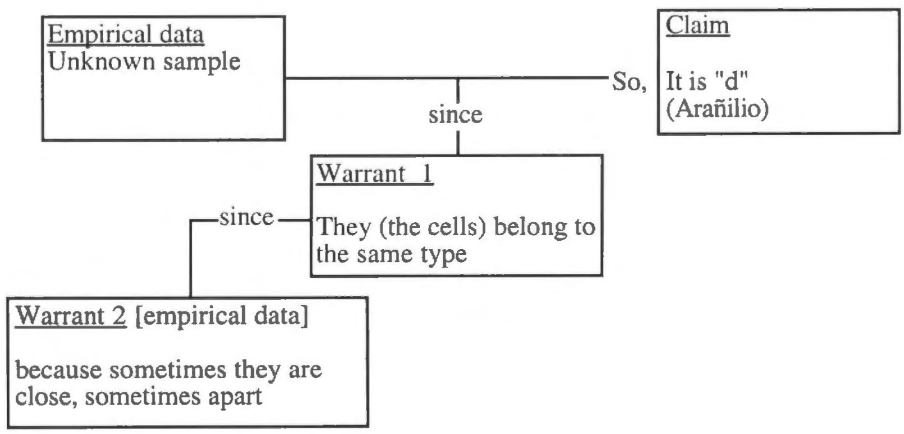


Table 2. Range of warrants used in the two groups

Group	Total	Warrant strategy	Warrant referent	Warrant type
Group F	Arguments: 18 Warranted arguments: 10	8 direct 2 subsequent	7 empirical 1 hypothetical 2 empirical	8 referential 1 comparative 1 referential
Group G	Arguments: 21 Warranted arguments: 10	6 direct 4 subsequent	4 empirical 2 hypothetical 4 empirical	3 comparative 2 referential 1 declarative 1 comparative 3 referential
	Total warranted arguments: 20	*14 direct* *6 subsequent*	*17 empirical* *3 hypothetical*	*5 comparative* *14 referential* *1 declarative*

4 Results: conditions which lead to the use of warrants

About the conditions which lead to the use of warrants, a set of conditions was developed as a consequence of our analysis. Three conditions were identified:

– Need to choose among options: which could be a general consequence of performing the task, or a specific prompt by teacher or other student. A particular case was when it followed a disagreement about the interpretation.

– Relating empirical evidence to background knowledge: discussing their interpretation of the data in relation to knowledge from different sources; in most cases the information in the handout, as they were trying to match the observed features of the sample with the options in the handout.

– Data co-construction: interpretation and reinterpretation of observation, trying to give meaning to what they saw and transforming statements into facts (Latour and Woolgar 1986) by means of discourse.

To give a sense of the different warranted arguments in connection with the conditions, a summary for group G is included below (table 3).

A summary of the conditions related to the use of warrants appears in table 4.

It is interesting to point at the similarities and differences among these conditions and the taxonomy proposed by Kelly *et al* (1998). It is clear that some of them are similar, for instance challenge from Kelly *et al* is probably equivalent to our disagreement, and writing prompts are found in both, while data construction in our frame is equivalent to actions in Kelly *et al*. Some differences could relate to the disciplinary contexts of the tasks (electricity and biology). A detailed discussion exceeds the scope of this paper.

Table 3. Warranted arguments Group G

#	Argument	Conditions
5	it has to be "d" if it had blood it would be red	– need to choose among two animals (task options) – relating empirical evidence to background knowledge in handout
7	or "c" or "d" "d" doesn't have blood. "c" has blood, is red but with hemoglobin	– need to choose among two animals (task options) – relating empirical evidence to background knowledge in handout
8	all the same type. Some bigger, some smaller...	– relating empirical evidence to background knowledge in handout – data co-construction
10	they belong to the same type because sometimes they are close, sometimes apart	– relating empirical evidence to background knowledge in handout – data co-construction
13	Gema: because the nuclei are not visible Gloria: and it has no hemoglobin	– need to choose among two animals (prompt in h.) – relating empirical evidence to background knowledge in handout
14	Gloria: you cannot distinguish the nuclei Gema: are you sure these are not the nuclei? Gloria: they cannot be so small Gema: Cells are always small	– relating empirical evidence to background knowledge: a) in handout; b) previous
18	"c"! because "d" is different	– need to choose among two animals (task options)
19	there is more than one cell type (...) because as they have flagelli	– need to choose among two animals (task options) – relating empirical evidence to background knowledge in handout
20	Some have scratches and some don't! (...) the one that has flagelli outside	– need to choose among two animals (task options) – relating empirical evidence to background knowledge in handout
21	Gema: it is "d" Gloria: it is type B (animal) Gema: because they are not plant cells	– need to choose among plants & animals (task options)
Summary Group G	*1. Need to choose among options: 7 warrants*	*a) required by task: 5,7, 18, 19, 20, 21* *b) prompt in handout: 13*
	2. Relating empirical evidence to background knowledge: 8 warrants	*a) in handout: 5,7,8,10,13,14,19,20* *b) previous: 14*
	3. Data co-construction: 2 warrants	*making sense of observations: 8, 10*

Table 4. Summary of conditions related to use of warrants in the four groups (sometimes more than one condition in the same argument)

Conditions Warranted arguments: N = 20	
1 Need to choose among options. N = 13	a) required by task (general) : 7 b) prompt in handout: 1 c) prompt by teacher/student: 1 d) following disagreement/ opposition: 4
2 Relating empirical evidence to background knowledge. N = 13	background knowledge origin a) in handout: 10 b) in notebook: 3 c) previous knowledge: 1
3 Data co-construction. N = 2	making sense of observation: 2

About the connection between Biology knowledge and warrants, there are some cases when the background knowledge is made explicit, but most of the time it is not, like for instance in argument #14 from group F (see figure 1) "*I think that the first one* (plant) *because I see the green blots*". We assume that the student knows that chlorophyll is green, and that this is backing his warrant supporting the claim about the choice. Here can be seen the differences among formal logic, where all the steps in the reasoning path could be expected to be stated, and natural conversation or discussion, when many things, and particularly shared knowledge, remain unsaid.

5 Discussion and Educational implications

A wide range of warranted arguments was found. It is difficult to establish a pattern, although some trends are: a) the great proportion of empirical referents as should be expected in an experimental context and b) most arguments could be assigned to the referential type, making reference to information in the handout or in their notebooks and books; also there was a considerable number of comparative arguments.

About the conditions which lead to the use of warrants, three conditions were identified as situations which seem related, in this particular context and task, to the use of warranted arguments:

1) The need to choose among options that was required by the task, being a particular case the arguments prompted by an open disagreement.

2) Relating empirical evidence to background knowledge: for instance trying to interpret the evidence in terms of the information in the handout.

3) Data co-construction: making sense of observations and trying to fit them in scientific terms and knowledge about cells and tissues.

There are several differences among these groups, which were solving a problem, and standard laboratory sessions analyzed in Jiménez and Díaz (1997). They relate, on the one hand, to the implication in the task (time on-task) which is much higher in the problem-solving context. Perhaps an indicator could be the hot discussions in which these students got involved, sometimes even losing their temper and using rough language. Although we did not intend to promote bad manners in the classroom, it shows that they are really deep into discussion and argument, while is difficult to picture 15 year olds shouting one another about drawing onion skin. A better quality indicator is the need that the students in the problem-solving context experience about referring the microscope task to the knowledge in their textbooks and notebooks; interpreted as the need to mobilize or apply their knowledge about cells and tissues, this shows the demand of the task in intellectual or cognitive terms, while again the usual tasks have very little demand of this character (or none). This application of knowledge leads the students from group F to go further that they were asked, attempting not only to match the slide with one of the four options, but to label it as parenchyma or phloem, terms that were not used in the lab, but that they found in their books and notebooks. In fact, although the sample was supposed to be epidermis, it had on one end, part from the tissues under it, which could be these mentioned by the students.

There are also other differences which refer to the type of interactions with microscope, books and notebooks, and to the personal interactions. In our opinion, the design of the task as a problem provided opportunities for reasoning with could be seen in the variety of arguments. Also some instances of the role of the instrument (microscope) in the shaping of the data could be identified. Future lines of research suggested are cross-content analysis which we are undertaking now, comparing these data with other from Genetic, Environmental Science and Physics units.

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Appendix

The tracks of the thief

Sample nº

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) ARAÑILIO: 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 form the same type.

Note: if you find a term that you don't know:
a) consult your book or notebook, or
b) ask your teacher.

You have to investigate to which suspect the sample belong:

1) First decide whether it is a/b (Clorofilio or Tunelio) or c/d (Galiñolio or Arañilio) explaining which features or data are behind your choice.

2) Describe in detail the cells of the individual making a drawing and indicating in it all the structures that you see.

3) If there are more than one cell type, explain how you distinguish each.

4) If you see some elements inside the cells, draw them and explain what it is, giving reasons.

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WHICH ETHICAL TRADITION DO STUDENTS PREFER WHEN JUDGING GENE TECHNOLOGY? A STUDY OF STUDENTS' ETHICAL ARGUMENTATION

Corinna Hößle* & Horst Bayrhuber**
*University of Hamburg, ** Institute for Science Education-Kiel (Germany)

1 Introduction

Critical discussions about the development and implementation of innovative technologies such as gene technology, reproduction medicine and organ transplants have become a normal part of life today. One topic in particular-the potential to improve the genetic code of living beings by gene technological methods-has stimulated the public debate. Practically no other technology which will be discussed from such an emotional point of view. With no other technology are such a great number of hopes and fears associated (Hößle 2000, Gebhard et al.1994, Todt and Goetz 1996).
To make a responsible moral judgement it seems necessary to consider at least two dimensions of gene technology:

1. The descriptive, scientific dimension of gene technology (what is gene technology?)
2. The normative dimension (what is the moral judgement on gene technology).

In this research most interest is focused on the latter dimension.
When people state their views on morally relevant issues, they usually voice only unspecified beliefs, feelings or internalized traditional norms. Sometimes their judgements express their own spontaneous subjective reactions to moral dilemmas, sometimes they merely reflect other people's feelings, as formulated by the media or by members of the family or friends. In those statements people often use philosophical terms as morality, naturalness, human dignity, welfare and pain. But it is striking that people are usually unaware of the exact philosophical meaning of these terms (especially the meaning of human dignity) and as a consequence have difficulty in reflecting these terms adequately in their own argumentation and in that of others.
Frequently argumentation refers to one philosophical tradition only (deontological or teleological ethics) to the exclusion of the other position. Yet a responsible and reflected ethical decision on gene technology requires consideration of both positions in a balanced way (Hößle 2000).
One common aim of innovative teaching today is to improve students' ability to make a responsible and reflected judgement on innovative

technologies such as gene technology. The here presented research outlines a method which sets out to help to improve the ethical argumentation on gene technology in biology teaching.

2 Aims

Our aims were as follows.

1. To investigate students' ethical argumentation (normative frameworks) when judging gene technology

The reactions of school students to moral issues are presumably even more confused than the responses of adults, but they are important in that they can tell us something about their ethical argumentation and instinctive reactions. If we wish to improve students' ethical argumentation on gene technology in biology teaching we first have to explore what view the youngsters already have and where we can pick up on them.

2. To test a strategy for improving the ethical argumentation on gene technology in school

Our aim was to find out if ethical argumentation on gene technology can be improved by considering students' hopes and fears in biology teaching.

3 Hypothesis

We set out to test the following hypothesis in our research:

Students` ethical argumentation on gene technology can be improved by teaching topics which relate to their hopes and fears.

4 Ethical argumentation

Following Frankena (1972) there are two main lines of philosophical thinking, the teleological and the deontological model. Both ethical traditions play an essential role in our research and will now be briefly described.

In the deontological ethics a moral judgement or an action is been to be good if it obeys:

- normative principles (for example, justice) (Universalismusanspruch in Englisch?)
- ethical values (for example, human dignity) (persönliche Werte in Englisch?)
- certain rights which are regarded as absolut for instance the right to live or the right to remain unhurt.

These principles and values are declared to be intrinsically good. They guide judgement or action without regard to consequences. It is an essential characteristic of this type of argument that there are certain things should not be done whatever the consequences (Ruth Chadwick 1996). There are also the concept of duty: certain duties are seen which cannot be overridden by a regard for the consequences however desirable. One key figure of the deontological tradition is Immanuel Kant: "It is everyone´s duty not to lie and to obey the moral law." (Kant 1963,).

A deontological argument can also claim that certain things are holy (for instance, nature or God`s creation) and therefore nothing which violates them should be attempted. Or there may be certain limits or boundaries that must not be crossed.

It is characteristic for the teleological model to argue that judgements and activities should only be allowed or be described as good if they are consistent with the telos. One main line of teleological thought is utilitarianism. A variety of different positions can be discerned which all have characteristics in common. Key figures in this tradition are for example Jeremy Bentham and Stuart Mill.

The research presented here focuses on utilitarian argumentation. Utilitarians typically wish to avoid pain, suffering and misery and to enhance welfare, pleasure, happiness and well-being. Moral decisions or activities which maximize the welfare of living beings or try to minimize suffering are considered to be good.

Lawrence Kohlberg (1974, 1976) describes in his research the development of moral judgement, focusing in particular on people´s moral judgements on ethical dilemmas. In his work he postulates that a moral judgement is good if it follows the normative principle of justice (1984, 1986). Individuals involved in the moral judgement are seen as autonomous and independent of other persons. Carol Gilligan (1984) criticizes Kohlberg's definition of moral judgement. She emphasizes that a moral judgement not can exclusively be defined within the moral dimension of justic which considers only rights, duties and rules. A second dimension is necessary if the moral judgement is to be defined completely. In Gilligan´s opinion moral judgement should be described by two dimensions: justice and care. A moral judgement can also be good if the decision-maker evidences care for everyone who is involved in the dilemma. Typical characteristics of care are responsibility for persons who might be hurt by the moral decision, maintenance harmony between the persons and stabilization of human relations. People involved in the moral judgement are seen as part of the society and in terms of their relations to others.

Following the theory of the philosopher Ottfried Höffe (1986) Kohlberg´s definition of morality is deontological because the principle of justice is taken to guide a moral judgement irrespective of the consequences. Kohlberg chooses the principle of justice as an absolute maxim. In contrast Gilligan´s definition is utilitarian because she emphasizes that a moral judgement is good if the consequences are good for the persons involved. Thus we should consider both dimensions, justice and care, if moral judgement is to be adequately described.

Following these theoretical assumptions we set out to answer three questions in our research:

1. Is the division into two main ethical traditions (deontological and utilitarian) suitable to categorize all arguments which students formulate in their ethical argumentation on gene technology?
2. Which ethical tradition do students prefer in their argumentation before and after the intervention in school?
3. Is it possible to improve students` ethical argumentation by intervention in school?
   (Our definition of improvement: students take both ethical traditions into consideration in a balanced way when arguing on gene technology)

5 Didactical and methodical strategy to improve the ethical argumentation of students

The researchers R. Döbert and G. Nunner - Winkler (1986) discovered that the quality of young people`s moral judgement depends on the content of the dilemma with which they are presented: the more the dilemma affects the students` hopes and fears the differentiated the moral judgement is. One component of moral judgement is the ability to consider the two main moral systems, the deontological and utilitarian ethical traditions, in a rational and balanced way (Hößle 1998, 2000). Mostly students refer only to one ethical tradition in their argumentation. As a consequrence students formulate one-sided judgements. We wanted to ascertain if it is possible to improve students´ ethical argumentation on genetechnnology by teaching topics in biology lessons which relate to their hopes and fears. The more students consider both ethical traditions in a balanced way in their argumentation, the more differentiated and reflected the argumentation will be.

6 Subjects

We worked with three groups of secondary students whom were between 17 and 19 years old and attending three periods of biology per week at the same school in northern Germany.

Experimental group I comprised 15 students who were taught gene technology topics which were related to their hopes and fears. Experimental group II comprised 19 students taught gene technology topics which were not connected with their hopes and fears. The control group was not taught gene technology. They were interviewed twice in a period of three months to find out if the interview itself has an influence on ethical argumentation.

7 Design of the research

Period	Method	Group I	Group II	Control group
1	Questionnaire to indicate students` conceptions of gene technology	+	+	-
2	Development of two gene technology units	+	+	-
3	Preinterviews to ascertain the ethical argumentation	+	+	+
4	Implementation of the units	+	+	-
4 a	Considering the hopes and fears during the lessons	+	-	-
5	Questionnaire to indicate students` affection	+	+	-
6	Postintervіws to indicate the development of the ethical argumentation	+	+	+

First we developed a qualitative questionnaire to explore which gene technology topics affect the students most or what hope and fear students associate with gene technology. We also explored students` knowledge of gene technology in order to gear the units to the level of knowledge.
In accordance with the findings we developed teaching material for the experimental groups I and II.
In a third step we interviewed the students of all three groups in face to face interviews to explore individual ethical argumentation.
In a fourth step the students of both experimental groups were taught gene technology in 29 biology lessons. Group I was taught topics which had gained the highest affective scores.
The students in group II were taught gene technology with no affective elements.
In a fifth step we asked the students of both experimental group after each lesson if their hope and fear had been touched during the intervention. For this we developed a quantitative questionnaire. By asking the students we

wanted to find out if the topics they have been taught definitely considered their hope and fear or not.
After the intervention in school we interviewed the students a second time to explore their ethical argumentation on gene technology and to find out if it had been improved.

8 Hope and fear in connection with gene technology
To analyze the questionnaire we developed a range of categories concerning hope, fear and knowledge, which we then used to classify the responses. We found that the students in both groups evidence very similar hopes and fears when thinking of gene technology.
Thinking of gene technology most students hope that :

- the methods of gene technology will be able to provide a cure for diseases such as AIDS and cancer
- the application of gene technology in its different areas will improve the standard of living.

Thinking of gene technology most students fear that:

- the application of gene technology may involve unforeseen risks and negative consequences
- people could lose control of gene technology

We also analysed the students` knowledge of gene technology ascertaining what they know about the methods, application, advantages and disadvantages of this new technology. We found out that the students have difficulties defining gene technology correctly and naming the methods it involves. But the students know a large number of fields of application and can a wide range of advantages and disadvantages.

9 Developing the teaching material
Drawing on these results we developed two units for the experimental groups. For group I we chose topics which relate to students` hopes and fears. The first was a topic from medicine: "Cause and diagnosis of the hereditary disease Chorea Huntington."
The second, taking students`fears into account, was: "Risk analysis of the conjugation-experiment associated with insulin production".
For the experimental group II we chose topics by which the students were not highly affected, which means that the topics were not related to their hopes and fears.
The first was: "Research on and production of the human growth hormon somatotropin". The second topic the students worked on concerned plant breeding: "Genetically modified aspen trees".

We developed the teaching material for each group in accordance with the knowledge our analysis had shown to be at the command.
Both groups were taught using optimally developed teaching units which only differed in the content of the lessons. The methods and media were practically the same in each group throughout.
Each group was taught 29 lessons. In both groups scientific knowledge and ethical issues were considered. For example both groups received a visit from a scientist of the subject matter: genetic adviser and genetic engineer; both groups performed experiments which were taken from gene technology; both groups were introduced to relevant ethical norms and did a role-play to familiarize themselves with different kinds of argumentation. As already mentioned the only difference in the lessons was the topics.

10 Questionnaire to indicate affection
To find out if the students definitely were affected by the topics taught we a quantitative questionnaire after each lesson.
As expected we found that the students in experimental group I were more affected by the topics which they had been taught than the students in group II.

11 Interviews to explore ethical argumentation
Before and after the implementation of the teaching material pre- and postinterviews were conducted with each student in the experimental groups and in the control group to find out if their ethical argumentation had changed. Following the tradition of Piaget (1973) and Kohlberg (1986) the interview questionnaires covered a variety of issues in different areas of gene technology. Before we interviewed the students we showed them a video which finished with a dilemma concerning genetic testing. We also developed two more dilemmas concerning prenatal genetic testing and germ-cell therapy. In the postinterview we chose issues of prenatal testing and preimplantation diagnosis. The students were requested to make reasonable decisions and to name consequences of the decisions.
For the interviews we developed an interview-guide which based on to the six categories of moral judgement. Each interview lasted approximately about 45 minutes at least.

Analysis of the interviews
To evaluate the interviews we made a qualitative ethical analysis of each interview following and modifying the theory of Ph. Mayring (1994, Hößle 2000).

Before we analyzed the interviews we developed different categories of ethical argumentation which will be described later. In a second step, which we called codification, we tried to assign students' different ethical arguments to these ethical categories. In a third step we checked whether all of the ethical arguments could have been assigned to these theoretical categories or whether it seemed to be necessary to add new categories derived from the interviews`data. This latter step was repeated two or three times to ensure that all arguments had been adequately considered.

Categories of ethical argumentation

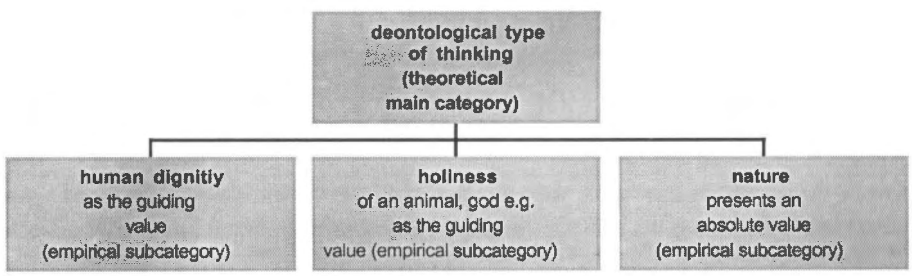
Firstly we tried to assign all arguments to the two main ethical models outlined above, the deontological and utilitarian traditions. These two main categories were described in accordance with Frankena (1972) before the interviews were analyzed. A detailed analysis of the students' argumentation on gene technology indicated that it is necessary to divide each main category into three subcategories. Thus the subcategories were derived from the data, their definition is an empirical result of the interview analysis.

As a result we have two main categories (deontological **d** and utilitarian **u** type of thinking) and six subcategories which will now be described.

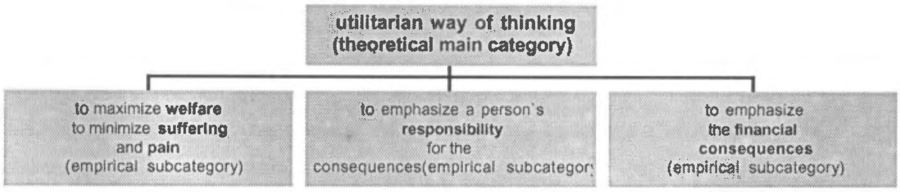
One characteristic of deontological thinking is that a decision is guided by normative principles or values which are declared as absolutly valuable without regard for the consequences. According to the data of our research these principles and values were:

- human dignity (it is typical for this type of **d**eontological argument that human **d**ignity is the guiding value or principle-**dd**)
- holy (**h**oliness) (it is typical for this type of **d**eontological argument that the absolute principle or value could be god, an animal or fate-**dh**)
- nature, (it is typical for this **d**eontological argument that the **n**ature itself presents an absolute principle or value-**dn**)

Categories of an ethical argumentation



Categories of an ethical argumentation



It is typical of utilitarian thought that a person`s decision or action is guided by the consequences of the decision or action. Following the data of our research the students formulated three types of consequences:

- welfare (it is typical for this **u**tilitarian argument that a decision or action is good which maximizes **w**elfare and minimizes suffering and pain-**uw**)

Example Peter: If we can avoid the transmission of hereditary diseases we avoid the transmission of pain and suffering for the whole family and especially the affected person and as a consequence we increase the welfare of these people.

- responsibility (it is typical for this **u**tilitarian argument that it describes decisions and actions as good which emphasize a person's **r**esponsibility for the consequences-**ur**)

Example Julia: I think everyone should have genetic testing because we should know about our hereditary diseases. We are responsible for our children's health.

- economy (it is typical for this utilitarian argument that a decision or action is good if the financial consequences are good-**uf**).

Example Simon: If everyone would underwent genetic testing by visiting his doctor it would be very expensive for the companies and as a consequence the contributions would increase for everyone. That's why I am against genetic testing

12 Results

Before the intervention in school, students in both experimental groups definitely preferred the utilitarian argumentation when judging on gene technology (about 90% of all arguments). Only very few students formulated arguments in order from the deontological tradition (about 10 %) to justify their own decision.

All in all the students of both groups had a similiar approach of arguing before we started the intervention in school: The majority of the students approved the application of genetic testing and germ cell therapy in future. The analysis of the interviews showed that more than 50 % of the students' arguments in both groups belonged to the utilitarian-welfare type. Most students approved the application of gene technology because it could maximize the welfare of people and could raise the standard of living.

About 20 % of the arguments conformed to the utilitarian-responsibility type. There students mostly emphasized that people are responsible for the health of their children. And thus genetic testing and germ cell therapy should be used to diagnose hereditary diseases.

About 10 % of all arguments were utilitarian-economical in orientation. Some students emphasized that it would be cheaper for the whole society if hereditary diseases could be diagnozed in time and if transmission could be avoided. Some students formulated that it is better to know if you have a hereditary disease or not. Then if you are affected it would be possible to take out insurance and to save money for the nursing up.

Only a small number (Ex. I: 10,1% and Ex. I: 8%) of arguments were of the deontological type. Mostly students referred to this type of argumentation when judging on prenatal testing and the possibility of an abortion. Here argumentations students emphasized that an abortion, following prenatal testing, would be against the human right to live or against god's will for human beings or against the course of nature.

It can be summarized that the students of both experimental groups preferred utilitarian thinking when making ethical judgement about gene technology. It is striking that the students formulated only very few arguments which belonged to the deontological model. This means that the students of both groups had difficulties to consider both ethical traditions in a balanced way when judging on gene technology.

After the intervention in school the students of both groups had improved their ethical argumentation. Improved means in our research that students turn from one-sided argumentation on gene technology towards a more differentiated way of arguing. The more students consider both ethical traditions in a balanced way in their argumentation, the more qualified the moral judgement is. And the greater their ability to consider different ethical subcategories of the main ethical traditions, the more developed the moral judgement is. Our aim is not to change the students`ethical position from utilitarian to deontological or vice versa. We don`t wish to make deontological Kantians or Benthamit utilitarians of them all. Instead our interest is focussed on the question whether students have differentiated their ethical reasoning by considering more ethical perspectives of the dilemma.

The students in the experimental group I whose hopes and fears were considered during the intervention in school have improved their ethical argumentation more than the others because they did not considered mainly one ethical tradition-the utilitaria and one ethical subcatgegory-utilitarian welfare. Instead of this they considered the utilitarian and the deontological ethical tradition in a more balanced way. The results demonstrate that after intervention the group I students referred less to utilitarian-welfare argumentation and to utilitarian–economy argumentation than they had in the preinterview. Instead of this the students used more utilitarian arguments which emphasized the responsibility of involved persons and strikingly more arguments of the deontological type of reasoning. The students used twice as much deontological argument with human dignity as the guiding value than before the intervention in school. The students also formulated far more arguments in which nature or the sacrosanctity of an animal or god is the absolute value. All in all it has been analyzed that the students of the experimental group I considered deontological arguments more than twice as much as at the beginning of the research. This result demonstrates that after the intervention the students considered both ethical categories in a more balanced way than before when judging on gene technology. They differentiated their ethical reasoning by referring in their argumentation to more than one just one ethical tradition and by referring to more subcategories than before.

In comparison, the students of experimental group II also improved their ethical argumentation on gene technology as well but not as much as the students of the experimental group I. The students of experimental group II also considered more deontological arguments in their decision than at the beginning of the research but not as much as the students of experimental group I.

It is striking that the students of both groups considered the utilitarian-welfare arguments less in their judgement after the intervention in school. Instead of this both groups considered more utilitarian-responsibility arguments, deontological arguments which referred to human dignity and holiness. This result shows the tendency that the students of both groups tended to improved their ethical argumentation in two ways:

- they turned their mainly one sided argumentation towards a more balanced argumentation by considering both ethical traditions in a more balanced way
- they put more emphasise on responsibility and the principles of human dignity and holiness of god or sacrosanctity of an animal

It is interesting that parallel to the way of argumentation the acceptance of the presented application of gene technology changed a little. After the intervention in school the students were able two consider more sides of this issue. As a consequence students did not became absolute opponents of gene technology but were able to judge gene technology in a more critical and balanced way.

Preinterviews

Group	ur	uw	ue	phd	ph	pn	p	u
Ex I	21.7	53.6	14.6	8.0	1.4	0.7	10.1	89.9
Ex II	24	57.7	10.3	5.7	0.6	1.7	8	92

Postinterviews

Group	Ur	uw	ue	Phd	ph	pn	p	u
Ex I	29.7	40.1	6.3	19	2	2.9	23.9	76.1
Ex II	34.3	41.0	13.0	9.6	1.3	0.8	11.7	88.3

Answers to the research questions

1. Is the division into two main ethical traditions (deontological and utilitarian) suitable to register and assign all arguments which students formulate in their ethical argumentation on gene technology?

By analyzing the interviews as described we found out that the division into the two main ethical models is suitable to register and assign all arguments of the students in an adequate way. The method allowed us to consider all ethical arguments and not focus exclusively on arguments which were related to justice **or** care as described in Kohlbergs' methods (1986). It would be interesting to explore out in a further study if our method is also suitable to analyze arguments on alternative bioethical topics.

2. Which ethical tradition do students prefer in their argumentation before and after the intervention in school?

It was striking that the students of both groups preferred the utilitarian way of thinking when first questioned. After the intervention in school both groups still mainly argued from the utilitarian point of view but they improved their argumentation in that they considered the deontological point of view more then before.

3. Is it possible to improve the ethical argumentation of students by an intervention in school (improving means that students take both ethical traditions into consideration in a balanced way when arguing on gene technology)?

It was striking that the students of experimental group II had greater difficulty considering both ethical traditions in a balanced way than the students of experimental group I who had been highly affected during the intervention in school.

This result demonstrates the tendency that the consideration of students' hopes and fears in biology teaching can be effective for improving ethical argumentation on gene technology. However given the small population of our research further research is necessary to confirm this first result and to find out if the ethical argumentation of students can also be improved with respect to further ethical themes of biology teaching like organ transplants, reproduction medicine, animal experiments and environmental problems.

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RELEVANT KNOWLEDGE IN DECISION MAKING ABOUT THE ENVIRONMENT: A CASE STUDY

Cristina Pereiro Muñoz & María Pilar Jiménez Aleixandre
Universidade de Santiago de Compostela

Abstract
Decision-making and the criteria considered when choosing one path or action is one of the capacities sought to be developed in environmental education. A case study is presented on the knowledge –concepts, issues, relations– considered by secondary school students working on an environmental management problem about which they have to reach a collective decision. Environmental education is a matter of values, of attitudes and behaviour, but in our perspective the development of values and attitudes should be founded on relevant knowledge. A real change in the value system of students should be supported by knowledge, by the understanding of the consequences of careless behaviour towards the environment or, as here, by assessment of different alternatives for environmental management.
This paper is part of a project about the relations between argumentation and concept learning. Participants are High School students in 3° BUP (11th Grade) and their teacher (first author), working on a real issue about water drainage in a wetland. Students were videotaped and audiotaped, and the transcriptions were analysed by means of discourse analysis. The problems explored are: which elements of the situation are viewed as relevant by the students, and which relationships are established by them among their conceptual knowledge and the decisions about the environmental management. Selected fragments from the transcription are discussed, showing that the students take a fair number of elements into account, not only the obvious such as animals or plants, but almost the same that would be used by experts. Instances of how they establish relationships between conceptual knowledge and decisions are discussed. The implications for the importance of problem-solving in Environmental Education are also outlined.

1 Knowledge, values and decision making: background and objectives of the study

Decision-making and the criteria considered when choosing one or another path or action is one of the capacities sought to be developed in environmental education. In this paper a case study is presented on the knowledge –concepts, issues, relations– considered and applied by a group of secondary school students working on a problem related to environmental management about which they have to reach a collective decision. Environmental education is a matter of values, of attitudes and behaviour, but in our perspective the development of values and attitudes should be founded on relevant knowledge (López Facal 1999), otherwise the risk is that an apparent change in the value system of students turns out to be little more that a slogan learned for school purposes and soon forgotten.

For Pérez–Echevarría and Pozo (1994) the efficiency in solving problems considered as a general skill, depends on the availability of appropriate conceptual knowledge and on its activation. In the field of Environmental Education, if solving environmental problems and decision-making related to this resolution has as a goal to promote behaviour for the environment, it must be founded also in the availability and activation of appropriate conceptual knowledge. In our opinion a real change in attitudes and behaviour should be supported by relevant knowledge, by the understanding of the consequences of careless behaviour towards the environment or, as in the case studied here, by the careful assessment of the different alternatives for environmental management.

The relationship among concept understanding and environmental attitudes is supported by different research studies. For instance Benayas (1992), exploring the cognitive schemes of landscape interpretation in University students, found that the ones which had cognitive schemes of greater complexity and variety tended to choose in a higher proportion rural or autochthonous landscapes and to reject scenarios including human intervention or presenting exotic plants or animals. On the other hand the ones with poorer schemes didn't exhibit this pattern. In a comparative study, also with University students from different disciplinary fields, Moore (1981) found that the ones assigning more importance to the need for taking steps about saving energy were these who had a higher degree of information about the problems related to energy resources and the consequences of its careless management.

The application of knowledge to situations different from the context where it was learned, the transference, is a goal for every educator. As Milá and Sanmartí (1999) point out, if transfer is an important issue when learning in any domain, the need for transferable learning is more acute in environmental education, because of the impossibility of dealing in the classroom with all the environmental issues. Only a few questions and problems can be chosen to work with them, but the objective is the mobilisation and application of knowledge, so it became available when it is needed in other issues. It follows that the question of choosing one (or a few) particular problem must be carefully considered. For Bernáldez, Benayas and De Lucio (1987) it is crucial to organise the environmental education tasks around the interests of the students. Their point is that a specific motivation gives greater stability to the knowledge acquired, enabling the articulation of cognitive schemes structured around the conceptual knowledge of the learner.

In order to achieve a greater motivation, in the study presented here the issue corresponds to a real problem: the planning and implementation of a project of drainage and cleaning affecting a river basin which has inside a part with the status of protected area of natural interest. To promote the students' interest the unit asked their involvement in the problem: they had to assess the impact of the project, which at the moment was in the phase of public information and discussion, and write a report about it. The unit is discussed in detail in Jiménez, Pereiro and Aznar (2000).

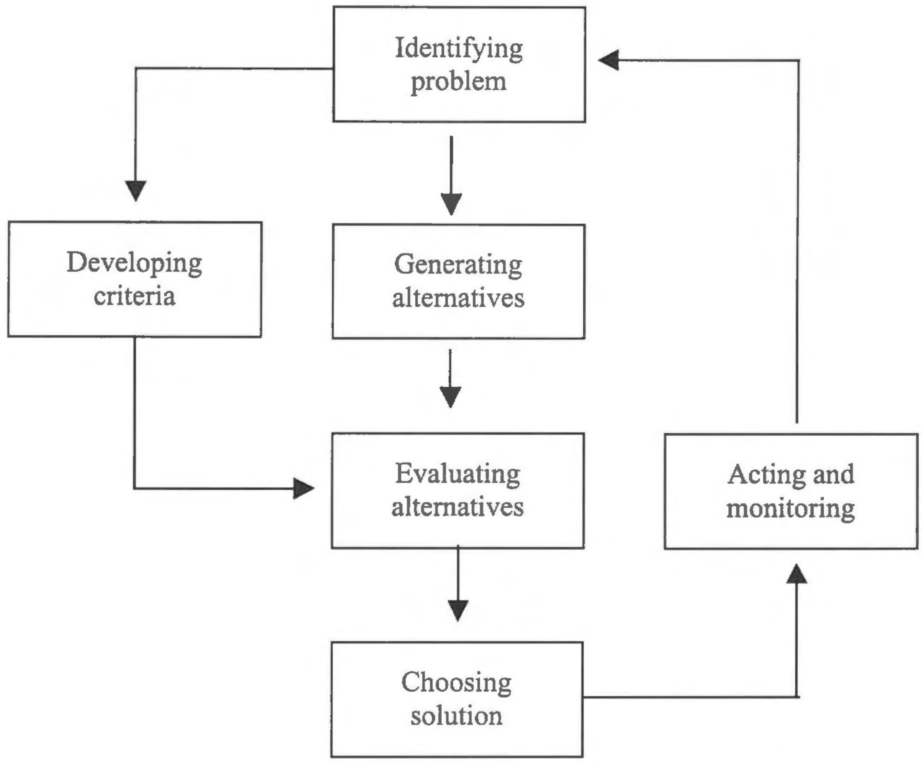
In a review about what counts as Science education and the different emphases given by different curriculum proposals, Roberts (1988) points that if the emphasis is Science, Technology and Decisions, the view of the learner corresponding to it is of one who "*needs to become an intelligent, willing decision-maker who understands the scientific basis for technology and the practical basis for defensible decisions*" (Roberts, page 45). This connection between decision-making and scientific understanding in learning is also discussed in an interesting paper by Ratcliffe (1996), and for her involves three related strands:

- Developing appropriate skills, including information processing and analysis.
- Understanding relevant science
- Recognising personal and societal values

We agree with Ratcliffe in the need of recognising the importance of these three dimension in decision-making, in other words the connection between the skills, the concept understanding and the values. This raises the question about if it is appropriate, in this school context, to talk about decision-making. Although it would be more precise to talk about opinion formation, given that decisions are directly related to actions, in educational literature, as the study by Ratcliffe, problem-solving involving assessment of different choices is referred to as decision-making.

It could be useful, in order to analyse the steps taken by the students, to use as a tool Kortland's (1996) proposal about possible routes for decision-making, that he represents in a concept map, reproduced in figure 1. In it great relevance is given to the development of criteria for evaluating the different alternatives.

Figure 1. Kortland concept map for decision-making



Using Kortland's frame we sought to identify the steps taken by students while solving the environmental problem during some of the seventeen sessions of the unit.

This paper is part of project RODA, carried in the University of Santiago de Compostela, which explores the relations between argumentation and reasoning and concept understanding in secondary school. Our interest focuses in natural discourse occurring in the science classroom rather than in responses obtained by means of a questionnaire or interview. The project intends to explore the relations among the processes of reasoning and the learning of science. As Zohar and Nemet (2000) show the development of argumentative skills is also related to an improvement in science learning. The research questions explored in it are:

- Which elements of the situation are viewed by the students as relevant for taking a decision about environmental management in a wetland?
- Which relationships are established by them among their conceptual knowledge and the decisions about environmental management?

In the next section the methods and participants are briefly presented, then the results, in terms of the concepts applied by the students at different steps are analysed; finally some educational implications are discussed.

2 Methodology and educational context

The participants are students in 3° BUP (11th Grade, ages ranging from 17 to 21 years) from the night shift in a High School in Vigo (Spain), enrolled in a Biology and Geology course and their teacher (first author). The unit about environmental management makes part of their regular coursework. They were asked to work in a real problem about water drainage in a wetland, assessing the impact of a project which involves building a pipe across the wetland and producing a report about the convenience of the pipe and, if this was the case, offering alternative solutions(Jiménez, Pereiro and Aznar 2000).

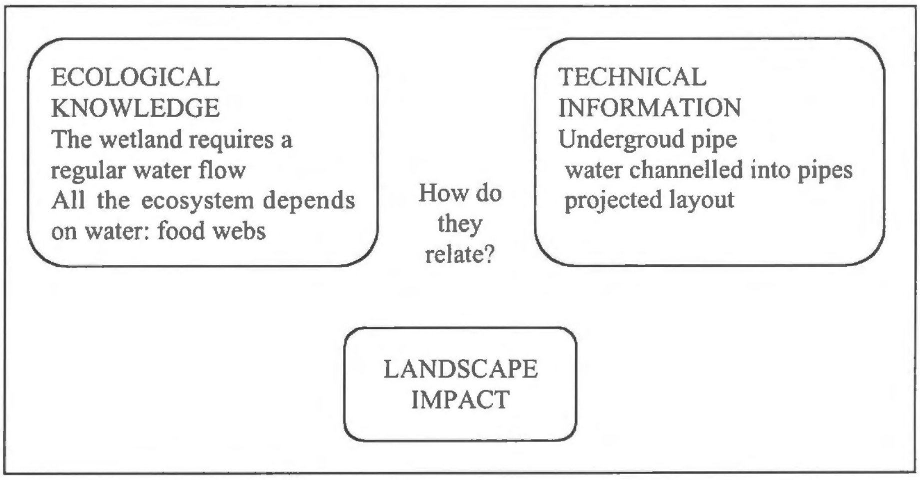
The unit was designed with the purpose of developing the students' capacity of analysing and processing information in connection with the problem, and at the same time the problem was intended to require the application of several concepts learned, relevant to its solution. Along the seventeen sessions of the unit the students were working in small groups, which were rearranged according to the task. The problem is complex, as environmental problems usually are, involving different perspectives, several aspects to be studied and having also several possible alternatives and not a single "correct" solution. At the beginning, there were six groups (Groups G) working in reports about selected aspects of the problems, plants, geology, drainage project etc. Then, using the Jig saw technique, they rearranged the six groups (Groups J), so in each group J there was one student from each group G, thus merging all the aspects of the problem by means of reciprocal teaching. Each student had to summarise for the new colleagues the report from her or his original group. Then each J group had to independently organise the work in order to reach a conclusion about the evaluation of the project, write a report about it and finally discuss it in the whole class, which was acting as a community of learners.

Students were videotaped and audiotaped, and the transcriptions were analysed by means of discourse analysis. Data collection includes also field notes by an observer and students' productions in portfolio format: responses to subtasks, notes and final reports, drawings, maps etc. The transcriptions were analysed trying to document the elements mentioned by the students: concepts, terms, etc. and the relations established by them as compared to the elements and relations that experts would locate; other dimensions as the epistemic and procedural operations belonging to scientific culture were also studied.

3 Results: combining ecology, technical information and the idea of impact

There were a number of concepts and relations mentioned and discussed by the students, showing that they considered them relevant for the problem. In our opinion, most of these concepts could be clustered in three areas: ecological knowledge, technical information and landscape impact. These three areas and some of the more important ideas related to them in the students' discussions are represented in figure 2.

Figure 2. Conceptual knowledge relevant for the students



The analysis intends not only to document the mentions to these concepts, but also to understand how do they relate each area to the other and in which way this knowledge influenced their decision.

Ecological knowledge

For some groups one of the most important issues is water. Not all discussed the water issues with the same meaning; for instance it is different for groups J1 and D: in group J1, the most relevant question is that in a wetland, like the area studied is, the water flow must be regular and not diminish, otherwise the ecosystem balance would be at risk.

Group J1, session 15

6 Alfonso: *Because it [*the drainpipe*] would destroy all the landscape, but also...*

7 Edu: *They have already destroyed enough, stop the destruction.*
8 Caio*: But the pipe would also try...*
9 Alfonso*: No, not the drainpipe! Not the drainpipe, the purifying plants would do it, located in... just there, close to the industries exit.*
(...)
14 Alfonso: *But because the purifying plants go where the industries are, that is, the drainpipe only carries the water to, to river Miño.*
16 Alfonso: *If they channel the water...it would be less [*the water flow*]*
Group J1, session 15
38 Alfonso: *(...) the little water remaining they want to channel into the pipe, it is polluted, they want to clean it and channel it, but if they clean it: What is the purpose to channel it? Why don't they let it flow and fill the pond again?*

Here it can be seen a sophisticated connection established by Alfonso among the technical features of the project (channelling of the water) and the need of a regular waterflow for the wetland.

But, on the other hand, for Group D, the most important issue is the situation of the water in terms of its pollution or cleanliness, because if the water is polluted, then the species living there wouldn't be able to survive.

Group D, session 11
269 Denís: *What we have to prove is that these particular species depend of the water..*

The students in the two groups are talking about quantity and quality of water, two key issues in keeping the system going. Both discussions mean a high degree of elaboration about the concept of ecosystem and about the connections among the different variables that could be manipulated. On a different level, when Denís says "*we have to show that all the ecosystem depends on water*", he is showing that knows something about arguments, and that he is placing the water in the highest position in the hierarchy, subordinating to it all the ecosystem as well as its important features.

Landscape impact

One of the terms that presented greatest difficulties for the students in the first sessions, when the problem was introduced to them, was "impact". But later, some as Antía, show that they have appropriated the concept and are able to use it:

Group A, session 10
90 Antón: ... *Forty thousand square meter the... the marshes... of a meter and a half of depth.*
93 Antía: *Look, this one they remove it... Does it affect to landscape? Wouldn't be about impact?*
(...)

95 Antía: *It says here: how much land it would occupy... It affects to the landscape: Doesn't refer to impact?*
96 Antón: *The building works. Sure, the land the works would take.*
97 Antía: *OK*
100 Antón: *The question is... everything is related... all these things.*
101 Antía: (to Ana, who is writing) *Write there: affects to the landscape.*
It can be seen that Antía is assessing the size of the land that would be affected by the drainpipe and how this means an impact on the landscape.

Technical features of the project
The project involves burying a pipe of almost two meters of diameter along the wetland, what means removing the land and the seasonal pond. The meaning of burying a pipe in a natural area, very different of doing it in a city street, is not understood at the beginning, but some students realise it when discussing the project:
Group GA, session 7
236 Ana: *Underground* (the pipes) *and... they are of concrete.*
(...)
242 Aldán: *Here it says: two meters...* (the diameter of the pipe)
243 Teacher: *Almost two meters.*
(...)
258 Aldán: *Same as the gutters, more or less.*
(...)
264 Aldán: *Damn it! To bury it, man, they would have to destroy all the ecosystem!*
Aldán is realising what would happen when the pipe is buried and a security zone without plants on both sides of it established. This shows that he is able to establish connections among the technical features of the project (material, size, diameter, location) and its consequences for the ecosystem.
These instances from the transcription, when the students were trying to decide in which issues to focus, and how to reach decisions, show, in our opinion that they take a fair number of elements into account, not only the more obvious such as animals or plants, but almost the same that would be used by experts, for instance: state of the ecosystem (the wetland); plants and animals, particularly endangered species; status of the area; water and noise pollution; the projected drainpipe, its layout, impact of the building works on the area or the purifying plants.

4 Results: steps in decision-making

Different steps in the process of decision-making, according to Kortland (1996), can be followed through the transcriptions.

Identifying problems: evaluating consequences

This is, according to Kortland, the first step and it must be noted that identifying the problems is not always easy for students. Some instances could be the realisation by students of the consequences of building the pipe, in terms of the evolution of a mature ecosystem:

Group J-1, session17

37 Caio: *We believe that the drainpipe should not be built, because it would mean a great disaster for the environment and the area would be damaged and as a consequence it wouldn't be a mature ecosystem but it would be an ecosystem at the beginning of its evolution*

He values that the alteration of the area is going to take the ecosystem back to the first steps of the succession, causing its regression. This evaluation means a high degree of elaboration, showing an understanding of the complexity and richness of the interactions, niches, relationships and balance in a mature ecosystem.

Generating alternatives

A second step is the generation of different alternatives, and the more complex and close to the real world a problem is, the more different alternative solutions can be offered. This variety difficults the choice and, in this problem the six groups offered not just positive or negative assessments about the convenience of building the pipe, but also alternative solutions for cleaning the river without so great an impact for the wetland. One of these is the idea, from group J1 about locating the purifying plants close to the industries:

Group J1, session 15

17 Edu: *I believe that if they would clean, if the water would be purified then: what is the purpose of building the pipe?*

Edu, from the same group that Alfonso, is recognising the importance of Alfonso's claim about the diminishing water flow into the wetland, once it will be channelled in the pipe, and this agreement leads to questioning the purpose of building the drainpipe (and to the alternative of several purifying plants).

Group J2 generates a different alternative: another layout for the drainpipe, one that is not so threatening for the environment. This alternative, of going back to the first draft of the projected layout, where the pipe was located around the pond and wetland, not across them, was supported by the environmental organisations in the pleas presented to the project.

Group J2, session 16

21 Begoña: *Instead of bumping of the ... area, driving the pipe there and destroying the ecosystem... these pipes, laying them in a different place.*

Evaluating alternatives

Once there is generated a variety of alternatives, the next step is to evaluate them, their advantages and drawbacks. For instance, Group J1 is discussing what happens to the water flow arriving to the pond (because of the industrial area near it) and what would happen now if the project is implemented:

Group J1, session 15

34 Fito: *You know, because of the industries the water flow arriving to the pond decreased, and with this is the pond... is going to have no water at all....*

(...)

106 Edu: *The birds will go away...*

107 Alfonso: *Damn it! The birds arrive and they see a couple of pools...*

108 Fito: *A mass migration, and they go back*

115 Brais: *The birds which migrate to this area, they arrive and...they break the migratory route*

(...)

115 Brais: *Yes, there would be no place to nest.*

After Alfonso and Fito point that the pond would have no water, Brais draws one consequence for the birds (the wetland is an important area for birds, with more of 120 species recorded there, about a half of them migratory), connecting the works for burying the pipe with the difficulties for nesting.

Making decisions

In order to choose an alternative or solution, the students have to take into account not only scientific evidences, but also value judgements, like in the decision of Denís from Group A:

Group A, session 11

112 Denís: *it is an ecosystem of particular interest because there are species in danger of extinction, unique species (...) all these species depend directly or indirectly on the water ... if they continue with sewage ... they would die or not existing anymore*

(...)

116 Denís: *on the other hand the drainpipe would destroy part of the ecosystem and it would damage also the species ...so another alternative would be needed.*

This argument is supported by warrants referring not just to scientific evidence; "it is an ecosystem of particular interest" is rather a value judgement about the area and it influences his decision: if the drainpipe is built in order to solve the problem of the pollution caused by sewage, but its building means the destruction of part of the ecosystem, it is not an acceptable solution. The drainpipe is considered here an impact for the ecosystem. To save it another solution must be generated.

The weighing of evidence and values could also be followed in other groups. In J1 Alfonso and Brais share the opinion about the purifying plants:

Group J1, session 15

126 Alberto: *The shit from the towns would go there*

127 Dora: *Listen! This word shouldn't go...*

128 Alfonso: *I believe that they should locate the purifying plants there, for the sewage of the towns.*

129 Brais: *Purifying plants for the sewage of the towns.*

This group is making a judgement, not only about the sewage from the industries, but about the black waters from the towns, recognising that everybody, all of us and not only the industries are responsible of river pollution. That is why they propose building purifying plants before the points where the sewage from the towns and industries goes into the river. This would solve the pollution, as the water would be clean and also avoid the decrease in the water flow and the risks for the wetland. The awareness about our own contribution to pollution is not a matter of fact, as most students (and grown ups) are happy to put all the blame on the industries.

The analysis of the steps taken by the students shows how they resorted to conceptual knowledge and applied it to the task, using the knowledge to found the evaluation of the alternatives and, finally, making also value judgements, choose one.

5 Discussion and educational implications

Attitudes and values have a paramount role in environmental education. The importance accorded to values in it may be the reason why some proposals treat value development as if it could happen "disembodied" from school knowledge. On the contrary, our perspective is that working with the goal of developing values in schools cannot rely on activities or tasks –whatever they are, lectures, reading, role-play– centered solely on attitudinal dimensions. Students can learn what do they have to answer, what attitude to exhibit, in order to fit the expectations of the teacher; and no doubt some activities and experiences may develop in them new attitudes and wishful thinking. But if the objective of environmental education is the development of a solid attitude, with sound basis, and transferable to out-of-school contexts, then the values development needs to be related to understanding of the complex conceptual issues involved in environmental problems. Other authors, like Keiny and Gorodetzky (1992), Benayas (1992) or Moore (1981) have discussed the relevance of this conceptual understanding for environmental education, showing relations among knowledge and attitudes.

In our research this issue is explored, not by means of comparative study, but trying to identify the particular concepts used by students and the relationship among the concepts and the decisions taken. The results show that the students in this classroom constituted a knowledge-production community, combining ecological concepts such as impact, wetland or water flow, with technical information about the project they had to evaluate. For reaching the decision in the final step of solving the problem, they had to apply the conceptual knowledge, as, for instance, in group J5, when they discuss the effect of the drainpipe on the animals and plants through the destruction of their habitat, which shows an understanding of the complexity of relations in ecosystems, well beyond of the simplistic views of many pupils who perceive only direct threat to species.
But the decisions were not made depending only on conceptual understanding or scientific evidence: value judgements played an important role, by assigning higher hierarchy to ecological values over economical ones (the cost of one or another project), or by discarding a position because the damages were perceived to be greater than the benefits. We believe that the problem-solving context of the task, involving the students in authentic activities, of a similar character of the tasks performed by experts on the field, facilitated an integrated work with concepts and values. This integration should, in our opinion, be one of the cornerstones of environmental education in the school.

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COMPARISON OF THE IMPACT OF A ROLE-PLAY AND A CONVENTIONAL DEBATE ON PUPILS' ARGUMENTS ON AN ISSUE IN ANIMAL TRANSGENESIS

Laurence Simonneaux
UP - Ecole Nationale de Formation Agronomique de Toulouse

This paper compares the impact of a role play and a conventional discussion on pupils argumentation on an issue involving animal transgenesis. Pupils were confronted with an imaginable but fictional situation. They had to decide whether or not to approve a giant transgenic salmon farm being set up in a seaside village. Pupils received the same teaching and information, the only differences being in the debate situation.
Pupils were asked to reach a decision on well-argued grounds, to identify areas of uncertainty and to define the condition or conditions under which a change of view might be considered. They had to write them down. Pre post-test were used to assess the pupils' opinions. The role play and discussion were all videotaped and audiotaped, and transcribed in full.
Our analysis focuses on the argumentative structure of the pupils' discourse and identifies the reference areas that pupils draw on to deliver their arguments. The theory on economics of "grandeur", which has recently emerged as a framework for the sociology of justification, has also been used in analysing pupils' discourse.

1 Introduction

Biotechnology applications raise questions in several areas, including ethics, sociology, economy, ecology, regulation and politics. Debates often lead to moral dilemmas because of uncertainties as to the risks involved.
Our aim is to help pupils to contribute to the debates, to understand that making decisions can be complex when there are important social issues involved – economic, ethical and so on.
Pupils placed in a situation in which they have to argue their case are more likely to appropriate the knowledge they call on to do so.
This kind of situation generates difficulties for pupils. During argumentation, they are potentially in situation of inter or intra subjective conflict. And they are not used to debate in schools activities. It generates difficulties for teachers too. They have to change position to become manager of debate instead of being 'those who know'.

Our aim was to assess the impact of an educational strategy that was unfamiliar to teachers on the way pupils come to decisions: the performance of a role play (variant 1) and comparison with a conventional debate (variant 2) on the same topic (animal transgenesis).

2 Rationale

Argument is a crucial aspect of scientific education (Kuhn, 1993). According to Driver and Newton (1997), ' if science is to be taught as socially constructed knowledge then this entails giving a much higher priority than is currently the case to discursive practices in general and to argument in particular'. Several recent studies have addressed the question of students' arguments on the subject of what is sometimes called "the new genetics" (Waarlo, 1998, Zohar and Nemet, 1998, Lewis *et al.*, 1999).

Some authors hold that argument is an integral part of present-day communication, originating in classic rhetoric (Breton, 1996). Others deal with the subject from a linguistic point of view (Adam, 1992). Others again address argument at several different levels in science teaching: as a means of improving the understanding of concepts, promoting a better grasp of epistemology in science, developing investigative skills (particularly in practical work), or improving the quality of decision-making on socio-scientific subjects (Geddis, 1991, Solomon, 1992, Ratcliffe, 1996, Driver and Newton, 1997, Jiménez-Aleixandre *et al.*, 2000a, 2000b, Duschl and Ellenbogen, 1999, Mortimer and Machado, 1999, Osborne, 1999).

A new approach in science education discusses the role of rhetoric in teaching and learning (Duschl and Ellenbogen, 1999, Martins, 1999, Mortimer and Machado, 1999, Osborne, 1999). Despite a vigorous anti-rhetoric tradition, this approach emerged from analyses of observations in the classroom which show that dialogue among students draws on a great deal more than demonstration or explanation – hence a need for rhetoric analysis. These studies on rhetoric in science analyse, *inter alia*, the strategies used in argument and the social procedures, which come into, play in the validation of scientific knowledge. Osborne (1999) expresses surprise at the apparent lack of interest for rhetoric and argument among science educators, even though these are core aspects of scientific practice. According to Geddis (1991) and Driver *et al.* (1996), this is a significant omission which has had a major impact on science teaching, as it tends to give the wrong impression of the way scientific knowledge is built up. Advances in science are driven by debate and disagreement: there is therefore a need to understand the role of controversy in modern science, and its rhetorical functions in handling uncertainty (Osborne, 1999). Analyses of argumentation in science education thus also aim to encourage students to develop a critical approach to scientific statements on the repercussions of biotechnology applications.

Studies on argumentation in science education also draw on research in linguistics. Working from a theoretical typology of text sequences, Adam (1992) defines several prototypes: narrative, descriptive, argumentative and explicative sequences, and dialogue.

The following shows how Adam (1992) defines his prototype argument sequence. The pattern of the argument rests on linkages that are made between *data* and a *conclusion*. These linkages may be implicitly or explicitly supported (by the *guarantor* and the *material*) or opposed (by *refutation* or *exception*). Conscientious readers or interlocutors will be attentive to linguistic clues, which lead them to expect some kind of argument. Whether a discourse is argumentative or not may be confirmed by an analysis of micro actions in language (e.g. promising, stating or questioning) and argument connectors (although, but, so, etc.) From the point of view of the cognitive treatment of a text, it seems that the understanding of schematic prototype representations that subjects develop over time has an impact on the way they store the information they have considered while coming to grips with a discourse, and on the way they look for blocks of information by a process of anticipation (Adam, 1992).

Analysing the argumentative structure of pupils' discursive reasoning and identifying the fields of reference they drew on to produce their arguments did not bring out a full meaningful pattern in the data collected. Pupils' values were difficult to be taken into account. This is why we used the "économies de la grandeur" theory as a framework, which may be translated into English "economics of importance".

This theory, sometimes also called "economics of consensus", "économie des conventions" in French, or "sociology of justification", has emerged only recently and is still being developed, but it has already made its mark on numerous studies in sociology and economics. It first appeared as a new theoretical and methodological paradigm in a work by Boltanski and Thévenot (1991), entitled *"De la justification. Les économies de la grandeur"*.

The authors consider that there are several "worlds" in which action takes place and where people call on various skills to cope with their undertakings. This implies that human actions are structured around principles of justification, commitment and criticism. The sociology of justification is a study of discussion and debate. The crucial point in justification processes is the "orders of importance", "états de grandeur" in French, that are attached to objects of debate. Agreement between those involved in a debate becomes possible when there is a consensus on these orders of importance.

In attempting to achieve a consensus over the perceived order of importance of sociological objects, societies draw on political metaphysics, which are themselves based on political philosophy and political physics. Political philosophy helps to highlight the values (or orders of importance) recognised in a society. Political physics sets up rules and laws which are inscribed into what the authors call a "political grammar" and which define an order of things in each "city". To identify the rules in different "cities", Boltanski and Thévenot have returned to the "topical tradition" (from topoï: places) and the place of rhetoric (where arguments are found) as defined by Plato, Cicero and Aristotle. They have drawn on the "canonical texts" which they believe make up the political philosophy of each "city". They have thus brought philosophical texts into the test-bed of the sociologist, making it possible to exploit semantic usage and the philosophy of language to clarify the discourse of people in empirical situations.

"Cities" and " worlds"

Boltanski and Thévenot then attempt to define the different "cities", though without claiming to be exhaustive. A "city" is defined by a set of conventions and rules that are recognised by each of its members, and represents a theoretical model built up from classic works on political philosophy. The concept of a "common world" bridges the gap between philosophical and political thinking and pragmatic action.

The "world of inspiration"

The political philosophy that serves as a reference for the "city of inspiration" is identified in the work of Saint Augustine. The true greatness of such a city rests on grace (faith), and is opposed to any quest for glory, fame or other form of human dependency. In such a city, imagination, mystery, originality and the invisible are the highest orders of importance.

The "domestic world"

The underlying philosophy here is drawn from the writings of La Bruyère and Bossuet. Rules are based on reputation and custom. There is an emphasis on the gradual accumulation of qualities through learning and proximity. Fidelity in relationships over time, good will and trust are the foundations of consensus.

The "world of opinion"

Here, the worth of a person is established through the opinion of others. Boltanski and Thévenot draw in this case on the writings of Hobbes, the 17th century philosopher whose thinking was devoted to the definition of honour.

The truth of an individual's worth cannot be brought into question when it is recognised by others: 'celebrity creates worth'.

The "world of civics"

To identify the values underlying this "city", the authors refer to Rousseau's Social Contract. The sovereignty of the "city" as a whole is disincarnate and depends on the will of all its members.

The value of individuals lies in their belonging to a collective being of greater importance. Collective values are instrumentalised and greater than individual interests, with democracy being the most appropriate order of importance.

The "world of trade"

Orders of importance here are drawn from an analysis of the work of Adam Smith. Competition between economic players, through markets, promotes an optimal use of resources and thus contributes to the overall good of society. Profits are legitimate, and any obstacle to freedom of circulation is prohibited. Quality is assessed through prices.

The "world of industry"

As developed by Saint-Simon, the political philosophy of the industrial "city" defines utility as the responses made in order to satisfy needs. The recognised order of importance rests on performance, methods, etc. Material investment has a predominant role. Methods of operation are highly instrumentalised, and rules and regulations, standards and technical constraints, have an important place. Standardisation of quality is at the core of the "world of industry".

Pupils' conceptions on biotechnology may be rooted in different worlds, and they may attach different orders of importance to them. Biotechnology is an area that is particularly liable to arouse debate. Whereas in the field of biology education, there is little basis for identifying the orders of importance attached to some areas of knowledge being taught (the cell, for example), this is not the case for other topics such as evolution, sexuality or innate vs. acquired characteristics. However, it is always to the point where biotechnology teaching is concerned. Orders of importance indicate the foundations of pupils' conceptions.

3 Devising the role play

As members of the European Initiative for Biotechnology Education (EIBE), we are working on ways of developing the content of biotechnology education for the purpose of teaching today's pupils, as future actors in the

21st century. The EIBE is a group of experts in biotechnology education from 17 European countries working under the aegis of the European Commission. We have thus been contributing to the development of a teaching document on animal transgenesis. The document comprises three modules. The first focuses on the production of transgenic ewes secreting a human enzyme in their milk for therapeutic purposes (alpha 1-proteinase inhibitor) – the ewe called Tracy symbolises the concept of producing transgenic animals as live fermenters of recombinant proteins. The second module deals with the production of transgenic mice expressing oncogenes to be used as models for cancer studies. The third focuses on transgenic animals in livestock breeding. Most of the goals of animal transgenesis are medical or zootechnic. In view of our mandate, the design of the latter module was entrusted to ENFA.

A preliminary choice then had to be made as to the example we would use. The types of transgenesis being considered by researchers (though whether for the short, medium, long or very long term is open to question, in view of the difficulties involved) aim to improve the various types of zootechnic performance, including modifications in milk composition (higher protein yields, higher cheese-making quality), genetic vaccination, muscle development, reduction of fatty deposits, enhanced use of food rations, improved wool growth, acquisition of independence from essential amino-acids in monogastric animals, changes in the composition of body fluids, improved prolificity, etc. Few transgenic animals have been born so far but experiments are under way.

We chose to draw on Canadian studies on the production of giant transgenic salmon expressing a foreign gene for the growth hormone, dubbed "Sumotori salmon" after the Japanese wrestlers (Devlin *et al.*, 1994). The value of producing transgenic domestic animals to improve zootechnic performance is debatable in view of the effectiveness and long pedigree of conventional selection methods, but for animals that are closer to their natural state, like Salmonids, the benefits could be more spectacular. Although we wanted to develop a fictional situation, because of the uncertain state of the knowledge involved, it still had to be realistic so as not to reinforce pupils' perceptions of biotechnology as somehow magical and all-powerful.

In preparing the didactic approach, we also had to consider the conceptions of those at the receiving end (Simonneaux, 1997a, Simonneaux and Bourdon, 1998, Simonneaux, 1999). In line with EIBE objectives, the target audience was made up of pupils in scientific and non-scientific secondary school education. The preparatory work turned out to rely on decision making: choices had to be made, especially on the references to be introduced and on linguistic options (as noted by Chevallard, didactic preparation results in the textualisation of knowledge).

We explored three different avenues to find and select the contents to be presented. First , the bibliographic references in the source publication printed in *Nature* in 1994 led us to the scientific articles published on this topic. Through these, we were able to interview the French research teams working in this area at INRA, to help us select the information to be presented on the Canadian experiment (performance and difficulties with the method used). After this, as we did not want to confine the process of didactic transposition to scientific knowledge alone, we decided to include professional references. This led us to interview the head of the French union of aquaculture breeders (SYAAF) to find out more about the salmon industry (especially the comparative importance of farmed and fished salmon, the role of fish processors and cooperatives, the state of the market and its fluctuations, as well as the opinions of the union and the fish farmers on the production of transgenic fish, European and international policies in this respect, etc.). This interview provided us with the basis for a realistic, contextualised document (two Sumotori salmon farms have in fact just begun to operate in Europe). In exploring each of these avenues, we listed the economic, ecological, ethical, legal and political repercussions as seen by those concerned. Possible repercussions mentioned in these fields are: increasing fish farm productivity, increasing over–production, technology transfers to the developing world and famine reduction, ecosystem disruption, loss of biodiversity, risks to human health, labelling and consumer reactions, patenting life forms, company monopolies.

We then decided to use a role-play to "stage" the contents of the document.

This role-play was an exercise in decision making. The pupils were faced with a situation that was fictitious but could be readily imagined: they had to decide whether or not they agreed with the installation of a Sumotori salmon farm in a seaside village. They acted out the roles of people taking part in a public debate organised by the Mayor.

In a seaside village close to a fishing harbour, a fish farmer, Yann Le Goff, is planning to breed genetically modified salmon which grow more rapidly and become giant, called Sumotori. The local population is very concerned about this project. A group including fishermen, consumers, conservationists, and traditional fish farmers formed a committee to fight against this project. However, Yann le Goff rallied support from the owner of the canning factory and a part of the local council. The mayor decided to organise a public debate with specialists in the field.

The characters are: the fish farmer who wants to open the transgenic fish farm, the owner of the canning factory who is interested in the project, a traditional fish farmer, a master fisherman, a "with it" media studies student, a gastronome, a fishmonger, a leader of an environmental association, a researcher in fish physiology, a member of the Surf Rider Foundation which is concerned on ecological issues on the seaside, a young mother who is pro organic agriculture, the Mayor, an African Ph D student in biotechnology.

From the linguistic point of view, choices had to be made on the lexical content and the textual register. We tried to adapt the scientific lexicon to our target pupils, or in other words, to reformulate the most abstruse lexical items. We also asked an economics expert to check both the quality of the economic arguments we had collected and the relevance of the economic terms used (added value, production costs, productivity, etc.). We drew on several different textual registers: the historical, scientific and contextual references supplied before the start of the role play are in an explanatory and descriptive register, while the description of the roles shifts from a descriptive to an argumentative register.

The preparatory didactic work involved a succession of adjustments. The didactic transposition process proved to be a process of didactic creativity, in which we were creating a unique teaching object by merging forms of scientific knowledge that are unstable and open to debate, with different aspects of a socio-professional situation. We made a great many adjustments in the course of selecting new information (Simonneaux *et al.*, 1997b, 1997c).

4 Classroom protocol

Our study was conducted in two classes at the Agricultural Lycée in Auch (Gers *département* in South-West France), with pupils in their 2nd year of upper secondary vocational education geared to scientific subjects. All the dialogues were recorded on audio and video tape and transcribed in full.

4.1 The role play situation

Before the role play, a questionnaire assesses pupils' opinions about different researches concerning animal transgenesis. After transgenesis has been introduced with a presentation of the history of domestication and the background of growth hormone gene transfer, the role play is presented.

After the subject and interest of the role-play have been presented, pupils express and justify their opinions on the setting up of a Sumotoris farm.

Once the roles have been handed out, pupils make up a list of questions that they wish to ask, and express their arguments, naturally from their role's viewpoint. The pupils know which individual characters are going to be involved in the role play. The teacher distributes labels on which are written the names and the job/role specification of the participants. The observers should organise themselves in order to gather together their observations.

Role-play is under way. The teacher plays the role of the mayor. He/she introduces the role-play and is responsible for the timing. At the end the teacher (the mayor) asks the pupils to vote.
At the end of the role-play, each individual participant expresses his/her opinion on the proposal and specifies under what circumstances he/she would change their mind.
After the role play, pupils fill in the questionnaire on opinions again. The method and individual feelings are discussed. The decision-making process is analysed with the assistance of the observers.

4.2 The conventional debate situation
Apart from being based on a debate, this situation was organised in exactly the same way as the role-play.

Table 1. Experiment protocol

Situation ❶ Role play	Situation ❷ Debate
Pre-test opinions	ditto
Introduction to the history of domestication and chronology of the transfer of the growth hormone gene	ditto
Presentation of the role play	Presentation of the debate
Written essay by pupils on the installation of a Sumotori fish farm (opinions to be supported)	ditto
Role play performed	Debate
Post-test opinions	ditto
Written essay by pupils on the installation of a Sumotori fish farm (opinions to be supported)	
Pupils explain under what circumstance(s) they might change their opinions.	

Presentation and organisation of the debate. The teacher explains the debating situation by making an analogy with the citizens conference that took place in France on the subject of biotechnology applications, and sets out the aims of the debate, i.e., to argue out a decision, explaining that the first task is to discuss the economic, political, ecological and human health aspects of the issue. The teacher remains neutral, leaving the pupils to take up the various points spontaneously. If one or more aspects are forgotten, the teacher asks for their opinion on these. Next, the teacher prompts a debate on the various topics addressed in the role play, unless they have already been taken up spontaneously by the pupils: increase in livestock productivity, increasing overproduction, technology transfers to the developing world, famine reduction, disruption of ecosystem balance, risks to human health, labelling and consumer reactions, patenting living organisms, company monopolies, and so on. As the debate proceeds, the teacher supplies the information that was contained in the role-play.

5 Comparative analysis of results

Methodology

The quantitative data from the study (pre and post test) were processed with Sphinx software to make calculations on the respondents' citations.
In this paper, we will not go into the details of our analysis of the pre and post tests on pupils' opinions concerning research on different types of animal transgenesis. The results we observed were similar to those in a previous study conducted with the same method (Simonneaux, 1999). Pupils' opinions varied according to the context and the research applications being considered. Medical applications were the most broadly accepted, followed by veterinary applications. Industrial applications (i.e. in food processing) were rejected. Opinions did not change between the pre-test and post-test stages.
We shall now describe our analysis of pupils' statements before and after the role play and debate.
Our analysis of pupils' opinions on the installation of a Sumotori salmon farm rests on the theory of argument and on the sociology of justification. We identified the fields of reference called upon by pupils as they developed their arguments before and after the role play and the debate. These fields of reference are disciplinary fields that are called upon by the *guarantors* of an argument. Specific themes that were outside the scope of these disciplines could only be treated by identifying the "orders of importance" attached to them (cf. theory developed by Boltanski and Thévenot). The argument sequences were also analysed from a linguistic point of view.

A Opinions and field of reference appearing arguments for and against the Sumotori fish farm

Opinions before and after the role play

When pupils expressed a train of thought with arguments for and against, their final verdict, once it had been explicitly stated in conclusion to their reasoning, was taken into account.
Before the role play, eleven pupils out of eighteen stated that they were against the installation of a Sumotori salmon farm. Fifteen were against research aiming to produce these fish. This suggests that four pupils who had

discussed the benefits and disadvantages of the fish farm in their responses without coming to an explicit conclusion were actually against the project. The same phenomenon was apparent after the role play.

This requires some comment. In opinion surveys generally, as in the Swiss referendum for example, there is evidence that people tend to reject biotechnology applications but not biotechnology research. There is less opposition to research as such, which seems to be considered as reflecting a quintessentially human drive to push back the frontiers of ignorance. Therefore, if the research is rejected, the resulting applications are necessarily rejected as well. In addition, pupils question the status of biotechnology research, which they see as different from fundamental research where the aim is to produce new knowledge that is not necessarily applicable. Biotechnology research is seen as research with a purpose that will necessarily be applied eventually.

Table 2. Pupils' opinions before and after the role play

Pupils' opinions on Sumotori research before the role play	Pupils' opinions on Sumotori research after the role play	Pupils' opinions on the installation of a Sumotori salmon farm before the role play	Pupils' opinions on the installation of a Sumotori salmon farm after the role play
15 out of 18 against 1 no reply	13 out of 16 against 3 no replies	11 out of 18 against 5 out of 18 discussed arguments for and against 2 out of 18 in favour under certain conditions 1 no reply	11 out of 16 against 1 out of 16 discussed arguments for and against 4 out of 16 in favour under certain conditions 3 no replies

Three pupils changed their minds on the installation of a Sumotori salmon farm. Their roles were as follows: one observer decided against the farm after the role play, after having discussed its benefits and disadvantages; the pupil playing the role of Yann Le Goff, the fish farmer intending to set up a Sumotori farm, had been against the project before the role play and subsequently came out in favour, subject to certain conditions (was the

change of mind linked with the fact of acting out the part ?); finally, the pupil acting the part of the "foodie" opposing the farm stopped weighing the arguments for and against after the role play, and came out against the project.
The pupils who discussed the arguments for and against thus confirmed the limits of conventional logic. Their verdicts were suspended between acceptance and refusal (see Giordan, 1999, on this subject).

Opinions before and after the debate
Before the debate, ten pupils out of seventeen said they were against the Sumotori salmon farm project. Fourteen said they were against research to obtain such fish. This suggests that four pupils who had discussed the benefits and disadvantages of the Sumotori salmon farm in their responses without coming to an explicit conclusion were actually against the project. The same phenomenon was apparent after the debate.
Moreover, after the debate, fourteen pupils said they were definitely against the installation of a Sumotori salmon farm.

Table 3. Pupils' opinions before and after the debate

Pupils' opinions on Sumotori research before the debate	Pupils' opinions on Sumotori research after the debate	Pupils' opinions on the installation of a Sumotori salmon farm before the debate	Pupils' opinions on the installation of a Sumotori salmon farm after the debate
14 out of 17 against	13 out of 17 against	10 out of 17 against 1 out of 17 in favour 2 out of 17 discussed arguments for and against 2 out of 17 in favour under certain conditions 2 out of 17 against unless restrictions are imposed	14 out of 17 against 1 out of 17 in favour 1 out of 17 in favour under certain conditions 1 out of 17 against unless restrictions are imposed

Four pupils changed their minds on the installation of a Sumotori salmon farm. It is important that decision-making process includes listening to the views of antagonists (Kolstoe, 2000).

From this point of view, the case of Marianne is interesting. Marianne's extreme positions had the effect of catalysing her colleagues' arguments. She was fundamentally in favour of the Sumotori salmon farm, and vigorously argued her case: 'it doesn't matter that much if a species disappears'; 'in any case, producing countries will always be the richest ones; and we won't be giving to poor countries anyway'; 'in any case we'll be discovering medicines to destroy what we've destroyed'; 'bankrupt fish farmers will just have to do something else, you don't make an omelette without breaking eggs'; 'we're not going to go back to the horse and cart are we ! It's just too bad if there's unemployment': 'cloning people might be useful: it might interest the army, or for work'. In every study we have conducted so far, there has always been a small minority expressing ideas like these. We had planned that the discussion leader (the teacher) would provide counter-arguments at the end of the debate to stimulate the discussion, if none had been forthcoming, but this turned out to be unnecessary.

Fields of reference used in arguments before and after the role play

Pupils' arguments are based on what linguists refer to as *guarantors*. These may be associated with different disciplinary fields. The pupils' arguments were selected from the entire corpus and classified by field of reference, using an iterative approach. Some of the arguments could not be classified into a particular disciplinary field, a point we shall return to later.

Table 4. Number of arguments in the different fields of reference used before and after the role play

Arguments	Before the role play	After the role play
In favour	Positive effects on human health (1) Positive ethical effects (2) Positive economic effects (4)	Positive economic effects (2) Positive ethical effects (2)
Against	Negative effects on human health (6) Negative economic effects (6) Negative ecological effects (8) Negative genetic effects (1)	Negative ecological effects (8) Negative effects on human health (4) Negative economic effects (4)

The disciplinary fields called upon in support of arguments were economics, ecology, genetics, medicine and ethics. Political, legal and professional fields of reference did not appear.

Fields of reference used in arguments before and after the debate

Table 5. Number of arguments in the different fields of reference used before and after the debate

Arguments	Before the debate	After the debate
In favour	Positive effects on science (2) Positive ecological effects (2) Positive economic effects (2)	Positive economic effects (1)
Against	Negative effects on human health (3) Negative economic effects (13) Negative ecological effects (5)	Negative ecological effects (5) Negative effects on human health (5) Negative economic effects (11) Negative effects on science (1) Negative political effects (3)

The disciplinary fields called upon in support of arguments were science, economics, ecology, politics and medicine. Legal, ethical, genetic and professional fields of reference did not appear.

B Origins of justifications according to the order of importance attached to the installation of a Sumotori salmon farm

Human actions (verdicts on objects of debate are considered here as actions) are structured around principles of justification. According to sociology of justification, what is important in justification processes is the "order of importance" attached to objects of debate. We have selected in the discourses items showing the "order of importance" attached to the installation of a Sumotori salmon farm, which indicate the world of reference of pupils. Specific topics (Nature, quality, patrimony, "disturbance" to the population) which we could not considered through the identification of arguments have been then analysed.

Table 6. Comparison between "orders of importance" brought out in the role play and the conventional debate

	Role play	Debate
Orders of importance in pre-test stage	Counter-arguments from the world of trade	Counter-arguments from the world of trade
	Arguments from the worlds of civics, inspiration, trade and industry	Arguments from the worlds of civics, inspiration
Orders of importance in post-test stage	Counter-arguments from the world of trade	Counter-arguments from the world of trade
	Arguments from the worlds of civics, inspiration, trade	Arguments from the worlds of civics, inspiration, trade

With reference to orders of importance, as seen in table 6, we identified four "worlds": trade, civics, industry and inspiration. Supporting arguments from the "world" of civics were in the majority. Here, the collective interest is predominant, through respect for legal forms. Supporting arguments from the world of civics partly overlapped with medical concerns. There were connections with other topics, such as poverty, animal welfare, loss of the village heritage or social development in the village, and also with "disturbance" to the population ('the population might be disturbed by the fish farm, and the region could be upset by the person'), unemployment ('it would be better to find jobs for hundreds more people'; 'what about the small fish farmers ? '), the crucial problem of maintaining quality, consumer information and the need to establish tests and inspections.

The "world" of trade was mostly called on in terms of opposition. Here, competition between the protagonists, through market forces, promotes the optimal use of resources. Profits are legitimate. This is where the pupils found most of their counter arguments. Commercial arguments that might have countered their own were rejected outright, to cut the discussion short, in line with the rules of rhetoric. 'Of course it'll bring in a lot of money, but it'll bankrupt the small fish shops and the fishermen'. 'Debts from the high costs of installing the fish farm might ruin the fish farmer; and prices might crash because of large-scale production'.

The "world of inspiration" holds all that is sacred. Here, it was called on in references to nature. Establishing the Sumotori fish farm goes against nature. Man sees himself as a demigod. The techniques invented by people to serve their needs and culture will permanently disrupt the balance of nature.

Nature must be left alone, as long as people do not intervene, it keeps in balance. Nature is the evolution of species which have adapted at random to a given environment. But the world is now dominated by humans and human culture, and species adaptation is under human control. We are trying to control the living world by artificial means, to assert ourselves as masters of the world, controlling all life; we want to become gods, we're tempted by eugenics, we want to adapt nature to our cultural, social and economic needs. Here, we are in a mythical register which has nothing to do with scientific logic, but a lot to do with what might be called "holy terror". Controlling the living world means trying to control what is random, using technology to overcome chaos and our own fear of life and death.

Supporting arguments from the "world of industry" were very much in the minority. Here, what is recognised as important is based on performance and method. Investment is linked with progress.

Ecological concerns are expressed in scientific terms (biodiversity, ecosystem, etc.) or in more commonly used terms (nature). Should these be classified in the "world of civics", or the "world of inspiration" ? Or elsewhere ? We placed arguments expressed in terms of biodiversity and ecosystems in the world of civics, and those associated with nature in the world of inspiration. But perhaps we should look into the possible emergence of another "world", in addition to those defined by Boltanski and Thévenot, a world in which new social demands are being expressed in connection with the environment, a "world of ecology" ?

C How pupils changed their minds

After the role play, when asked under what circumstances they would change their minds, five pupils stated that they would not change their minds under any circumstances: their opinions were definite. This question was asked to launch the pupils' discursive processes and to encourage them to justify their decisions. These circumstances have to do with ecology, economics and science, and also relate to food problems in the developing world, food safety issues and human health. Safety and inspections are also mentioned. After the debate, these circumstances have to do with ecology and economics, and also relate to food problems in developing countries, food safety issues and human health. Safety, control and inspections were also mentioned. Two of the pupils would feel happier about the project if the fish were sterile. Three pupils would not change their minds under any circumstances.

D Comparison of difficulties, advantages and disadvantages

These comparisons were made on the basis of teachers' comments, pupils' comments after the debate and our own observations.

The disciplinary fields called upon in support of arguments were economics, ecology, genetics, medicine and ethics. Political, legal and professional fields of reference did not appear.

Fields of reference used in arguments before and after the debate

Concerning the role play

The main obstacle was the teacher's lack of familiarity with role-play practice, which was in fact one of the reasons for conducting this study. Teachers need to be reassured and offered training sessions on organising role-plays, which are particularly well suited to interdisciplinary approaches. The role-play assessment shows that the teacher was unable to remain neutral throughout in performing the Mayor's role. The following exchange shows that the pupils, when it came to voting, were aware of the impact of the teacher/mayor on their classmates and were not taken in:

The foodie: 'No, no, no, there's a fiddle going on. If the Mayor's being paid as well…'.

The Mayor: 'My concern is for the development of our village'.

The foodie: 'Someone's getting a bribe, we'll take another vote. Right, who's in favour ? Nobody. Who's against ? '.

"Switched-on" communications student: 'If you'd done communications studies, Sir, you'd realise there's a boss here who keeps the meeting in order'.

The foodie: 'So who's the boss ? '

The Mayor: 'The Mayor of your village, Sir. I'm here because I'm responsible for our citizens' welfare. We'll take a final vote. Who's in favour of the project ? Five. Who's neutral ? Two'.

The traditional fish farmer: 'No, I didn't raise my hand'.

The fish physiology researcher: 'You're not allowed to influence people. Careful ! '

The Mayor: 'Who's against ? Seven'…

The pupil playing the part of the communications student put her finger on the institutional relationship with the teacher.

Some pupils found it difficult to appropriate the information contained in the description of their roles. As observed by Kolstoe (2000), role playing increases possibility to understand other people's point of view when you have to place yourself in their situation. But whether or not their interpretations were correct, the pupils kept strictly to the information supplied. Should they be asked to carry out some documentary research beforehand ? The pupils were very enthusiastic about this activity, and said they did not feel ill at ease with it. However, some emphasised the difficulty of acting the part of a person they did not agree with. The observers felt frustrated at not being able to take part.

The teacher was keen to try the experiment again, and also said how interesting it had been to 'see the pupils in a different light that brings out their personalities'.

Concerning the debate

The major problem here was the reserve of some pupils. Although they were asked several times for their opinions, seven pupils did not take part in the debate. When they were questioned afterwards, they stated that they were very interested but did not want to repeat opinions that had already been expressed, and in fact, in their written answers five of these pupils were the most loquacious on the subject. The quality of their argumentation, as measured by the number of arguments given, had improved between the pre and post debate stages. All the pupils expressed enthusiasm for the exercise.

The role of the teacher

As noticed before, the role of the teacher is difficult. It is difficult to keep a neutral attitude during the debate and to promote an attitude of respect towards antagonists' opinions. And he/she is supposed to play an active role at the end of the debate by asking reflective questions to increase the pupils' awareness of the role and of the limits of scientific knowledge and of values issues brought into the debate. This aftermath of a discussion, whatever the form it takes (debate, role play) is essential to the process: this is the stage which, as the different steps in an argument are highlighted *a posteriori*, helps pupils to achieve greater distance in relation to the topic - or, in other words, to adopt a metacognitive and "meta-emotional" approach.
In this kind of issue, not only biotechnological knowledge but also societal consequences are to be taken into account. This point, as well as the unfamiliarity of science teachers with debate situation should promote the participation of humanities teachers.

6 Conclusion

The fundamental value of the didactic strategies concerned here lies in their potential for opening up the school environment to a dimension that reaches beyond the acquisition of knowledge, by socialising and contextualising such knowledge and discussing the issues that arise from it. The fundamental goal is, therefore, to help pupils become full and active members of society.
Jiménez-Aleixandre *et al.* (2000a) have shown that the way pupils argue on environmental issues is different from what has been observed in more conventional "scientific" subjects of surveys, insofar as the pupils used several different arguments. In this field, in their view, there is no single reference argument resting on an expert's point of view. Moreover, these authors highlight the importance of values in pupils' arguments (e.g. pragmatism versus utopia, economics versus ecology). Their research draws on the method developed by Toulmin (1958) to analyse arguments. By using a different theoretical framework (based on the sociology of justification), we were able to analyse the values supporting pupils' arguments in terms of

the orders of importance they attached to them. This framework, which was borrowed from sociological and economics research, seems to us to be very promising for studies on justification and argument situations, and for studies on classroom interaction in general. It enabled us to analyse responses that were not directly connected to disciplinary fields and, especially, to describe more fully what are often simply referred to as the "values" underlying arguments and decision making.

This study draws on observations of real classroom situations rather than on experimental situations that are set up specifically for research purposes. We found few significant differences between the arguments put forward by the pupils in each variant (role-play and debate).

However, among all the studies we have conducted so far, this was the first in which we observed changes of opinions. Our previous results had not been particularly surprising insofar as opinions – as the foundations of social representations - are not easily shifted. Before and after a number of formal and informal learning sequences (visits to exhibitions), we had always found knowledge being appropriated without any changes of opinion. But in these situations, the pupils had not been asked to discuss issues orally. Could it be that it is in expressing points of view and being confronted with opposing arguments that pupils clarify their thoughts on a given subject, as asserted by Barnes and Todd (1977) and Lewis *et al.* (1999) ? If so, the didactic strategy involving class discussions, whether through role play or debate, would seem to be a useful way of helping pupils to develop their arguments.

Science teaching has only made a modest contribution so far to the way opinions are formed (at least, in France). Teaching pupils to identify and assess opinions and to form their own well thought-out opinions on a complex problem of both scientific and social importance should logically be considered an essential aspect of scientific education and the acquisition of scientific literacy.

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DISCOURSE ANALYSIS: PUPILS' DISCUSSIONS OF SOIL SCIENCE

Francisco Sóñora Luna, Isabel García-Rodeja Gayoso & Manuel P. Brañas Pérez
University of Santiago de Compostela

Abstract
As a part of the RODA project on classroom discourse, we recorded pupil interactions during one month unit on soil science. At the beginning of the unit, the pupils (aged 14 -15 years) were presented with a land allocation problem to solve using information about soil properties. In this paper we analyze 50 minutes of recorded session. The recorded group discussions were analyzed using Toulmin's scheme and categorization of actions was carried out. The analysis of results suggest that the tasks were successful in encouraging the pupils to reason and argue in scientific terms.

1 Introduction

Scientific discourse should exhibit clarity of argument, precision in distinguishing among the various factors that may be relevant to the phenomena discussed, and consistency with facts. These qualities should be developed by the pupil in the course of his or her scientific training. This applies to all pupils - not only those intending to pursue a scientific career - because today's citizens are continually called upon to have opinions about matters of public or private concern on the basis of the reports or declarations of professional scientists.

Previous reports in the literature concerning science education show that there are different reasons for analysing the discourse in science classrooms:

- The social constructivist model considers that learning is not confined to the individual mind but that cultural processes are also involved. This model suggests that opportunities for reflective interaction should be given, for example through discussion and argument, to support the construction of knowledge, as outlined by Newton et al. (1999).
- The view of science as social construction considers that scientific knowledge is generated from the conclusions made through argumentation and it is clearly important to give students the opportunity to take part in activities that require them to argue the basis on which their conclusions are made. In this way the students can appreciate the epistemological basis of science itself.

- Duschl, Ellenbogen and Erduran (1999) also point out the importance of argumentation strategies by stating that " Given that the language of science involves the evaluation and justification of knowledge claims, argumentation strategies are recognised as a important tool for doing and talking science"
- Argumentation is also important in terms of scientific literacy: Patronis et al. (1999) and Newton et al. (1999) highlight its importance in decision making and consider that the act of taking decisions is central to an education aiming at democratization.

The present study was carried out as part of the RODA project, a programme of research into the argumentation skills of secondary school science pupils, in which classroom discourse analysis techniques are used and in which teachers collaborate as researchers (Díaz de Bustamante and Jiménez 1997; Duschl 1998; Lemke 1990). Part of this project involved a one-month teaching unit on soil science, created as one of a series of units on subjects of environmental relevance. In keeping with the philosophy outlined above, the unit was constructed in accordance with SEPIA design principles (Duschl and Gitomer 1996) so as to promote the development of argumentation skills. In this paper we present the results obtained from the analysis of the transcript of 50 minutes of taped sessions.

The objective of the present study is to describe the construction of arguments by groups of students in the preliminary tasks of a unit related to soil science in order to activate their knowledge of this subject.

2 Method

Participants and setting

The unit was part of the Natural Science course of a class of thirty 14-15 year-olds (28 boys and 2 girls) in their penultimate year of compulsory education (ESO 3) in a rural community. The class was divided into 8 groups of 3 or 4 students.

The teacher was the usual Natural Science teacher (first author) and an external researcher (third author) was present as an observer during all sessions. The activity of two of the groups of students was recorded on video and audio tapes.

Instructional Context

The context of our study was a unit on soil science. The main themes of this unit included: the factors involved in soil formation, soil composition and structure, uses of soil, soil weathering and reclamation.

The teaching unit comprised four phases, as follows.

Phase 1: Introduction. The pupils were given a fictional land allocation problem in the guise of a request for help by their local town council, which supposedly had a budget too small to allow consultation with professional experts. The students had to decide how to allocate three available plots of land for use as a football pitch, a garden for use by a gardening school, and a block of council offices, in the light of existing data on the properties of the soil in each plot.
Phase 2: Approaching the problem. With the help of the teacher and using the teaching material the pupils looked up basic information concerning formation, composition, management and reclamation of soil.
Phase 3: Evaluation of data. The pupils applied the knowledge gained in Phase 2 to the fictional data characterizing the three plots in order to obtain a solution to the problem posed.
Phase 4: Final report. Each group presented a final report with reasoned conclusions.

Data sources and analytical methods
We made videotapes of all of the sessions in this unit using video cameras and audio tapes with external microphones. For the present study we focussed on the interactions of one group of four male students. A total of fifty minutes were transcribed and analyzed.
The session took place during the preliminary task of phase two of the unit, which, as previously mentioned, was mainly concerned with activating the students' knowledge. The students discussed the following questions:

1. How long does it take for a soil to be formed?
2. Where do the materials that form soils come from?
3. Why are soils fertilized with manure more fertile than those fertilized with inorganic fertilizers?

Analysis was made of the transcription of the taped conversations of a group of four male students. As pointed out by Gee (1991), discourse in the classroom reflects both the actions and the language of a community of people. Analysis of actions was carried out using a modification of the system of observation designed by Hollon et al. (1980) and Newton et al. (1999) using the systemic network (Bliss et al., 1983) for categorization of actions (Fig.1).
Analysis of argumentation was carried out using Toulmin's argument scheme, adapted on the basis of different proposals made for the analysis of classroom discourse (Alvarez, 1997, Dusch et al. 1999, Jiménez, 1998, Pontecorvo and Girardent, 1993). Thus for the purposes of the present study we categorized the elements included in the students' arguments as: claims (conclusions whose merits are sought to establish), warrants (statements that justify the connection between data and conclusions), backing (knowledge,

of a theoretical nature, used to support the warrant), hypothetical and empirical data (facts referred to as a basis for the conclusions), challenges (statements questioning the validity of a claim), opposition (any claim that denies what has been claimed by another, with or without giving reasons), concessions (any claim that concedes something to an addressee, admitting a point claimed in the dispute), qualifiers (qualification or restriction, statement specifying the conditions for the hypothesis or conclusion), rebuttals (specifying the conditions for discarding the hypothesis or conclusion). Unlike the analysis of interactions, the analysis of language centres on only three events of relative interest to the construction of the arguments.

3 Results

Analysis of interactions

A total of 50 minutes of taped were transcribed. A total of 244 contributions were made during the 50 minutes of taped session.

The teacher made nine (3.7%) of the total contributions, in seven of these the interaction was with a working group and two were with the whole class. The teacher's action comprise: asking questions (7), making notes on the blackboard (1) and give or help search for information (1).

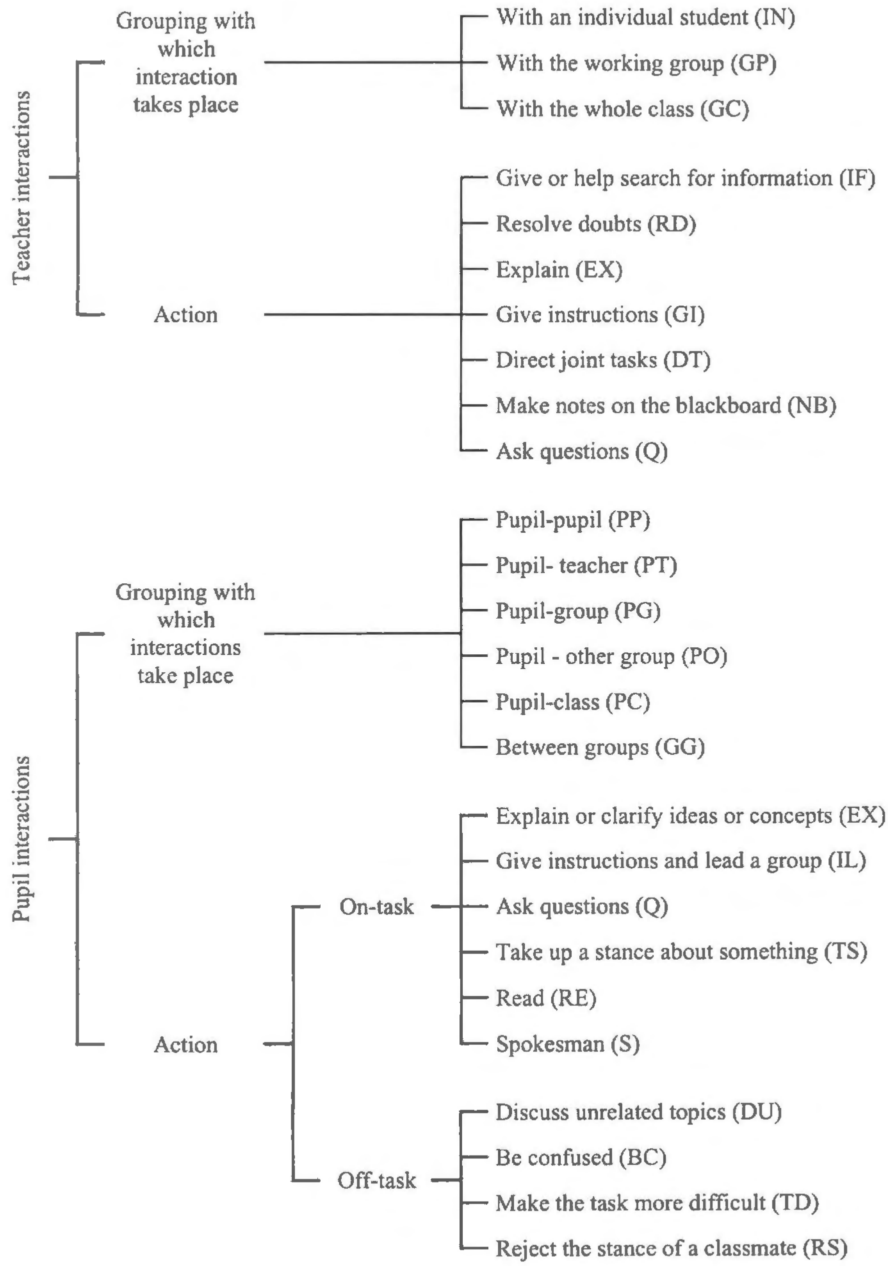
The pupils made most of the contributions interacting with the various grouping with the following frequencies: pupil-pupil 18.0%, pupil-teacher 1.6%, pupil-group 70.5%, pupil-other group 0.82%, pupil-class 3.3% and between groups 0.4%.

Most of the interactions that took place were between pupils, within their own working group, consistent with the methodology proposed for facilitating argumentation. Dialogues between pupils were much less frequent and pupil-teacher interactions were even less so, usually taking place to resolve doubts.

Of the contributions made by the pupils, 74.6% took place on-task, meaning that around 25% of the contributions were not directly related to the topic in question, although many arose from discussion of it.

The frequency of contributions made on-task for each of the categories established was as follows: explaining or clarifying ideas or concepts 26.2%, giving instructions and leading a group 10.6%, asking questions 18.0%, taking up a stance about something 15.6%, reading 0.8% and being a spokesman 3.3%. It can be seen that most of the contributions made within the task involved giving explanations, asking questions and taking up a stance about something. The percentage number of explanations was higher than that of questions because one question can elicit several explanations, which can be either complementary or contrasting.

Figure 1. A systemic network for students' actions



The categories of direction, spokesmanship and leadership had significantly lower numbers of contributions and corresponded to contributions made in order to direct the discussion.

Of the 182 contributions made within the task, 71 were included in the three arguments that were analyzed. Thus we can assume that the three excerpts selected, which represent about a third of the transcribed session contain 70% of the contributions made within the task. This clearly indicates that argumentation helps in carrying out the task, in line with the aims of the design of the unit.

Analysis of the argumentation

As previously mentioned the data analyzed was taken from the transcript of recorded conversations between the members of a group of four pupils during two classes. The analysis consisted of identifying the parts of the dialogue that corresponded to each argument. These were understood as those parts involved in reaching of conclusions using the hypotheses and data to justify, agree, oppose, etc.

Excerpt 1 response to the question- Why did you choose this length of time for the formation of soils? a) *between 1 and 100 years* , b) between 100 and 15.000 years, c) between 15.000 and 1.000.000 years or more

Agustín	We chose b, which is between 100 and 15 000 years	Claim
Agustín	It couldn't be between 1 and 100 years...	Claim
Agustín	...because the mountains would be much more pointed	Hypothetical data
Agustín	And if it was a million years or more...	Challenge
Agustín	.....they would be much more eroded because more time would have passed	Warrant
Teacher	What do you mean that they would have been more eroded?	
Agustín	Everything would be flatter	Hypothetical data
Alfonso	This would be like Holland	Hypothetical data
Alvaro	I don't know if that's right	Challenge
Agustín	What? I think so	
Teacher	What do you mean that it would be flatter?	
Agustín	That there would be more soil and less rock	Hypothetical data
Teacher	Why would there be more soil and less rock?	Challenge
Agustín	Because there are lots of stones...	Empirical data

Teacher	Yes?	
Agustín	There wouldn't be so much...stone in the countryside and there would be more soil, more earth, there would be more topsoil because in some areas the layer of topsoil isn't very deep	Hypothetical data Empirical data

The argumentation in the transcribed and categorized fragment corresponds to the joint discussion that took place in order to explain the reply to the question indicated.

The conclusion was made by the pupils choosing what they considered to be the correct option from the different possible solutions to the problem. They arrived at the conclusion by excluding the other option on which they based the replies that they did not consider to be correct.

Thus, in the reconstructed argumentation scheme (Fig. 2) we considered a complex argument where the warrant in the principal argument is composed of two subsequent arguments. The first option refers to the shortest time interval (*between 1 and 100 years*) and the hypothetical data given for discarding this is that the mountains would be much more pointed. The warrant, implicit in this case, is that the mountains would be less eroded.

The option more than a million years is rejected with the warrant that the mountains would be more eroded because more time would have passed. In this argument, the backing, (here, the students' knowledge or general ideas that the students use, not exactly scientific ideas) is related to the concept of erosion being linked to long time intervals and the process of soil formation understood by the students as a process of sedimentation.

Excerpt 2 (reply to the question: Where do the materials that form soils come from?)

Agustín	Let's see. Where do the materials that form soils come from? Are they always above the materials from which they originate?	Focussing on the question
Alfonso	No	
Agustín	First question. First things first. Don't start at the end. Where do they come from? Do you know?	
Afonso	From other materials	Claim
Agustín	From the parent rock....	
Alvaro	That's it	
Agustín	They come from the parent rock	
Agustín	The parent rock ...that was eroded	Claim and warrant
Antonio	Are they always above it?	
Alfonso	Listen (directed at Agustin) the question is that you can't make something from nothing	Challenge

Agustín	What?	
Alfonso	In other words if there's no rock you can't make anything from it and you can't make something from nothing	Challenge
Agustín	But look, listen, listen, listen... where do the materials that form the soil come from? Where do they come from? From the parent rock	Claim
Antonio	But, are they always above?	
Agustín	Well, that's another question	
Agustín	Why do they come from the parent rock?	
Alvaro	Because it was eroded	Warrant
Alfonso	Because you can't make something from nothing	Challenge
Agustín	Of course, so they come from the parent rock...	Claim
Alfonso	Why can't they have come from a piece that broke off from the rock?	Challenge
Agustín	But that piece is the same as the parent rock.. it's part of the parent rock	Warrant
Alfonso	.....but before that it was magma	
Agustín	Well... it comes from the parent rock just the same, the parent rock breaks and makes sand, the sand gets broken up and makes earth, it makes everything, they come from the parent rock	Backing
Alvaro	Everything comes from the same place	
Alfonso	Ha, ha, that made you work, eh!	

This argument is practically constructed by Agustín alone and he supports it with basic knowledge of external geological processes. Alfonso opposes him by stating that the parent rock cannot form soil as it does not form a part of it. He expresses this with the phrase *"you can't make something out of nothing*" However he ends up by giving support to Agustín's proposal by asking "why can't it have come from a piece of rock?", because the reply to this is the conclusion established by Agustín.

The stance taken maintained by Alfonso in this argument does not appear to be related to the substance of the argument (Fig. 3) but rather to assert himself within the group and dispute Agustín's leadership, an attitude that he displays throughout the course of the teaching unit. This explains why once the conclusion is finally established, Alfonso says to Agustín " Ha, ha, it made you work, eh!."

Figure 2. Argumentation scheme from excerpt 1

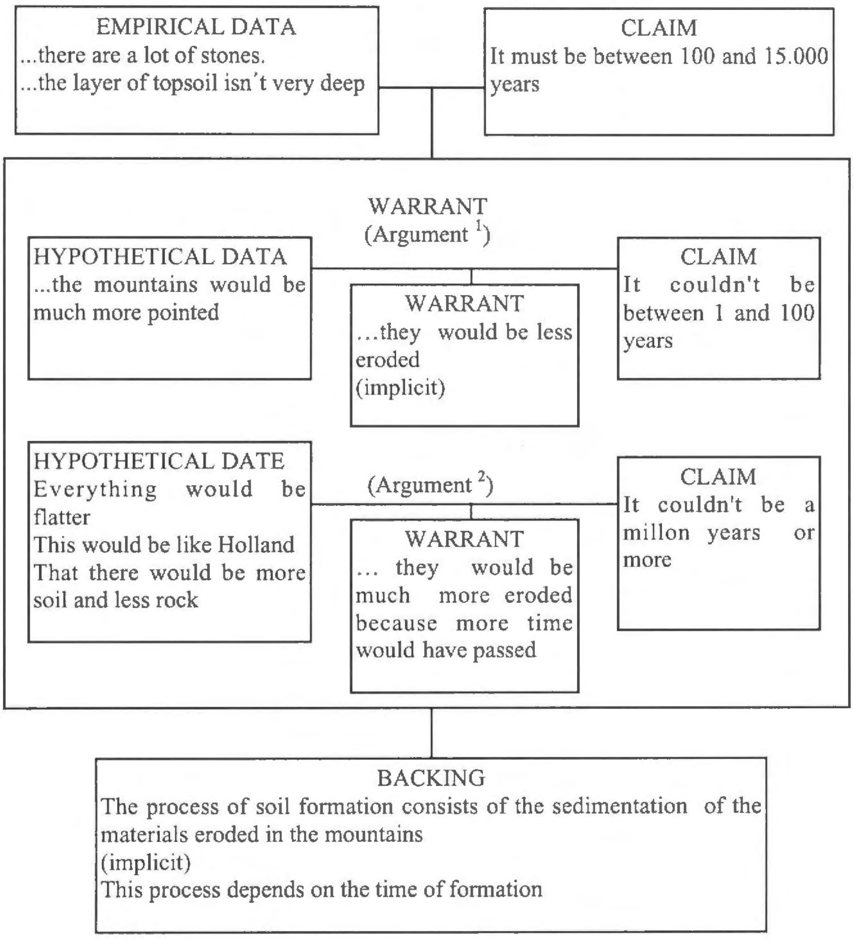
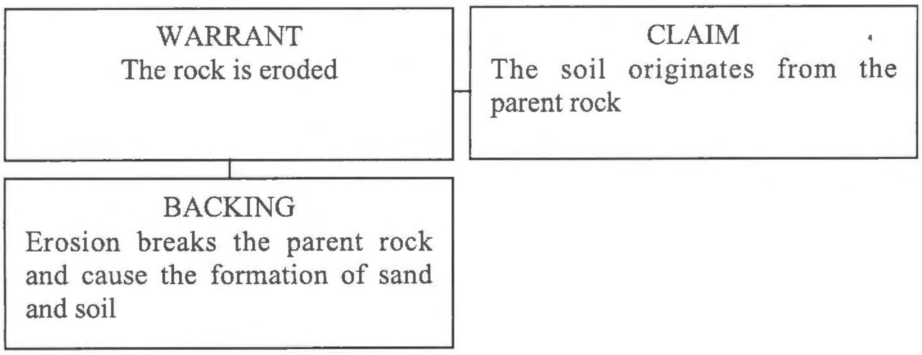


Figure 3. Argumentation scheme from excerpt 2.



Excerpt 3 (reply to the question: Why are soils fertilized with manure more fertile than those fertilized with inorganic fertilizers?)

Antonio	Why are soils fertilized with manure more fertile than those fertilized with inorganic fertilizers?	Focussing
Antonio	Because the ones that are fertilized with manure have got more....	
Álvaro	Because manure's better than fertilizer	Claim
Agustín	Its all fertilizer, man!	
Álvaro	Manure's better	Claim
Antonio	Fertilizer's 5x5x5 isn't it?	
Agustín	Or 15x15x15, or 10x10x10. It depends what you use it for	Backing
Álvaro	10x10x10?	
Agustín	10x10x10 is for lawns, 15x15x15 is for grass for feeding cows and I don't know what 5x5x5 is for. For house plants	Backing
Alvaro	And 4x12x8, what about it?	
All	Laughter	
Agustín	I've only heard them talking about these	
Alvaro	For potatoes	
Alvaro	A lot of people use 4x12x8 on potatoes instead of manure because 15x15x15 is really strong	Backing
Agustín	Of 15x15x15, but they don't use much	
Álvaro	15x15x15 is the strongest of all of them	Backing
Agustin	I know, it's nitramon	Backing
Alvaro	You can use it on the roots of pine trees ...	
Alvaro	...you put it on the roots and they grow faster. You make a hole...	Backing
Agustín	15% N, 15% K and 15% P	Baking
Álvaro	You put the fertilizer in the bottom and the pine tree on top	Baking
Antonio	But do you not put the fertilizer on top?	
Alvaro	But you can't touch the surface...	
Alvaro	..because if you touch the root it burns	Backing
Agustín	Yes, it burns and dies	Backing
Antonio	But if you put it in the bottom of the hole you would burn the roots	Backing
Agustín	You put it in the bottom and put a layer of soil on top, add some water and it dissolves, then after all that, you put it in	Backing
Alvaro	Yes, the pine tree on top and that's it...	

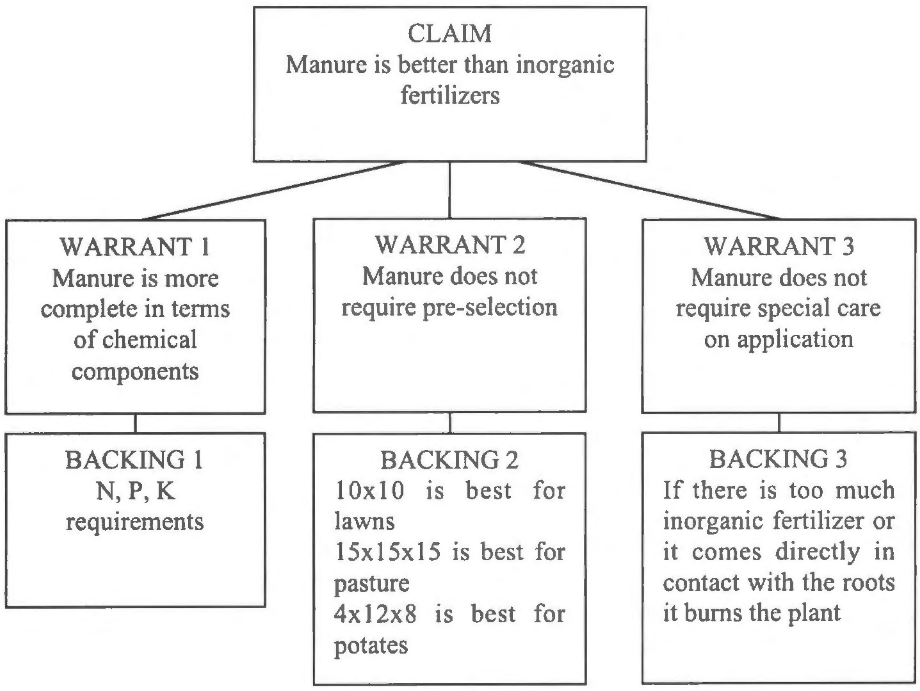
Alvaro	, and now we've finished doing that...what... we're not here to talk about pine trees	Focussing
Antonio	I'm going to see if I can grow canes, man	
Agustín	What?, what?	
Antonio	Canes	
Agustín	Canes?...these..	
Antonio	Of bamboo	
Agustín	There's tons of them on our land	
Alvaro	Where I live too	
Antonio	I've got about five, just small	
Agustín	If you came there man... they must be a metre high or more...	
Antonio	And that's a lot, is it?	
Alfonso	You get them four metres high	
Agustín	Mine, well they're not mine, I haven't got any, the ones that are there are about 2 or 2.5m	
Alfonso	There beside the river they're about 4 metres high	
Agustín	***I can't reach them***	
Antonio	They grow at the river because there's water	
Agustín	They've got to have water, or else...	
Agustín	Right, come on, work...inorganic fertilizer	Focussing
	They read in silence	
Alvaro	I put it like this.. because the manure	
Agustín	Is better than the....	
Agustín	Let's see... let's find it in here, does it put it here or not (reads a page from the dossier)	
	They read in silence	
Antonio	Because since it's got more chemical components and..... it fertilizes the plants better, and the soil	Warrant

This argument (Fig.4) is the least clear of the three analyzed and at the same time, the conclusion is more indirect and less convincing to the group. In fact the group discussed the topic again because of Agustín's doubts about the conclusion. The first warrants were supplied by Antonio *"..those fertilized with manure have got more..."* and by Agustín, when he lists the different kinds of inorganic fertilizers in a statement that he completes when he outlines the use for each one.

This argument shows two clear differences from the previous ones. Firstly, in the use of warrants and backing obtained from the pupils' own experiences. All come from families in which agricultural and farming activites have an economic significance. The second difference is that the

discussion diverges to topics that are related but do not come into the argument. For example, Antonio leads the conversation on to the cultivation of bamboo when he comments " I'm going to see if I can grow canes, man".
Later on, outwith the fragment of the transcription shown here, the same happens again. This time it stems from an attempt to find a relation between the food that animals eat and the value of the fertilizer they produce. Comments are made about the problem for rabbits on ingesting a plant known as "maruxa", as when they eat it they die. The explanation for these divergences also lies in the relation between the argumentation and the pupils' own experiences.
The activation of existential knowledge by posing a question that seeks conclusions similar to those found in formal scientific knowledge is interesting. It enriches the argumentation and leads to the use of many backings that strengthen and consolidate the conclusions.

Figure 4. Argumentation scheme from excerpt 3.



4 Educational significance

The first results of this study allow us to confirm that the learning environment generated by these tasks encourages the pupils to reason and argue in scientific terms. Our observations have revealed that the conversations focussed mainly on the discussion of students' ideas. The pupils frequently referred to their personal experiences during the argumentation, and this is probably made easier by the learning environment generated in open situations. The roles played by the pupils and the teacher in the class were different to those in traditional classes and furthermore, the classroom discussion was not dominated by the teacher. This allowed the discussion to be enriched by the contribution of the pupils' knowledge, gained from their lives in a rural environment.

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ANALYSIS OF THE WRITTEN DISCOURSE OF STUDENTS OF FIRST LEVEL OF HIGH SCHOOL ABOUT THE CONCEPTUAL FIELD OF RESPIRATION

Oscar Tamayo Alzate & Neus Sanmartí Puig
Universidad Autónoma de Barcelona

Abstract
At present, the importance that studies about language have for science education resides in a wide range of aspects, from which we want to highlight only two. First, the central function of language as a communicative tool is privileged within the educational field. Second, we consider language as a mediator and regulator of students' thought development. In this work we emphasise the importance and necessity of the study of language concerning teaching processes and science learning. For this purpose, we initially intend to focus on the study of some aspects of the communicative function of language. Then, we will focus on the study of the elements related to the semiotic function of language, next we will stress some topics related to language as a regulator of different central processes in science education. Finally, we will show partial results on the analysis of texts in the conceptual field of respiration written by students in the first level of high school.

1 Introduction

In this study about students' written discourse, we will focus mainly on the existing relationship between discourse elaboration and scientific concept formation and evolution. In science education, it's interesting to know the interdependence between discourse production and conceptual construction. This interdependence constitutes one of the central cores, that conducts leads to the concept formation, to science learning and, as a last resort, to thought structuring. In this sense, in the study of discourse, we are initially interested in identifying possible linguistic obstacles, which in conjunction with the epistemological and ontological ones, are taken as an initial point of reflection, which orientates the educational intervention in a particular field of knowledge.

One of the most relevant aspects of language function in the concept construction in science, is the linguistic contribution to the development of abstraction and generalisation processes. When a scientific concept makes part of the formation process, the acquisition of scientific language, associated to this formation produced. This implicates the acquisition of a new semantic structure as well as a new form of thinking and seeing reality. New language makes students' attention to be moved from the sign-object relationship to the sign-sign relationship. In giving a certain meaning to a word, we find ourselves above all facing a generalisation. The word is then a verbal act of thought and its meaning should be considered not only as a thought and discourse unit, but also as a generalisation and communication unit. (Vygotsky, 1995).

The use of words and language is important in the action movement from the material level to the mental level. This makes possible to consider language as a regulator not only of its perception, but also of its representation and action. In synthesis, experience and language are two indiscernible factors during science learning (Sanmarti, 1997). Students should learn to talk about the processes seen in science classes, learn to observe, to discuss, to represent concepts and phenomena studied in different ways, as well as to regulate and to self-regulate the learning processes in which language plays an important role.

The here by presented research has the following objectives:

1. Characterising language used by first level high school students (16-17 years old) in the conceptual field of respiration.
2. Analysing the coherence, appropriateness and conceptual demand of the texts about respiration written by the students.
3. Identifying possible linguistic obstacles in the learning of the conceptual field of respiration by these first level high school students.

2 Analysis of the students' written discourse

The empirical studies of discourse in the classroom have revealed the implicit rules that take part in this discourse, its particular characteristics and the ways of using discourse by teachers to orient and to evaluate the learning process (Edwards and Mercer, 1987, Lemke, 1997). These studies have been done from different perspectives, among which, it is worth considering discourse as a bridge between cognitive and social dimensions (Cazden, 1990); in this case, cognitive and linguistic development is considered as a form of socialisation and cultural learning. Other studies consider language as cultural mediator for thought and action expressed in daily practices, whereas other perspectives affirm that cognitive development is socially and culturally conditioned (Candela, 1999).

The analysis of written discourse in the classroom must consider the structuring function that the context has in relation to the content that is taught. The meaning of abstract objects such as *mol*, *electron* and *gene*, is constructed not only through perceptive experience of students, but also through the ways of "speaking" about the evidence or the activity in the classroom. In addition to conceptual aspects, the students should learn to recognise when an explanation is valid and when it is not, they should learn how to speak, listen and direct discourse about the subject. In synthesis, they should learn not only the specific content, but also the rhetoric of scientific communication in the classroom.

The present importance of the studies about the rhetoric of science in the classroom (Candela, 1999; Jewitt, 2000; Lemke, 1997; Martins, 2000; Millar, 1998; Scott, 2000; Sutton, 1998a), has provided evidence that a new perspective for the analysis of language is appearing, in which conceptual, rhetoric and contextual aspects are considered as fundamental.

As last objective related to the language used in science classes, we attempt to identify some of the central aspects related to the analysis of written discourse. We can do it from two perspectives: structural and functional. The structural dimension centres discourse meaning on the function of words, propositions and sentences that constitute it, based on logic rules. The expression structures are considered as meaning structures, which can be obtained by means of the analysis of sentence sequences. This first aspect of written discourse analysis permits to find out how sentence sequences of a discourse are related to the basic propositional sequence, and how the meaning of such sequences is a function of the meaning of the constituent sentences or propositions. Within this type kind of written discourse analysis, the generalised use of causal connectors is intimately related to the kind of explanation and the kind of thought used by students.

At present, it is recognised that not only logical connectors unite sentences and propositions in a written discourse. The influences exerted by the objects or phenomena about which the discourse is developed, moods and previous experiences are of great importance, too. In this sense van Dijk (1989) maintains that a smaller contribution to the global meaning of a discourse is derived from the facts denoted by the discourse, while a greater contribution comes from the own knowledge or beliefs about the situation.

Based on the previous ideas we want to emphasise on the second functional perspective that recognises the important influence of the subjective dimension in the use of language, (Berger and Luckman, 1984; van Dijk, 1989; Lemke, 1997, 1999, Scott, 2000). Subjective aspects determine which meanings receive special attention, which belong more to the scope of beliefs, previous experiences, and opinions, as well as how personal and contextual meanings are constructed.

As far as the analysis of written texts produced by students is concerned, we consider their study from a functional perspective of special importance for didactics of science. Although we recognise the value of syntactic aspects *per se* and their relevant function in the final construction of meaning according to the order of the words and sentences that constitute it, we mainly emphasise the study of meanings of the discourses based on the contexts in which written discourse is constructed. Therefore, we give special importance in our analysis to cognitive-linguistic elements summarised basically in the following general considerations:

- Written discourse analysis, as well as language analysis, allows us to approach qualitatively to different representations that students have about different facts or phenomena.
- Analysis of the written discourse produced by students in the classroom informs us about elements of different nature, which constitute central aspects within the representations made by them.
- Knowledge of students' alternative conceptions, as a way of representation, demands deep study of language, not only in its structure, but also in its function.
- Language is one of the essential tools for communication and structuring of thought. That is why the language is of great importance for the school.
- Scientific concept formation and the achievement of conceptual change are both in intimate relation with an adequate use of the scientific language, because to some extent it is considered impossible to separate them.

3 Research methodology

The investigation was carried out with a course of 21, 17-year-old students of grade 1 of Secondary School, I.E.S. Gorgs, located in Cerdanyola del Vallès, (Barcelona). In order to collect the information, a questionnaire was designed and validated in which a series of open questions were proposed to the students. The principal goal of these questions was to encourage students to write the response to the question or the formulated problem. The analysis of the information was made in long texts (5-15 lines). The linguistic as well as conceptual analyses (Tamayo, 1999) were accomplished taking into account not only long texts, but also short expressions (2-3 lines) produced by the students.

In our research, the long discourses on respiration produced by the students were analysed and possible important cognitive-linguistic obstacles in the learning of this conceptual field were identified. The different conceptualisations of students were evaluated according to three criteria: *coherence*, *appropriateness*, and *conceptual exigency*. These criteria allowed us to make an initial characterisation of the kind of discourse used by the students. In this characterisation we determined the *coherence* criterion as a central aspect, while we considered the other two criteria of analysis as contribution to the central one.

Coherence: Written discourse coherence is determined not only by the sentence order, but also by its meaning in a certain context; it can be global or local. Local coherence is in intimate relation with the sequence of sentences that constitute the discourse; it can be conditional, when the conditional or temporary relations have priority among facts or actions; or functional, when propositions have a semantic function by themselves defined in terms of the relationships with previous propositions (see figure 1). In this second case, a proposition can act as a specification, an explanation, an example, a comparison or a generalisation with respect to previous propositions (van Dijk, 1989).

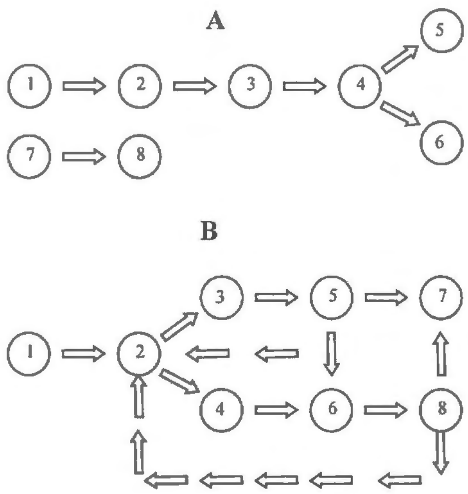

Figure 1: Concept representation of local and functional coherence with a group of 8 different variables used hypothetically in students' written discourse. In scheme A, corresponding to local coherence, a cascade disposition can be observed for each of the different variables used in the discourse. It is worth noting the insignificant interrelation established among them and the possibility to find groups of unconnected variables. In scheme B, corresponding to functional coherence, a different organisation of the same number of variables is observed, functionality of variable 2 stands out in the organisation of students' written discourse; in this is assumed, case the presence of a variable or a concept around which the other variables used by the students are organised.

The most important element in the semantic information of the written discourse is the explanation contained in its macrostructure or global coherence; without this, it would not be possible to control the local connections already done and those that come after them. The absence of global coherence make student connect sentences in an appropriate way by following local coherence criteria. In other words, global coherence of the text orients the establishment of relationships between the different propositions and a sentence used in the discourse and, besides, it is semantic information that provides total discourse unity. In the analysis of students' written discourse, local and global coherence determine its multiple meanings, in addition to the context in which the discourse is generated.

Appropriateness: This evaluates students' written discourse according to the different paradigms that have historically prevailed in the conceptual field of the respiration. It should be noted that the appropriateness of these constructions was evaluated based on the paradigm to which they belong, and not the paradigm that is currently accepted for the conceptual field of respiration. In the study of respiration, we consider as central paradigms the following: vital breath, gas exchange, combustion, oxidation and chemi-osmotic connection (Tamayo, 1999). As illustration of the previous consideration, we are presenting two answers to the questions: *When you exercise, have you noticed that you breathe more quickly than when you rest? Why do you think there is this difference in respiration?* First of texts belongs to the paradigm of the respiration as gas exchange,

> *This difference in respiration is due to our consumption of oxygen. When exercising we make an effort, so we consume more oxygen because our muscles need more blood, then, our heart pumps more frequently. According to the exercise that we are doing our respiration will be aerobic (with oxygen) or anaerobic (without oxygen). Sportsmen recommend not to stop immediately, but smoothly when you finish an exercise so that the heart relaxes regularly (Maria).*

and the second text belongs to the paradigm of combustion at a cellular level.

> *When doing unusual activities such as walking, running, etc., the cells of our organism need more oxygen, because they " burn " nutrients by means of oxygen in a process called cellular respiration to obtain more energy for this activity. This energy must be very high when we exercise, for that reason much oxygen is needed. Based on this, first we must catch that oxygen and we have the respiratory system to do it (Carlos).*

Conceptual exigency: We considered pertinent to include the number of variables used by students within the analysis that we made as a conceptual exigency of their written discourse. As an example we present the text produced by Ana, in which we identified the following central ideas: taking oxygen from the air, combustion, gas exchange, energy obtention and blood irrigation.

> *We take oxygen from the air and it goes to the lungs where combustion takes place where carbon dioxide is comes off and oxygen remains. This helps us to obtain energy that goes to the heart, and the heart will pump blood (that takes oxygen) to all parts of the body. (Ana).*

Joint analysis of coherence, appropriateness and conceptual exigency in students' written explanations allows us to go over the central aspect within the cognitive-linguistic analysis that we proposed: the kind of discourse and its sense, one of the aspects that we will develop next.

4 Analysis and discussion

The written texts were analysed from two perspectives: structural and functional. Next we will talk about each one of these analyses. 70% of analysed texts have simple causal structures, in which variables or concepts are presented in a linear way. Without going deeper into these aspects, it is at first important to recognise the prevalence of causality and causal thought in the training group, and with these aspects the production of causal discourses by students.

From a functional perspective, consideration of multiple epistemological, ontological and cognitive-linguistic influences in written discourse analysis provides us valuable tools to understand its global coherence. The last of these aspects is the most relevant information as far as the content of texts produced by students is concerned, so we will dedicate more attention to it in the analysis that we present in the following paragraphs. In synthesis, we orient the contribution of the analysis of coherence, appropriateness and conceptual exigency to the characterisation macrostructural of different kinds of causal discourse produced by students about respiration.

- **Causal discourse with low functional coherence**

The linear sequence of ideas united by temporary and/or conditional relationships is characteristic within this kinds of speech. For example, in *Maria*'s text, the identified facts or actions follow a sequence that includes 7 different variables used adequately within the paradigm of gas exchange, and located according to a causal order. The exposition of one or several sequences of relationships presented in parallel and not related to one another is characteristic within this kind of discourse (see table 1). In synthesis, several groups of variables or concepts are expressed independently without establishing possible relationships among them. We consider important to mention that the variables used in the explanation belong to the group of variables used historically for the explanation of respiration within the mentioned paradigm.

As an example, let's look at Ana's text shown in the previous page, in which we can observe conditional local coherence, that is a central characteristic in causal discourses. A particular aspect of this discourse is the presentation of proposition in a linear way, and the new exposed propositions do not have a specific functionality within the discourse (see table 1). It seems that the new propositions are connected with the previous ones spontaneously, the latter propositions determine the appearance of the new ones. In synthesis, there is a discourse in which the explanatory intentionality of the student is not clear, and the propositions used are not oriented towards a unified explanation.

As it was shown clearly in previous texts, we can find causal discourses in which not only coherence, but also appropriateness and the number of ideas used is to be different; nevertheless, this kind of discourse follows the same dynamics in its construction: its production responds to a space or temporary association of facts or phenomena, the product is a discourse with low functional coherence. In this type of texts it can be difficult to find the central meaning given by the student due to the absence of unified ideas or propositions around which the discourse is constructed as a whole. This absence of functional character in written discourse production can easily make a student divert from his/her initial explanatory intentionality and produce written discourse in the form of "mosaics" of ideas.
As a final aspect of this kind of discourse, we want to emphasise that the absence of a functional character is independent of the variables used in its construction, in such a way that it is possible to find texts with high functional coherence within paradigms that are not shared at the moment by the scientific community.

• **Causal discourse with high functional coherence**
We consider within this group of written discourses those that display functional coherence, and can have greater or smaller cognitive and conceptual demand. The aspect of greater relevance within these discourses is the recognition by students of some central propositions around which discourse is constructed. In this case, the student identifies the central idea and the sense that he/she wants to give to the discourse. Besides, he/she uses other ideas taking into account the unitary character of the discourse. In synthesis, the student puts to the service of his/her explanatory intentionality a group of ideas, each one of which has a more or less precise function within the final discourse. We illustrate some of the aspects mentioned before in the following text.

> *The cells of our organism when doing an unusual activity, such as walking, running, etc. need more oxygenation, because through a process called cellular respiration, they "burn " the nutrients by means of oxygen to obtain more energy for this activity. This energy must be very high when we exercise, for that reason much oxygen is needed. Based on this, first we must catch that oxygen and for it we have the respiratory system. Part of the air of our environment goes to the blood and the red globules are in charge to take it to the cells. As the cells need many nutrients and much oxygen, the heart works more quickly in order to "pump" more blood and therefore the respiratory system must take more oxygen. Due to this, we breathe more quickly. (Carlos).*

In the mentioned text, there are 7 identified different ideas (centred in the concepts of: cellular activity, oxygen necessity, nutrients, energy, respiratory system, blood and cell), which are related initially in a linear way and later they are interrelated (see figure 2). It is worth noting the clear definition within the paradigm of combustion at cellular level, with support of the paradigm of gas exchange.

We mainly centred the importance of this kind of discourse in the obtained final unity. It is a discourse in which the student uses concepts originated from different paradigms in order to achieve a global explanation. In synthesis, contradictions in the explanation given by the student are not identified; rather than contradiction, we found complementarity the explanation.

It is worth noting the important difference found between those who make explanations with greater conceptual content and these who limit themselves to use a low number of propositions. In the text produced by Carlos, there are a total of 7 concepts related to logical sense through 12 propositions as far as the respiration concerned, while Javier uses in his explanation 4 concepts (see table 1). The use of a greater number of propositions with logical sense within the field of study causes that the explanation given by the student is more complete. In Ausubelian terms we would affirm that Carlos's text displays a greater conceptual content in this field of study; or in terms of cognitive psychology we would talk about a conceptualisation with greater cognitive demand.

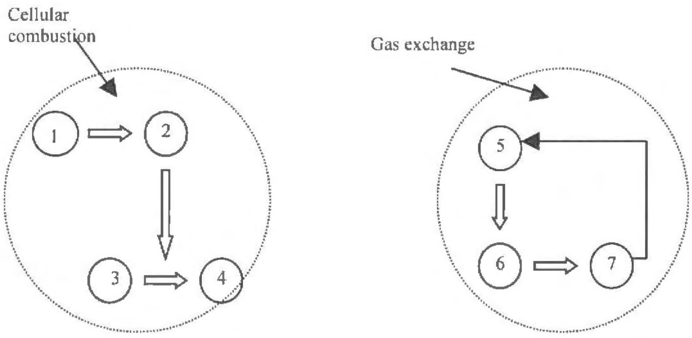

Figure 2: (a) The figure outlines the relationships established by Carlos. The concepts of cellular activity (1), oxygen necessity (2), nutrients (3) and energy (4) are related linearly. It is interesting to note the organisation of these concepts with certain functional character, where concepts 1, 2 and 3 are used based on concept 4. The concepts presented in figure 2b are related more directly to aspects that deal with the gas exchange process. In figure 2a as well as in figure 2b, certain functional character in the explanation given by Carlos is observed. Analysing the relationships established between two groups of concepts, this functionality is more noticeable. In the relationships between two groups of concepts, the concept cell (7) acquires importance, and is related to oxygen consumption (2) as well as to the use of nutrients (3). In addition, we emphasise the use of summarised expressions in the discourse, such as: "based on this, first ", " due to this ", which reinforce the functional character of Carlos's discourse

- **Mixed causal discourse**

We could initially say that this kinds of discourse is halfway between the other two kinds mentioned before. The relationships among the propositions have certain character of functionality; nevertheless, the sequences of propositions in cascade are preserved, which leads to a text production where the predominance of either local coherence or functional coherence is not easily observed.

> *There are two processes in respiration: inspiration and expiration. Inspiration is a process in which we take oxygen. Lungs are filled with oxygen and oxygen combustion takes place in the cells. Expiration is the process in which we release CO2 from our body. Lungs return to their normal state. (Marta).*

This kind of texts needs our attention in the sense that it does not follow rigorously a causal sequence of conditional propositions as in Maria's or Ana's cases. In other words, it is a text in which some functional intentionality in the student explanation is demonstrated. In addition, certain "effort " is observed to produce an explanation that is not to be restricted to space and temporary conditioners of simple causality. Besides, the mentioned text is very different from texts with functional coherence, as in Carlos's case (see table 1).

We basically centre the importance of the different kinds of discourse described previously for didactics of science in the existing relationships between their production and the formation and evolution of scientific concepts. The interdependence between discourse production and conceptual construction is one of the central strands that leads to concept formation, science learning and finally to thought structuring. In this sense, in didactics of science, the study of written discourse should be oriented initially to identify possible obstacles in the linguistic sphere, which in conjunction with epistemological and ontological obstacles would be a point of initial reflection that orients the didactical intervention in a certain field of knowledge (see figure 3).

5 Conclusions

Now we want to summarise the main characteristics of the written discourse of the studied group:

- The analysed texts showed local conditional coherence. 70% of the studied texts belong to this category.
- As a consequence from the previous point, the sequence of the analysed texts is linear; ideas are related by means of causal connectors.
- The identified functional coherence in the training group tends to be low. Only 22% of the analysed texts showed functional coherence.

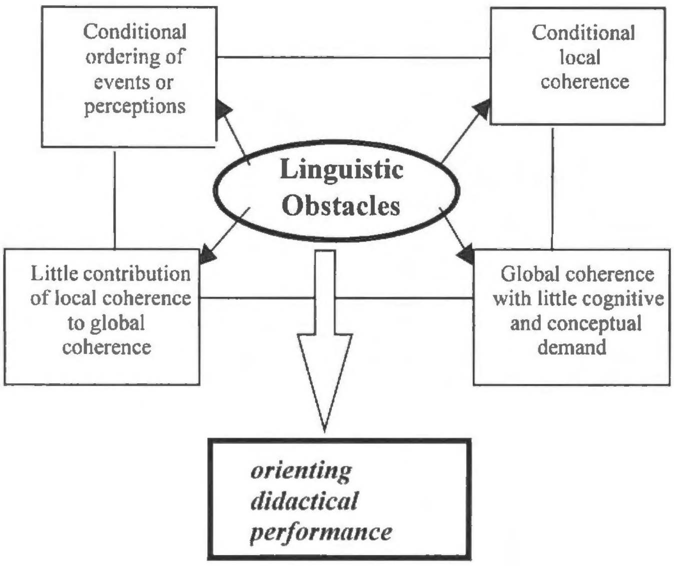

Figure 3: Main linguistic obstacles identified in texts produced by students and their importance for didactics of science.

- Since global coherence depends on the specific topic, it is important to note students' tendency to make conceptualisations in which a clear global structure is absent. In other words, low global structuring was found in students' expressions; these belong to one or other paradigm of respiration. From this point of view, sentence sequences connected by causal connectors are frequent; the function of each sentence within the whole text is not clear.
- When considering global coherence as the most important aspect of written discourse analysis in science classes, we can find high or low quantitative or qualitative estimations. In these estimations, "cognitive demand" of conceptualisation and its content rich in concepts play a central role. In synthesis, global coherence of the analysed texts seems to depend extremely on the use of a low number of sentences organised sequentially, causing the production of coherent discourse production with little cognitive and conceptual demand.

In didactics of science, identifying possible obstacles -in our case, linguistic obstacles-, allows to define various central elements for didactical intervention, not only at the initial stage of programming, but also in all self-regulation activities of the teaching-learning processes.

Consequently, the aspects indicated before allow to a certain extent to orient didactical interventions, from a linguistic perspective, at least in the following senses:

1. Favouring non-linear discourse production in students.
2. Encouraging the gradual acquisition of a greater global coherence in the field of study.
3. Stimulating knowledge of the global structure of discourse and, within it, the contribution meaning of the different propositions and sentences that constitute it.
4. Using multiple representations of facts, phenomena, concepts and theories, as well as, relationships among them.

Partial results that we have advanced here are the first part of a written discourse study in science classes; this is an open and dynamic field that will undoubtedly permit in the near future better understandings of educational processes and science learning.

[illegible]

Text	Representation	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

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Section Four: ENVIRONMENTAL EDUCATION

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FLOWERS AND HORSES FOR GIRLS? ON GENDER-SPECIFIC DIFFERENCES IN NATURE EXPERIENCE, ENVIRONMENTAL KNOWLEDGE AND ENVIRONMENTAL ACTION

Susanne Bögeholz
Institute for Science Education (IPN) at Kiel University

Abstract
This paper reports on gender-specific differences in nature experience, environmental knowledge and environmental action in German adolescents. The analyses are based on a nation-wide, cross-sectional study (n=1243).
Female students report 11 nature experiences per month more than male students on all twenty nature experience items. Specifically, female students report more frequent and more appreciated aesthetic and social nature experience, while male students show more ecological nature experience. Frequency and appreciation correlate stronger in boys than in girls. Thus, the gender-specific difference in the ratios between appreciation and frequency is higher for girls, especially, highest in the ecological dimension. Female students know more plant species, but male students show higher action-specific knowledge and higher knowledge on global life support systems. Girls show higher motivation and intention for environmental action. Appreciation (frequency) of nature experience explains 32.9% (30%) of the variance in the intention to act in girls; and 30.2% (27.3%) in boys.
The higher frequency and appreciation of nature experience in girls is reflected in their higher intention for direct environmental action, especially, in the aesthetic and social dimension ("flowers and horses"). Because of the high difference between frequency and appreciation, girls also reveal the highest potential to respond to instructions promoting ecological experiences.

1 Objectives of this paper

Nature experience, environmental knowledge and environmental action are important foci of the didactics of biology. Nature experience and environmental knowledge contribute significantly to the intention for environmentally sound action; in addition to their instrumental value in fostering environmental action, they are of high pedagogical valence in their own right. Thus, the knowledge of gender-specific differences in any of these fields contributes to the gender-sensitive design of curricular as well as extra-curricular activities in biology didactics.

Nature experience is a powerful predictor of the intention for environmental action. Its influence is only surpassed by the influence of family and peers on the intention for environmental action (Bögeholz 1999a, b). Particularly, nature experience is a better predictor than environmental knowledge and than perceived environmental thread. It has also been shown that the frequency of nature experience corresponds with the appreciation of nature experience in students (Bögeholz 1999a, 2000).

This paper supplements the preliminary discussion of gender-specific differences in Bögeholz (1999a) by additional in depth-analyses of the question: Do male and female students differ in their nature experience, their environmental knowledge and their motivation and intention for environmentally sound action?

2 Theoretical background

Theoretical considerations as well as empirical studies point to the existence of gender-specific differences relevant to biology didactics. Differences can be found in the affective, the cognitive; and the performative domain.

Higher values for women and/or girls have been shown for affective aspects of the individual-nature-relation (Gifford *et al.* 1982-1983, Grob 1991, Szagun & Mesenholl 1993, Szagun *et al.* 1993). Female children display a greater emotional attachment for domestic pet animals than male children (Kellert 1985). This attachment results in a differing attitude towards educational encounters with zoo animals or biological exhibit specimens. While girls tend to explore their feelings and emotions, boys tend to search for factual knowledge (Tunnicliffe 1998). Consequently, there is evidence that pretty and cute animals are better known by girls (while fish and predators are better known by boys; Eschenhagen 1982, Kellert 1985). The relevance of affective approaches to the environment in girls expresses itself in above-average appreciation (and frequency) of social and aesthetic nature experience (see below; Bögeholz 1999a, Lude 2000).

Generally, boys display higher environmental knowledge (Arcury *et al.* 1987, Bögeholz 1999a, Eschenhagen & Schilke 1973, Gifford *et al.* 1982-1983, Grob 1991, Lyons & Breakwell 1994, Schahn & Holzer 1990, Zimmermann 1996). Knowledge of plant species may be higher in girls, however (see references in Bögeholz 1999a).

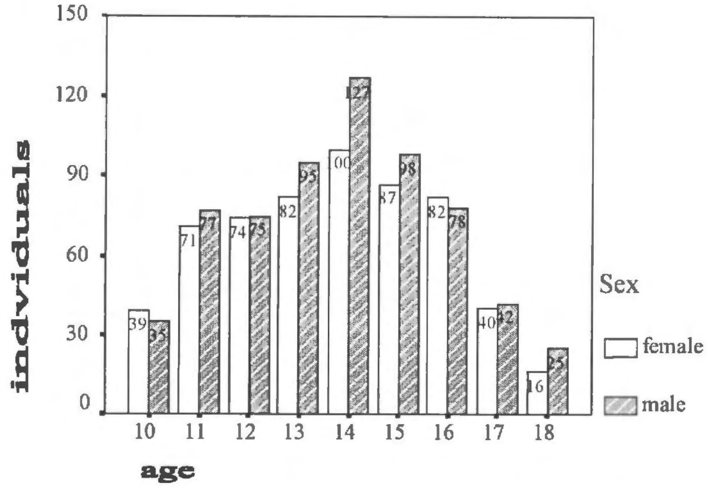
Regarding motives for environmentally "friendly" action, differences in environmental concern and attitude are well documented. For local issues – such as river/air pollution, waste disposal and houshold behaviour – women are more environmentally concernd than men (Blocker & Eckberg 1989, Schahn & Holzer 1990). While local environmental hazards qualify as "women´s issues" (Blocker & Eckberg 1989), there are not conclusive data on the concern for the environment in general (Blocker & Eckberg 1989, Davidson & Freudenberg 1996, Mohai 1992, Arcury *et al.* 1987). Environmental activism, however, is substantially lower for women than for men (Mohai 1992). Kals (1996:112) reports that sex is statistically correlated with eight out of eight "ecologically relevant attitudes" ("Bereitschaften") for environmental behaviour.
Regarding environmental action itself, the empirical results are equivocal. Grob (1991) finds that women act more environmentally responsible than men do, while a meta analysis indicates that there "appears to be no relationship between gender and responsible environmental behavior" (Hines et al. 1996/97:6).
The inability of some studies to demonstrate gender differences may be related to a subcomplex differentiation of the *different domains of environmental action* (cf. Diekmann & Preisendörfer 1992). The present study seeks to overcome this potential short-coming by a detailed assessment of different domains of action, such as nature conservation, waste, energy, and traffic behaviour. Additionally, the eventual formation of the intention for environmental action is viewed as the final step in a complex action-generation process (see Integrated Action Model, IAM; next section).

3 Research design and methodology used

Sample

The study is based on a nation-wide cross-sectional survey (n = 1243; 200 items-questionnaire) covering grade 5-13 of all school levels. The survey was conducted in winter 1996/1997 in five different German states. The questionnaire asks in four sections for (a) positively perceived nature experience, (b) environmental knowledge, (c) environmental action, and (d) for socio-demographic factors (Bögeholz 1999a: 213-237). Because the participants of the survey were recruited not only from school classes, but also from adolescent members of nature related groups, e.g. Friends of the Earth, Youth Scouts etc., an above average number of participants (54 %) was active in such groups. Of the participants, 52 % were male and 48 % were female students. Figure 1 depicts the sample composition. Boys and girls are nearly equally represented in all age classes.

Figure 1: Sample composition (n = 1243)



Assessment of nature experience

Nature experience (frequency and appreciation) was surveyed in five dimensions: aesthetic, scientific, ecological, instrumental, and social nature experience (Mayer & Bögeholz 1998, Bögeholz 1999a, Bögeholz *et al.* 2000).

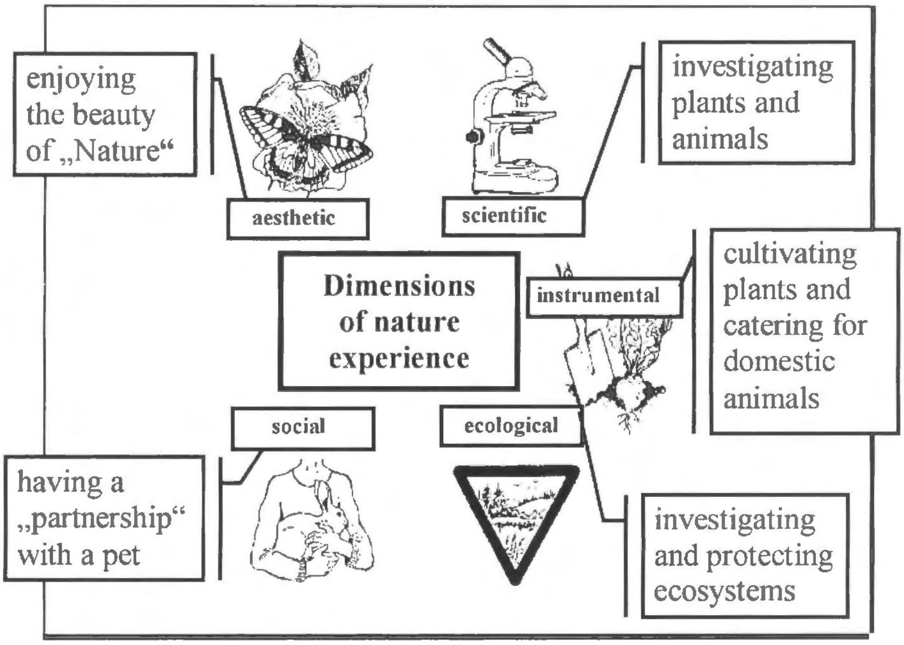
I used a four-tier answering format (see Tab. 1). For the statistical analyses, Coding 1 was used if an assessment of the absolute number of nature experiences per month was sought, otherwise I employed Coding 2 for measuring the frequency of nature experience as in Bögeholz (1999a). Appreciation of nature experience is coded exactly as in Bögeholz 1999a (0 = I do not enjoy it, 1 = I enjoy it a little, 2 = I really enjoy, and 3 = I enjoy it very much).

Table 1. Recoding of the frequency data of nature experience for Figure 3a

Relative response format	**Quantitative specification in the questionnaire**	**Coding 1** [times per month]	**Coding 2**
I never do it.		0.0	0
I seldom do it.	Maximum once a month	0.5	1
I often do it.	One to four times a month	2.5	2
I do it very often.	Minimum once a week	7.0	3

In order to calculate the appreciation/frequency-ratio of nature experience, Coding 2 was used for the frequency of nature experience. Additionally, '1' was added to all appreciation and frequency values to prevent divisions by zero. This re-coding operation results in a more adequate representation of the sampled population. Otherwise, important information on the appreciation of nature experience was lost for those participants who did not report any nature experience. It has to be noticed that the ratio itself represents only an abstract construct.

Figure 2a. Dimensions of nature experience



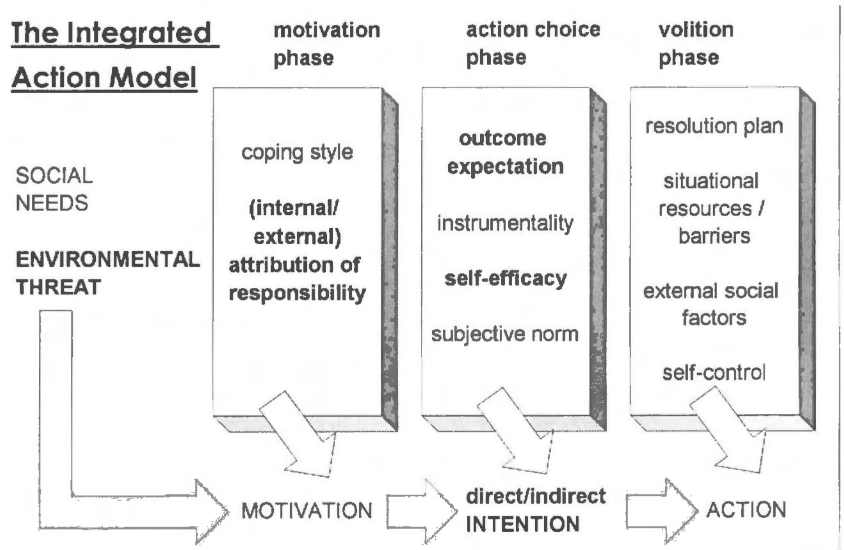
Environmental knowledge

Environmental knowledge on five topics –knowlegde of plants, knowledge of animals, knowledge on ecological concepts, action-oriented environmental knowledge, and knowledge on global life support systems– was sampled (for a more extensive explanation see Bögeholz 1999a). Trivially, environmental knowledge is expected to increase with age. Thus, in the analysis of environmental knowledge, age was used as a covariate. For all investigated constructs age in years showed a significant effect as expected ($p < 0.0005$).

Environmental action

I surveyed environmental action employing the Integrated Action Model (IAM), which integrates several psychological theories to reconstruct the action generating process (Rost 1997, Rost 1999, Bögeholz *et al.* 2000, Dempsey *et al.* 1997, Martens *et al.* 2000). Based on perceived social needs and perceived environmental threat, the model postulates three phases: (i) the motivation phase that leads to the formation of a motive, (ii) the action choice phase, resulting in the generation of an intention to environmental action, and (iii) the volition phase, concluding with the conduction of an environmentally sound action. Seven constructs of the IAM, which are potentially accessible by curricular biology education, were selected for this study (cf. Figure 2b, employed variables printed in bolt face).

Figure 2b. The Integrated Action Model (Bögeholz *et al.* 2000)



Social needs and environmental threat (as well as nature experience) are fundamental, initialising factors for environmental action. I assessed environmental threat because of the attention it continues to receive in environmental psychology, and because of the historical relevance of 'threat-based' instructions in environmental education. Within the motivation phase, I assessed to whom the participants attributed environmental responsibility (external attribution, e.g., attribution "to the industry" or "the state", and internal attribution to oneself). From the action choice phase, I investigated the outcome expectation and self-efficacy. Outcome expectation describes the knowledge and believe that a certain environmental action has the desired proximal effects. Self-efficacy measures the degree of competence feeling to perform the environmentally sound action.

The intention for environmental action is investigated for direct as well as for indirect action. The intention for direct action comprises the propensity of a person to act himself or herself, while the intention for indirect action measures the propensity to interact with other people as to induce environmentally sound behaviour in them.

Statistical data analyses

Statistical standard methods are applied (linear regression, t-tests). Explained variance is reported by adjusted R-square values (r^2_{KORR}). All calculations were performed with SPSS, version 7.5. Asterisks in tables and figures denote significance levels: ***: $p \leq 0.001$; **: $p \leq 0.01$; *: $p \leq 0.05$; $^{(*)}$: $0.05 < p < 0.10$ (tendency).

4 Results

Nature experience

The females of the sample are calculated to have 46 ± 1 (mean ± 1 SE) nature experiences per month on all twenty nature experience items. In contrast, male students report only 35 ± 1 nature experiences. Differentiated according to the five nature experience dimensions (see Fig. 3a), female students show more frequent aesthetic, instrumental and social nature experience than male students ($p < 0.001$). In contrast, male students experience nature slightly more frequently in the ecological dimension ($p < 0.05$). Furthermore, girls appreciate aesthetic, scientific, instrumental and social nature experiences stronger than boys do ($p < 0.001$; see Fig. 3b). Regarding the ecological dimension, the higher appreciation of girls is not statistically significant.

The *frequency* of nature experience explains 57,7% of the variance in the *appreciation* of nature experience in girls and 63,0% of the variance in boys. The regression equations are

$$\text{appreciation}_{\text{girls}} = 0{,}626 + 0{,}840 * \text{frequency}_{\text{girls}}$$
$$\text{appreciation}_{\text{boys}} = 0{,}434 + 0{,}907 * \text{frequency}_{\text{boys}}$$

Figure 3a. Frequency of nature experience dimensions (Coding 1) (mean of 4 items/dimension; ± 2SE, n = 1243)

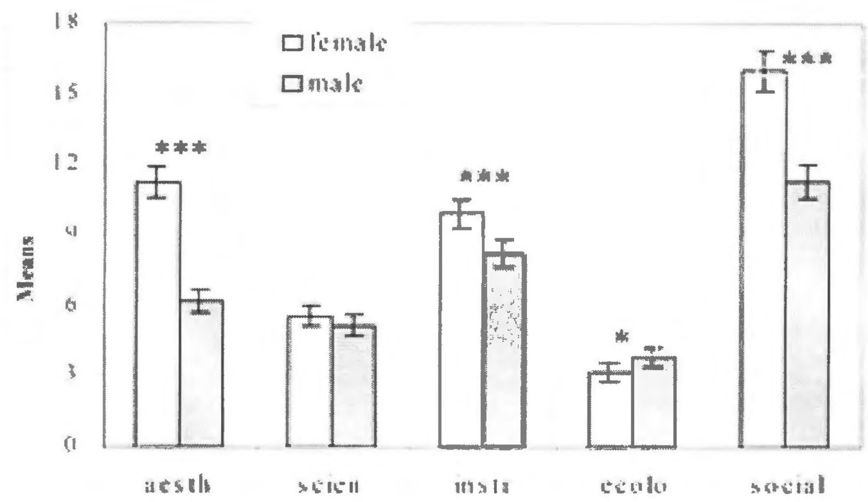


Figure 3b. Appreciation of nature experience dimensions (mean of 4 items/dimension; ± 2SE)

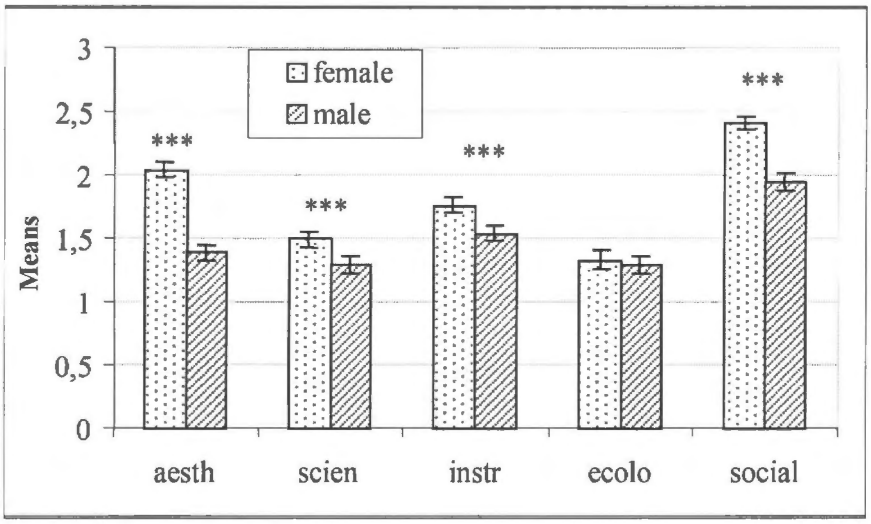


Figure 3c. Appreciation / frequency-ratios of nature experience per dimension à 4 items (mean of ratios ± 2SE)

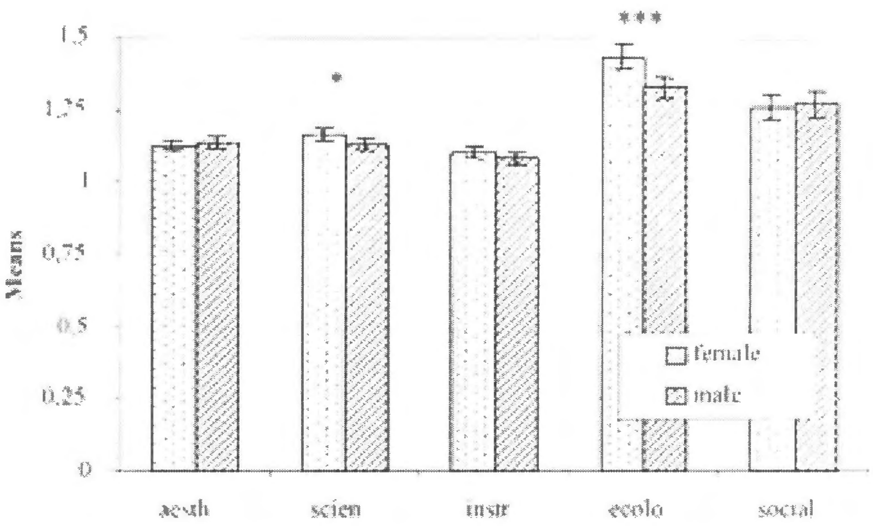


Table 2. Appreciation of nature experience explained by frequency of nature experience in female and male students (P-value = p-value of the differences between females and males in their correlations between frequency and appreciation)

Dimension	P-value	Females r^2_{KORR}	Males r^2_{KORR}	Difference in r^2_{KORR}
Aesthethic	0,350	0,671	0,659	0,012
Scientific	0,002	0,582	0,680	0,098
Instrumental	0,001	0,504	0,618	0,114
Ecological	0,011	0,415	0,511	0,104
Social	0,316	0,427	0,406	0,021

Regarding the correlation between frequency and appreciation of nature experience, boys show stronger correlations in the scientific, instrumental and ecological dimension than girls ($p < 0.05$; r^2_{KORR} about 0.1 higher; see Tab. 2). In the aesthetic and social dimensions, there are no statistically significant differences between boys and girls.

The results from the comparison of the appreciation/frequency-ratios of nature experience are displayed in Figure 3c. The appreciation/frequency-ratios of nature experience range from 1.08 (instrumental dimension, boys) to 1.43 (ecological dimension, girls). As these ratios represent an abstract number, it cannot be inferred that boys and girls "want more nature experience than they get" just because the ratio is > 1. However, a comparison of these ratios allows for a relative assessment of the relationship between frequency and appreciation of nature experience.

The gender-specific difference in the ratios is highest in the ecological dimension. The ratios are higher for girls in the scientific, instrumental and ecological dimension. The differences between boys and girls are significant for the ecological ($p < 0.0005$) and the scientific dimension ($p < 0.05$). For the aesthetic, social and instrumental dimension, ratios hardly differ.

Environmental knowledge

Female students show higher knowledge on plant species ($p < 0.001$; see Fig. 4). Particularly, girls know more common Angiosperms ($p < 0.001$), more cereal plant species ($p = 0.001$) and more trees ($p < 0.001$). Male students only show a tendency ($p = 0.069$) for higher knowledge on animal species. For insects as well as for birds, no significant differences were found. In contrast, boys know more fish species ($p < 0.001$).

For action-oriented environmental knowledge as well as for knowledge on the global life support systems, male students have more environmental knowledge than female students ($p < 0.05$). There are no significant differences between males and females concerning knowledge on ecological concepts.

Environmental action

For three of the seven investigated constructs of the I A Model, girls show significantly higher motivation and intention for environmental action (internal attribution of responsibility, $p = 0.023$; self efficacy, $p = 0.001$; direct intention, $p < 0.0005$; see Fig. 5). For the intention to direct action, appreciation (frequency) of nature experience explains 32.9 % (30 %) of the variation in girls; and 30.2 % (27.3 %) in boys (data not shown).

There are no differences between male and female students for energy saving in the household and personal use of public transportation; but there

Figure 4. Environmental knowledge with age as covariate (mean ± 2SE; n = 1243)

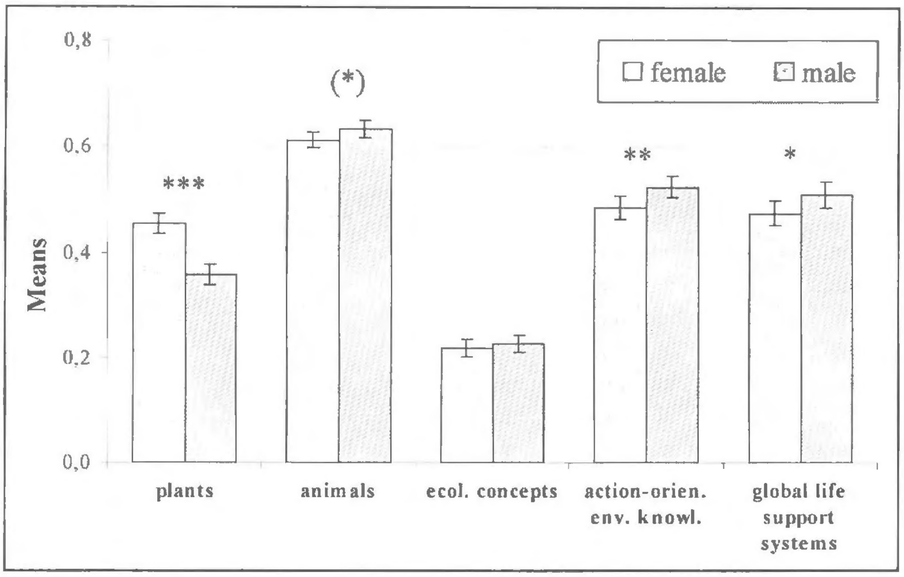


Figure 5. Environmental action-generation by selected constructs of the Integrated Action Model (mean ± 2SE; n = 1243)

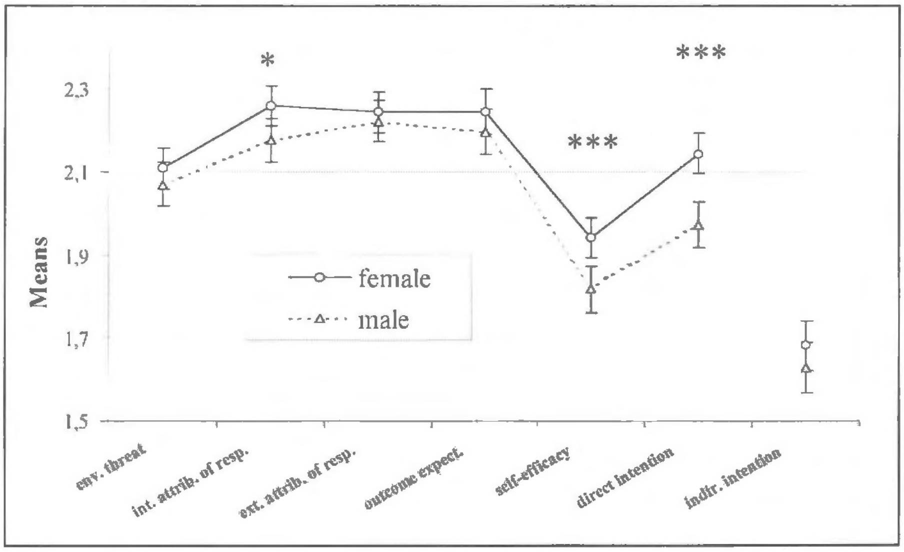
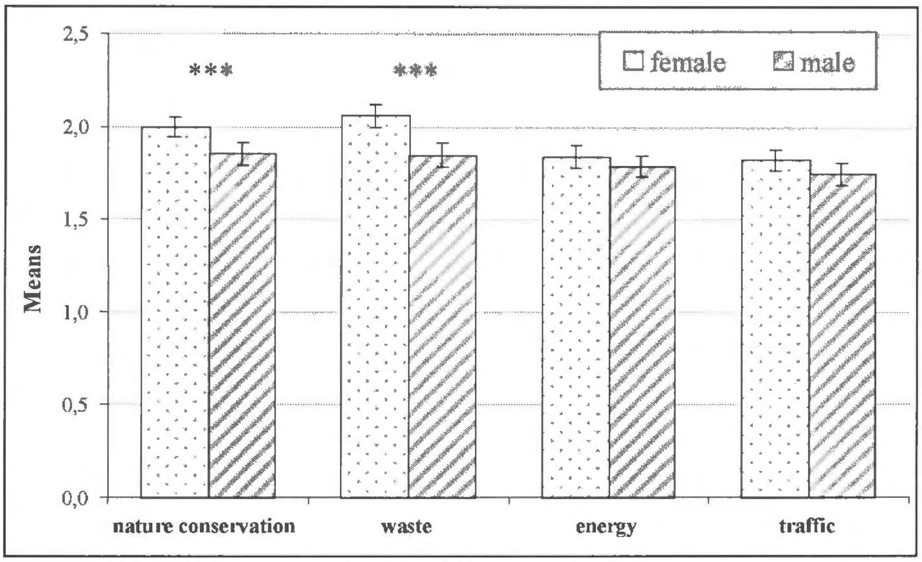


Figure 6. Area-specific intentions for environmental action (mean ± 2SE; n = 1243)



are significantly higher intentions of females concerning nature conservation and waste reduction ($p < 0.0005$; see Fig. 6).

5 Summary and discussion

The differentiated assessment of environmental knowledge presented here yields a more detailled pattern of gender differences than previously documented (Gifford *et al.* 1982-1983, Grob 1991, Lyons & Breakwell 1994, and Zimmermann 1996). Specifically, the highest difference is found in the knowledge about plants, where the suspected superiority of female students could be proven unequivocally. Male students showed slightly higher knowledge on global life support systems (cf. Arcury *et al.* 1987), and higher action-oriented knowledge. The general knowledge on animal species and the knowledge on ecological concepts hardly differed.

Gender specific differences regarding environmental action could be demonstrated for three out of seven constructs of the IAM, including the intention for environmentally sound action. Across all constructs, female students tend to report higher motivations and intentions. Focusing on area-specific environmental action, girls have higher intentions for nature conservation and for waste reduction. Silberzahn-Jandt (1999) and Schultz (1994) find that elaborate "waste cultures" exist among women that may also influence the waste behaviour of female adolescents – e.g. by compliance to a waste reduction culture in order to attain social recognition. In spite of the *statistically* significant differences, it has to be noted that gender has only a very weak effect on waste behaviour (cf. also Schultz *et al.* 1995). The effect on nature conservation is even smaller.

At first glance, the higher intention for nature conservation in girls seems to contradict the lower ecological nature experience – a dimension also operationalized by "nature conservation items", but the items differ in an important aspect. The items assessing the area-specific environmental action are of a "private" character focusing on the observance of conservation codes of individual behaviour. The items of ecological nature experience, however, mainly target group activities that aim at ecological problem solving or restoration.

There are pronounced differences between boys and girls in the frequency and appreciation of nature experience. It could be objected that the higher values of girls (especially in the aesthetic and social dimension) may be influenced by the greater willingness of girls to describe their feelings and personal experiences concerning their relationship towards nature (cf. Aho 1984). Even if this explanation was true, it would not explain why girls specifically appreciate ecological nature experience much more than they conduct it. This "nature experience gap" is demonstrated for the first time in this study (see Fig. 3a-c).

Regarding the nature experience gap, girls reveal high potential to respond to instructions that promote ecological nature experience, a crucial dimension for environmental action: (a) it is the only dimension of nature experience in which girls trail boys, and (b) the "gap" between appreciation and frequency of nature experience is highest here – as roughly indicated by the differing appreciation/frequency-ratios (see Fig. 3c).

Regarding possible reasons for the nature experience gap in the ecological dimension, the social setting in which ecological nature experience is carried out must be analysed. It is known that female adolescents spend much time in close-knit social groups, often even in close two-girl friendships (Fend 1998:328f). In contrast, male students tend to live in larger peer group "cliques". As ecological nature experience consists to a large degree of group activities akin to the social preferences of males, I suggest that the current mode of organized hands-on nature conservation activities for adolescents may carry an undiscovered structural gender bias. The high intention of girls for nature conservation activities in a private setting, and the skewed gender ratio in naturalist and conservation groups (Bögeholz 1999a) support this interpretation.

Which implications for the practice of environmental education should be drawn? Biology curricula that stress nature experience may help girls to catch up in those fields of environmental knowledge where they trail boys (action-oriented knowledge, knowledge on global life support systems). Especially the high appreciation of social and aesthetic nature experience in girls represents a hardly exploited resource to transport environmental knowledge. In so far, "horses and flowers for girls" represents a promising approach to an enhanced utilization of nature experience in group-specific environmental education or teaching of biological topics. The most promising approach, however, is likely to target the nature experience gap for girls in the ecological nature experience dimension.

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INTEGRATION OF ENVIRONMENTAL AND HEALTH EDUCATION IN CONTAMINATED AREAS. THE CONTRIBUTION OF BELARUSSIAN TEACHERS

Fred Brinkman
Hogeschool Holland. Diemen. The Netherlands

Abstract

Teachers participate regularly in in-service courses. The lesson material and the way in which we developed it was presented in one of the experimental schools to 35 science, biology and health teachers from the region during a one day in-service organised by the regional educational inspector. Next to the teachers, people from the Red Cross and the educational department assisted to the course in which the use of pupils' ideas and local contexts in lesson material was presented.

In this course the participating teachers developed a lesson in which they integrated man in a local food cycle. This is in contrast with the school curricula in which such an integration never occurs. Evidently, the concept that man is an integral part of the cycle in nature is easily acceptable for them.

Pupils' ideas are only used by half of the teacher groups. So this didactical approach presented in the teacher course is taken over less eagerly.

Local conditions are generally taken up by the teachers in their new lesson scheme. Although not present in the curricula, this contextual didactical approach meets no resistance in the Belarussian teachers.

Contamination with radioactive materials was integrated by the teachers in a variety of subject areas, like Biology, Science and Physics. This in contrast with the curriculum where we found 'radiation' treated as a subject on its own, separated from health and environmental subjects' areas.

1 Introduction

This paper is a part of the outcomes of the EC-founded research-project: *Living in contaminated areas*. (Brinkman,1999). The project pays attention to the continuing confrontation of the Belarussian population, in the Kostyokovichi region, with contamination of long-living radioactive isotopes persisting in the natural cycles of matter after the Chernobyl disaster. The communication about this topic between government and society is subject of study here. Especially future generations that have to live in areas that are still contaminated for the coming 100 years should be informed about the risks of the continuing contamination of their local foodcycle.

Our aim was to describe the character of the state of information for young people in contaminated zones as formalised in school curricula and practised in their education about health and environment. To do so we studied the role of the main factors in the flow of information: the government and related agencies, local educational authorities, the teachers, local communities and the children themselves.

In this paper we focus on the role of teachers in the curriculum development process that was started in the contaminated regions in Belarus.

1.1 The teachers and the preconceptions of their pupils

Teachers in Belarus are confronted with schoolchildren (12 -14 years old) that have their own ideas about contamination, health and environmental issues before they are teached about these subjects.

Via interviews, drawings and conceptmaps of Belarussian pupils we found .they think that radioactivity, once ingested, stays in their body, especially in the stomach, forever. Most think that the food goes not further either. The function of food is to still hunger, not the delivery of nutrients. The only nutrients they name are vitamins. Contamination is a sort of anti-vitamin that can be compensated by medicines, some say.

Pupils do not know that mushrooms from the wood can be contaminated. The recycling of radioactive materials in nature does not occur according to the pupils, because radioactivity, once in the soil, disappears. Human beings are no part of the cycle, animals are. Animals can ingest radioactive materials and will die of it.

Pupils did not refer to their own conditions of life and local circumstances in their preconceptions about food and environment (Kievits et al, 1998).

The teachers are not aware of these ideas of their pupils. as the current curriculum, formal as it is in its time schedule and subject-matter does not give much opportunity for interaction on these topics.

We investigated the formal school curriculum for lower secondary education and looked after the subject areas contamination, health and environment.. The most striking outcome was that the three subjects never were interrelated: environmental contamination did not occur in the health curriculum, the role of man and his behaviour in contamination did not occur in the cycling of matter and the flow of energy through life and contamination and its effects on men health and the influence on foodcycles did not occur at all.

We used the findings on the content and the time-schedules of these curricular subjects for integration into the pilot lesson series that we developed (Van den Akker, 1998)

We developed on this base lesson material about food, cycles and contamination in the Russian language. Included in the lessons were the preconceptions of the pupils we found and some real life contamination problems that we registered in the local community. Three schools in the contaminated region in Belarus. tried the two lessons out.

Pupils gave in general adequate solutions for the problems presented to them in the lessons and thus showed a better understanding of their environment and of the role of themselves in coping with contaminated food.(Kievits et al., 1998).

These outcomes and the development process of the lessons were subject of an in-service course we organised for all secondary school teachers in the Kastiocovice region.

1.2 The dissemination for teachers

Belarussian teachers in and near contaminated areas are concerned about the radioactive safety of their environment. Can we let the pupils swim in the river here? Why do we hear no results after we have seen passing the man who measures the radioactivity in the neighbourhood? are some of their questions.(Brinkman, 1999)

The lesson material and the way in which the material is developed was presented to other teachers in the Oblast (province)of Mogilev during an in-service course in order to spread the information and to let the teachers be aware of the integration of local context and pupils' ideas in the material and the positive effects upon the learning process.

To facilitate the implementation of our findings in Belarussian lessons, we asked teachers during the in-service course to develop their own lesson about contamination in a local food cycle for their own curriculum.

This paper will focus on the in-service course and lead us to the following research question:

In what way integrate Belarussian teachers local context and pupils' preconceptions in developing new lessons for cycling of matter in contaminated areas?

2 The in-service course

On Thursday September the 24th 1998 an in service course for teachers has been organised in co-operation with the educational department of Kostyokovichi in school number 4 of Kostyokovichi (see for the programme table 1). In total 35 teachers (from the Kostyokovichi region) from different disciplines participated in the course. Next to the teachers, people from the Red Cross and the educational department assisted to the course.

The first goal was to disseminate the found conceptions of the pre-research to (science) teachers and to health and educational authorities in the Oblast Mogilev. The way in which teachers could take the found conceptions into account in their own lessons was also discussed. A second goal was to increase the responsibility to one's own health. With the help of different case studies (see table 2) the teachers were shown that people in contaminated areas could make their own choices in relation with contaminated (food)cycles. Based upon this information teachers were asked to design their own lesson about environmental radioactive pollution their local area including pupils' conceptions. The designed lessons were presented and discussed with the participants of the seminar.

Four groups of teachers worked on the development of a lesson (see table 3) during the day. Each group was asked to use one of the case studies to make a cycle and explore the possibilities and difficulties for using this case in their lesson. The teachers presented their lessons at the end of the course via flap-over.

In what way the teachers take to local context into account can be found in the cycle (drawing) they were asked to construct. The pupils' ideas can be found in their lesson designs.

Table 1. Programme of the in service teacher course on Thursday the 24th of September in Kostyokovichi

Programme	
09.30 – 09.35	welcome (by deputy of the educational department in Kostyokovichi)
09.35 – 09.40	short introduction of project-members; programme of the conference
09.40 – 10.15	activity (HC test and drawing about teaching)
10.15 – 10.35	development of lesson material
10.35 – 10.45	discussion
10.45 – 11.15	three case studies (see table 2) and information about caesium
11.25 – 11.35	instruction of activity (use one of the case studies to make a cycle and explore the possibilities and difficulties for using this case in your lesson; see also table 3)
11.35 – 12.30	working on activity in four groups
12.30 – 13.00	lunch
13.00 – 13.30	working on activity in four groups
13.30 – 14.00	presentation of each group
14.00 – 15.00	presentation of Red Cross and discussion
15.00	closing (by inspector)

Table 2. Case studies

Case studies	
1	chicken are fed on a contaminated place and the eggs become contaminated too
2	contaminated wood is burned and the ashes are used as fertiliser for strawberry
3	horses eat contaminated grass and the horse-shit becomes contaminated

Table 3. The activity given to each of the four groups

Activity

Drawing a cycle

Draw a cycle in which Cs circulates making use of the case study available in your room. Add new steps in the case-study where needed to make sure the cycle is closed.

Make a lesson that focus on Cs leaving the body and Cs re-entering in the cycle

1 Write down for which grade and which curriculum subject the lesson is meant.

2 Write down three starting questions for pupils to activate their pre-knowledge and give the pupils' answers you expect.

3 Which information will be given to the pupils (in great lines)?
From what source (book or own information)?
How will the information be transferred to teachers and pupils?
Write down three questions that control if information is understood by the pupils.

4 Develop an activity for pupils in which they can apply the information that remediates on Cs-excretion and Cs-re-entry pre-knowledge in your cycle.

5 Write down three control questions for this activity.

Present your lesson

Use flap to communicate your lesson to your colleagues during the presentation.

3 Results

3.1 Local context

Each group made a drawing of a cycle in which the cycling of Cs is included.

The first group of teachers used the second case study (see table 2) and added grass and cow with milk. The contamination is not coming here from a nuclear power plant or another source but is already present in the local cycle. Different producers (grass, wood) and animals (including man) are represented, although reducers are .not included on the cycle.

The second group didn't use one of the case studies but present different sources of contamination caused by man. The spread of radiation is shown in various ways. Man is included and can become contaminated by Cs via various foods. But after Cs has left man by excrements, urine, endocrine system or even meditation the flow stops and no recycling occurs. Man initiates the contamination by using radioactive materials but doesn't hold a place in the continuous cycling of Cs. Producers and consumers are present in the cycle, reducers aren't.

The third group used the first case study (see table 2) and added rain and man in the picture. This drawing shows a permanent input of caesium via rain. In this picture are reducers (bacteria) present next to producers (wheat) and consumers (chicken and man). Although the reducers only reduce (faeces from) consumers, no producers.

The fourth group used the third case study (see table 2) and added rain and man. The rain gives a permanent input of caesium. After the contaminated wood is burned in the stove, the radioactivity stays in the ashes. But the ashes are not used for something else, the cycle stops there. Reducers are not present in the picture but producers and consumers are.

The case studies were used by three of the four groups. All groups integrated man in the cycle.they constructed Next to producers and consumers, reducers (bacteria) are only present in the cycle of the third group. In three pictures rain causes a permanent input of radioactivity.

3.2 Lesson design

The groups were asked also to produce a lesson design about contamination for a curriculum of their own choice. In table 4 the lesson designs of the four groups are presented.

The designs were made for different subjects and different grades: physics (8^{th} grade), special course (9^{th} grade), universe (6^{th} grade) and biology (9^{th} grade) respectively.

Every group has integrated some questions for checking knowledge and/or questions for those who didn't understand the topic. However the starting

questions for pupils to activate their pre-knowledge are only mentioned by two groups (group 3 and 4), without the expected answers. So only group 3 and 4 made adequate use of pupils' ideas in their lesson design.
The way of transferring information to the pupils is a form of one-way communication by the groups 1, 3 and 4. The teacher gives the information.
The activities for applying the information in a cycle are not very clear. Group 1 only talks about self work, without identifying what should be done. The second and fourth group are talking about concrete examples without giving them (maybe the are referring to the cycles they construct earlier). The third group uses the cycle they constructed before to apply the new knowledge in the local context.

4 Conclusions about the development of lessons

Knowledge is not an objective in itself, but that it has to be applied to everyday contexts to be accepted as valuable knowledge (Fensham, 1994).
Teachers developing a lesson in the in service course integrate man in their local cycle. This is in contrast with the school curricula in which such an integration never occurs. Evidently, the concept that man is an integral part of the cycle in nature is easily acceptable for them.
Pupils' ideas are only used by half of the teacher groups. So this didactical approach presented in the teacher course is taken over less eagerly. It could mean that in their conceptions about teaching, the teachers stick to a teaching concept that takes less into account the ideas of their students.
Local conditions are generally used from the information presented in the course. Although not present in the curricula, this contextual didactical approach meets no resistance in the Belarussian teachers.

5 Discussion

Seeing the different courses for which the teachers designed their lessons (see table 4), the subject 'contamination' is not restricted to one specific subject. It can be integrated in a variety of subject areas, like Biology, Universe (the General Science course) and Physics. This in contrast with the curriculum where we found 'radiation' treated as a subject separated from health and environmental subjects' areas. The subject radiation can also be taught for pupils from different ages, seeing the levels (6^{th} till 9^{th} grade) for which the lessons were developed.
In Belarus every subject has it's own programme fixed per grade. In the programmes is exactly indicated what the teacher should teach and how much time this takes. Even for a lesson of one hour it's indicated what

Table 4. Summary of the developed lessons by the four groups of teachers

	Group 1	Group 2	Group 3	Group 4
Subject / Grade	Physics / 8th	Special course / 9th	Universe / 6th	Biology / 9th
Starting questions with expected answers	-	-	What associations do you have when you hear the word cycle ? Name the simplest food links in the cycle. How can Cs get into an organism? *no expected answers given*	Why does a man need food? What way does food go in the organism? What do you know about radiation? With which radioactive element is our region contaminated? What are the ways of getting rid of radioactive elements from organisms? *no expected answers given*
Information given to the pupils	Information about radiation and radioactivity. And the influences of radiation on man. Using local examples (hey, wood, cow, house, stove, milk, man and bread) to show the cycle of Cs.	The basics of security of life activities (so called special course) Technical and natural catastrophes Radiation Geography of radioactive contamination of the Republic of Belarus	Talking using the scheme of cycle: producer → consumer ↖ ↙ decomposer	Radioactive elements and their influence to organism. Cycle of Cs in nature. Ways of getting Cs into organism. Ways for removing Cs from the body.
Source	-	The map of contaminated territories of Republic of Belarus. Tables and posters. Textbooks and methodical literature.	-	Scheme of cycle of Cs in nature. Table digestion .
Way of transfer	Lecture	Discourse with pupils	Lecture	Lecture
Three question to control if the information is well understood by the pupils	Why do we study this question? The ways of getting rid of Cs from human beings. What are the measures of protection against contaminated Cs 137?	What is a catastrophe? Consequences? Concept of radioactive radiation. Radioactive substances and their half-life. Contaminated territories in Republic of Belarus. Contamination of given territory (Kostyokovichi).	Draw a scheme of cycle and show how Cs gets to organism. Finish the given scheme of cycle and show the source and the ways of removing of Cs from organism.	What radioactive element is the most dangerous for humans in our region? How long does Cs stay in the organism? How can you fasten the process of removing radioactive Cs from the body. organism?

Activity in which the information can be applied in a cycle.	Self work	Individual working with a concrete example.	Make up the parts of a cycle. What is the role of decomposers? What do you think, will one meat of chicken be contaminated?	Discussing the concrete information.
Three questions to control the activity	How Cs influences the man organism? What are the results of this influence? How it gets to organism? How to fasten the process of removing radioactive Cs from organism? Suggest the ways for limit the intake of Cs in the organism.	To ask leading questions on different topics.	What are the ways to remove Cs from the organism? How to prevent the contamination of chicken? How will the cycle change if you remove one of the components of cycles?	Stimulating of students activity
Conclusion	Radiation exists in our region. We live with it. Our aim is to find the ways for not getting contaminated products into mans organism.	The easier and more visually you deliver this material the easier it would be to understand it.	Usage of schemes makes easier understanding of the topic. Help to orientates in life situations to preserve your health.	The territory of our region is contaminated with radioactive Cs. It s practically impossible to avoid it getting into the organism. But you should try to avoid it. You shouldn t eat products grown in the contaminated territory, without checking them. To follow the recommendations of specialists.
Local context	Using local examples (hey, wood, cow, house, stove, milk, man and bread) to show the cycle of Cs.	Using concrete examples. Contamination in the Kostyokovichi region.	Using life situations (how to prevent the contamination of the chicken?)	Using concrete information (our region).
Pupils ideas	-	-	About cycles How can Cs get to organism?	The need of food Ways of getting radioactive elements to organisms

should be taught and in what time and order. The programme is like a timetable for the teacher, which should be followed to deal with the schoolbook (furnished by the government). The teachers strongly feel to follow the programme strictly. So implementation of new or adapted materials will be difficult. They also don't have the possibilities and technologies to make own lesson material (no time left because of the strict programme, no paper, no typewriters, no copiers etc.)

The curriculum for schools at all levels centrally organised as it is, doesn't include man as a component of the environment and does not lay relations between radioactive contamination and human health. This construct does not allow teachers to teach for better understanding of contamination. Although we have seen that teachers are able to include man in their local cycle.

We didn't investigate if the teachers used their lesson designs in the schools. It will be interesting to continue this research in order to investigate if there exist possibilities for implementation the lesson design of the teachers in their normal curriculum centred lessons.

The purpose of intervention by the teacher is to bring pupils' conceptions to fit criteria such as, to promote concept development and change. Much writing about conceptual change is in terms of abandonment of primitive views and acceptance of a sophisticated one (Fensham et al, 1994). In their developed lessons the teachers don't use the preconceptions of the pupils to discuss the differences and similarities mentioned and to focus on the new concept in the orientation phase. Even the comparison between the associative frameworks before and after teaching is not mentioned yet. However the constructivist teaching strategy (orientation – information – processing/application – reflection) we used in our lesson (Boschhuizen et al., 1991) can also be found in lesson design from two of the four the groups (group 3 & 4).

Teachers in Belarus are able and willing to contribute to a new approach of conceptual learning about contamination but are hampered by curricular constraints and by shortage of additional material for school-use.

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DETERMINANTS FOR PRACTISING EDUCATIONAL METHODS IN ENVIRONMENTAL EDUCATION - A COMPARISON BETWEEN TURKISH AND GERMAN TEACHERS USING THE THEORY OF PLANNED BEHAVIOR

Sinan Erten, Sebastian Bamberg, Dittmar Graf & Rainer Klee
Justus-Liebig-University, Giessen

1 Summary

The presented study has three main goals: 1. To find indications for reasons which hinder or foster the use of practical work and excursions in environmental education. 2. To test the applicability and power of a well established social psychological theory in our research field. 3. To compare results from two different countries.
As theoretical background we use Ajzen's Theory of Planned Behavior. This theory postulates that the more favorable the attitude and the subjective norm, and the greater the perceived behavioral control (PCB), the stronger the person's intention to perform the behavior in question should be.
The variables of the Theory of Planned Behavior were measured via a standardized questionnaire. 180 questionnaires were filled out by Turkish teachers (Ankara), and 107 by German teachers (Hesse). For the empirical test the structural equation approach (AMOS) was used.
Our results confirm the utility of using the Theory of Planned Behavior for explaining the teachers' intention to use different methods in environmental education.
We had different findings in the sample of the German teachers for the influence of the three variables (attitude, subjective norm, PCB) on the intention to carry out practical work and excursions in environmental education. PCB showed a very high path coefficient whereas the value for attitude was moderate and the value for subjective norm was low.
This indicates that a succesful way to foster the use of practical work and excursions may be to establish better conditions. As underlying beliefs concerning practical work we found: more laboratory space and equipment; concerning excursions: adequate abilities of the students, fewer discipline problems, lower costs.
In contrast to the German sample, the Turkish sample displayed only low values for the paths from PBC and attitude to intention. However the

influence of subjective norm was moderate in the case of practical work and nearly moderate in the case of excursions. The underlying beliefs for practical work are parents' and students' expectations, ministry orders; for excursions we found: adequate abilities of the students, fewer discipline problems (same as in the German sample). From these results it seems to be possible to strengthen the Turkish teachers' intention to use practical work in environmental education by increasing their awareness that important others expect them to do so. Whether this is a useful approach is discussed.

2 Goals of the study

The first and most important goal of our study is to find factors hindering or fostering the use of practical work (especially experiments) and excursions in environmental education. These two methods are considered to be successful in environmental education. Therefore they should be used more often in this field. (Berck 1999, Eschenhagen, Kattmann & Rodi 1998). It would be possible to improve environmental education if we have more knowledge about the obstacles which hinder the use of the above mentioned methods.

The second goal is to find out whether there are cultural differences in environmental education with regard to practical work and excursions. For this purpose the present study compares a sample of Turkish and German teachers.

As the third goal we want to test the applicability of Ajzen's Theory of Planned Behavior (in the following abbr. as TOPB). This theory is often used in social psychology and marketing, but applications in biology didactics research are rare. Shuman & Ham (1997) view the TOPB as a useful approach in studying determinants of environmental education, but they have not done such research themselves.

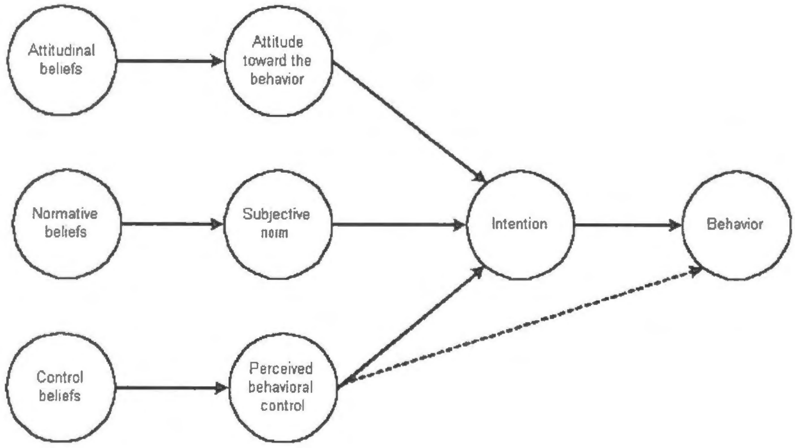
3 Description of the Theory of Planned Behavior (see Klee et al. in press)

The TOPB was developed by Ajzen (1991) and is an extension of the Theory of Reasoned Action (Ajzen & Fishbein 1980).

According to the TOPB human social behavior is reasoned, controlled, or planned. Although people's beliefs may be unfounded or biased, their attitudes, subjective norms, and perceptions of behavioral control are assumed to follow reasonably from these beliefs, produce a corresponding behavioral intention, and ultimately result in behavior that is consistent with the overall tenor of the beliefs.

Fig. 1 depicts the model of the TOPB graphically.

Figure 1. Model of the theory of planned behavior (Ajzen, 1991)



The theory postulates that only intention and perceived behavior control (abbreviated as PBC below) are the direct determinants of behavior. The intention itself is determined by attitude, subjective norm and PBC. Attitude, subjective norm and PBC themselves are determined by attitudinal, normative and control beliefs. The attitudinal beliefs represent the perceived positive or negative consequences associated with a behavior, normative beliefs represent the perceived expectations of important others (social pressure), and control beliefs represent perceived factors hindering or fostering the performance of a behavior.

As a general rule, the more favourable the attitude and subjective norm, and the greater the perceived control, the stronger the person's intention will be to perform the behavior in question. Finally, given a sufficient degree of actual control over the behavior, people are expected to carry out their intentions when the opportunity arises. If a behavior is not completely under volitional control, that is its performance requests social and environmental support , the TOPB postulates an additional direct effect of PBC on behavior (dotted line in Fig.1).

Compared with models which stress the potential role of personal norms as behavioral determinants (e.g. Schwartz 1977) the TOPB stresses the importance of benefit and cost arguments. The individual is seen mainly as a utility-maximising actor.

Because of time and money constraints actual behavior was not measured in the present study. However meta-analyses show a strong empirical relation between intention and behavior in other behavioral domains (e.g. Conner & Armitage 1998, Van den Putte 1993).

4 Method

4.1 The questionnaire

The constructs of the TOPB were measured via a standardised questionnaire. The scales and the items are constructed in accordance with the instructions given by Ajzen & Fishbein (1980); this means correspondence of target, action, context, and time. For more details see Erten (2000).

4.1.1 Measurement of the variables of the core model

One or two items were used to measure these variables. As an example for the operationalisation of the variables items for practical work are given:
Intention: I intend to conduct practical work during the next school-year while treating environmental issues. (bipolar 7 step scale: very likely - very unlikely)
Attitude: If I let the students do practical work in my class during the next school - year while treating environmental issues I will find this ... (bipolar 7 step scale: very great - very bad)
Subjective Norm: People who are important to me expect me to conduct practical work in my class during the next school - year while treating environmental issues (bipolar 7 step scale: very great - very bad).
PBC: Conducting practical work in my class during the next school-year while treating environmental issues is ... (bipolar 7 step scale: very easy - very difficult).
For the part of the questionnaire concerning excursions, there are corresponding items (in principle the term ”practical work” is replaced by the term ”excursion”).

4.1.2 Measurement of the beliefs

In a pretest (free elicitation method, Ajzen & Fishbein 1980) the salient attitudinal, normative, and control beliefs of 50 Turkish and 25 German teachers associated with the two educational methods were collected.
Three questions concerned practical work and three concerned excursion. As an example the question used to collect the attitudinal beliefs is given: "What are, from your point of view, important consequences of carrying out practical work with your students while treating environmental issues in the next school-year (for instance testing water, soil, damaged plants)?"
The answers were used to formulate the standardised items to survey the beliefs. The questionnaire contained different numbers of items measuring

the attitudinal, normative and control beliefs associated with the two educational methods. In the case of practical work there are 13 items for the attitudinal beliefs, 6 for the normative beliefs and 7 for the control beliefs. As an example for the measuring of the beliefs the question and the first 5 items concerning the attitudinal beliefs for the case of practical work are given (for the complete questionnaire see Erten 2000):

If I have practical work carried out in the next school-year in my class while treating environmental issues, it would have the following effect: 1.The students learn the relevant subject matter better. - 2. The students understand the relevant subject matter better. - 3. The students remember the relevant subject matter better. - 4. The students can better recognise environmental pollution. - 5. The environmental concern of the students is intensified. - 6. It can be better taught to the students that environmental pollution may lead to a catastrophe. - 7. Practical skills are better learnt by the students to protect the environment.

The subjects give their responses on seven-step scale with the anchor points "very likely" to "very unlikely".

In the empirical part we only concentrate on those beliefs which have a statistically significant effect on the corresponding attitude, subjective norm, and PBC.

4.2 Conducting and analysing the survey

The empirical part of the main study was conducted in 1998/99. A total of 180 questionnaires were filled out by Turkish teachers, 107 questionnaires were obtained from German teachers. All of the teachers (male and female) were involved in teaching environmental education, their subjects were biology or chemistry.

For the empirical test of the TOPB the Structural Equation Approach was used (AMOS, Arbuckle & Wothke 1999).

5 Practical work

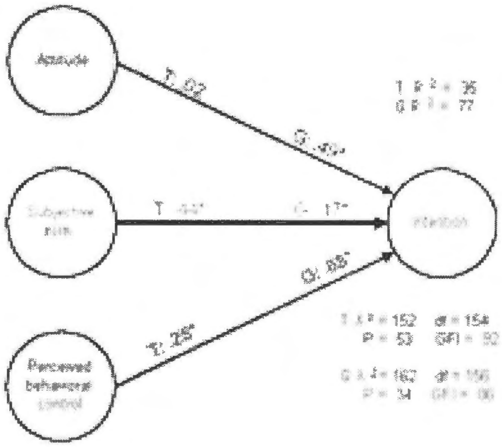
5.1 Core model

5.1.1 Results

Figure 2 shows the core model with the path coefficients for practical work. Overall the model fit is sufficient; only the GFI (Goodness of fit index) for "German teachers" is too low. The explained variance (R^2) is very high in the German sample, in the Turkish sample R^2 can be regarded as sufficient.

The figure shows considerable differences between the Turkish and the German sample. With a path coefficient of .02 the attitude has no statistically significant effect on the Turkish teachers' intention to carry out practical work with their students, whereas in the German sample the attitude (.49) exerts a rather high effect on the intention. Regarding the influence of the subjective norm on the intention the finding is the opposite: here we find a much higher coefficient in the Turkish sample. In the German sample PBC has the strongest effect on the intention to use practical work in environmental education.

Figure 2. Path coefficients of the core model "Practical work" (*: Significant at the p= .05 level) T: Turkish teachers, G: German teachers



5.1.2 Discussion

First of all we want to stress the explorative nature of our study. As stated above one main goal was to test the empirical applicability of the TOPB in the domain of biology didactics. Our results confirm the usefulness of such an approach. But the results have to be confirmed through further investigations; as a consequence the interpretations are preliminary.

The finding that the attitude of the Turkish teachers has a low influence whereas the subjective norm is high, - and by contrast the results are the opposite in the German sample - can be explained by a statement of Frey et al. (1993). These authors assume that if a person is highly integrated in a group and therefore perceives high social pressure, the attitude will be without relevance for the intention. Personal experiences of persons who are well acquainted with the situation in both countries confirm the assumption that social integration in Turkey is greater than in Germany.

Increasing the awareness of Turkish teachers that important others expect them to use practical work may strengthen the intention of the teachers to do so. But from our point of view this strategy to improve teachers' educational practises alone is problematic. A better strategy would be to strengthen the impact of the attitude. The German sample shows that this strategy might be more effective.

This assumption is supported by Crawley's (1990) research in the USA concerning the use of investigative methods by teachers of physical science. He showed that attitude was the most important predictor of behavioral intention. However, Koballa's (1986) findings (Austin, Texas) suggest that prospective teachers' attitudes toward science cannot adequately predict or provide a satisfactory explanation of using hands-on activities in science education. Further studies must analyse the relation between intention and behavior more intensively.

A possibility to increase the intention especially of German teachers to use practical work is indicated through the high path coefficient between the PBC and the intention. Thus the next section concentrates on the special salient beliefs underlying attitude, subjective norm and PBC.

5.2. Beliefs

For reasons of clarity we have split the complete models into three parts and we only present the probability of the beliefs because they give the most useful information. For the complete models see Erten (2000).

5.2.1 Results

Figures 3 - 5 show for the method "practical work" for each variable of the core model the effects of the underlying beliefs (attitudinal, normative, control) and the indicators which have been proved as the statistically most important ones of these beliefs.

On the left side of the figures one can see the results concerning the Turkish, on the right side the ones concerning the German teachers.

The coefficients of the paths from the attitudinal beliefs to the attitude are not very high but statistically significant (Fig. 3). The salient indicators of the attitudinal beliefs for the Turkish teachers are "better learning" "better illustration of subjects", "more motivation". For the German teachers we found "better remembering", "better illustration of subject matter" and "better learning of skills" are the indicators with the greatest explanatory power.

Figure 3. The attitudinal beliefs with their indicators in the model "Practical work" (*: Significant at the p = .05 level)

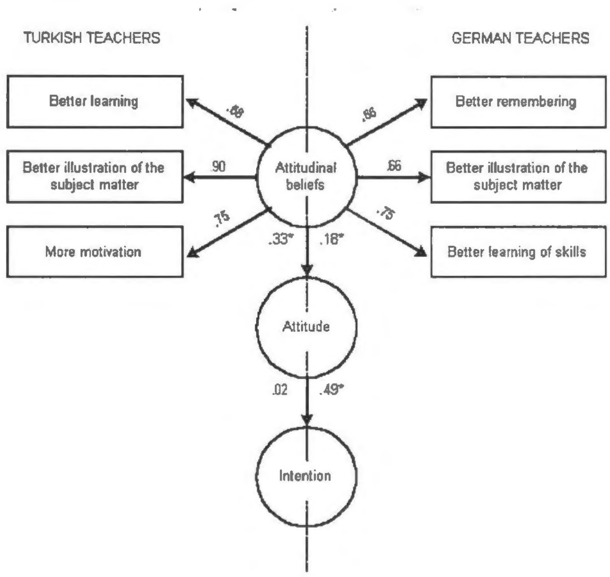


Figure 4. The normative beliefs with their indicators in the model "Practical work" (*: Significant at the p = .05 level)

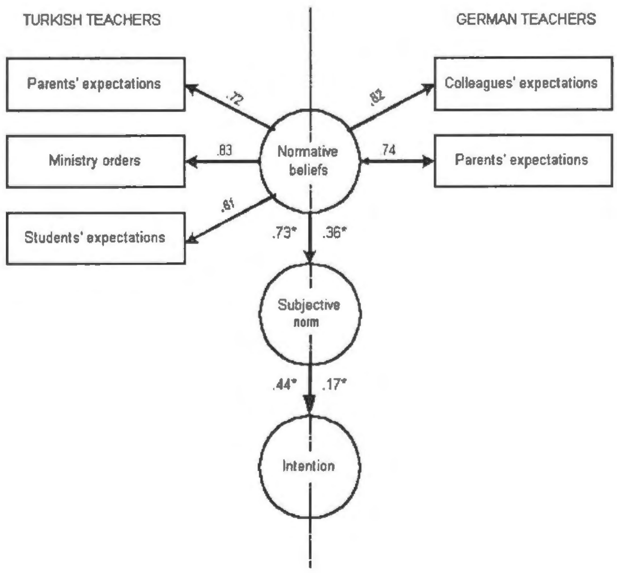
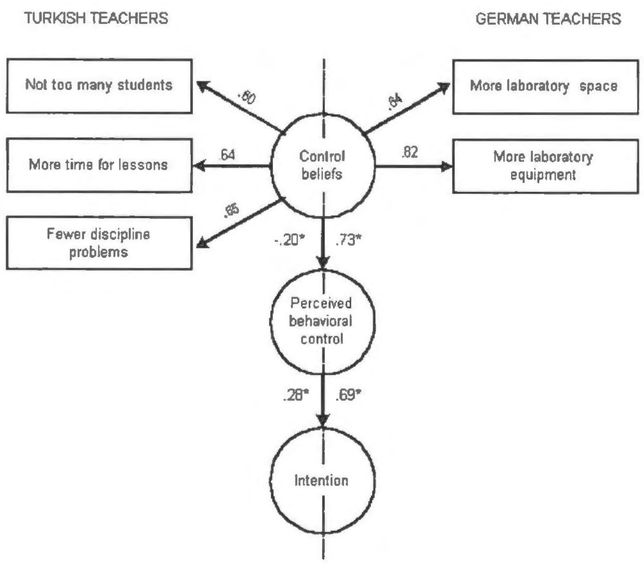


Figure 5. The control beliefs with their indicators in the model "Practical work" (*: Significant at the p = .05 level)



As one can see from figure 4 in the Turkish sample the subjective norm can be explained very well by the corresponding normative beliefs. "Expectations of the parents", "orders of the ministry", "expectations of the students" are the most salient indicators of these beliefs. In the German sample there is a moderate effect of the normative beliefs on the subjective norm. The indicators here are "expectations of colleagues" and "expectations of parents".

In the case of the control beliefs (Fig. 5) we found also a great difference between the Turkish and the German sample. Concerning the latter the effect of the control beliefs on the PBC is very high, whereas for Turkish teachers the relation between the control beliefs and PBC is low and negative.

5.2.2 Discussion

One problem of the present study consists in the low empirical relation between the attitudinal beliefs and the attitude. Thus we cannot explain yet the factor underlying the influence of the attitude towards practical work. But it can be pointed out that in the model of the Turkish sample the "practical skills" have no influence; in the German sample the corresponding case is "more motivation". If these findings are replicated in further studies these aspects have to be emphasised in pre-service and in-service teacher education.

Because of the high influence of subjective norm on intention (Fig. 4) in the Turkish sample the normative beliefs underlying the subjective norm are of special interest in this sample. They indicate the persons or institutions whose expectations are important for the teachers. According to our results the parents are important in both Turkey and in Germany.

To foster the intensity of practical work in environmental education it seems to be a possible and successful way to let the teachers know such demands through parents.

In Turkey orders of the ministry would possibly have the strongest effect; however here we have to take into account the above mentioned relation between subjective norm and attitude.

The very high relations between the control beliefs, the PBC and the intention in the German teachers sample (Fig. 5) indicate that trying to influence these factors might be a good way of fostering the intention to use practical work in environmental education. Because the two control beliefs "more laboratory space" and "more laboratory equipment" are of special importance these two aspects have to be improved.

In the context of the present study we cannot explain the low relation between the control beliefs and the PBC found in the Turkish sample.

6 Excursions

6.1 Core model

6.1.1 Results

Figure 6 shows the core model for excursions. The fit of this model is as good as the fit of the model practical work. The explained variance (R^2) is also very high in the German sample, the corresponding figure of the Turkish sample can be regarded as sufficient.

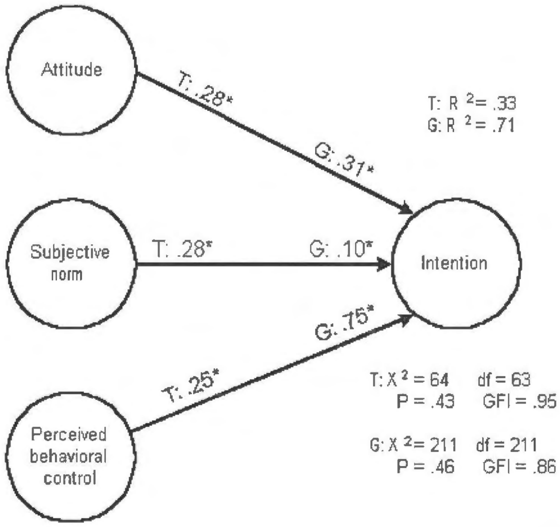
As one can see in figure 6 the path coefficients of the Turkish sample tend to have the same value. They are all low but significant. In contrast the German teachers show remarkable differences: the attitude has a moderate, the subjective norm a very low and the PBC a very high influence upon the intention.

6.1.2 Discussion

In the German sample the results of the TOPB core model for excursions are quite similar to those reported for the model practical work: The subjective norm has the lowest effect on intention and PBC the strongest. This means

that the intention of the German teachers can hardly be affected by persons or institutions. In contrast the great effect of PBC indicates a good chance to foster the intention to carry out excursions in environmental education.
From the finding that the effects from attitude, subjective norm and PBC on intention are in the same magnitude a hypothesis can be deduced: Subjective norm (that is the influence of important others) is of no importance for the intention of German teachers at all; whereas the PBC (that is for instance equipment and rooms) has generally a great influence. We hope to prove this hypothesis by further investigations.

Figure 6. Path coefficients of the core model "Excursion" (*: Significant at the p= .05 level) T: Turkish teachers, G: German teachers



Comparing the two methods - practical work and excursions - in the Turkish sample one can observe a change: For excursions the relative importance of subjective norm is considerably lower, whereas the importance of attitude is much higher. This matches the statement in section 4.1.2 that a strong effect of subjective norm hinders the influence of attitude. Because the effect of the subjective norm on the intention is low here, the attitude can have an influence upon the intention.
The reasons for the relatively low effects of the attitude in both the German and the Turkish samples has to be analysed in further studies.

6.2 Beliefs

6.2.1 Results

Here we proceeded in the same way as described in section 4.2. Accordingly figures 7 - 9 show each of the part of the core model and in addition the salient indicators for the method "excursion". On the left side of the figures one can see the results concerning the Turkish, on the right side the ones concerning the German teachers.
Concerning the attitude (Fig. 7) the effect of the attitudinal beliefs is not very high, but statistically significant. The model of the Turkish sample contains two, the model of the German sample contains four salient indicators. Most of them refer to the fact that excursions facilitate better teaching of special objectives concerning environmental education. In addition as a result of making excursions the Turkish teachers expect a more effective use of teaching time, whereas the German teachers expect an increase in students environmental concern.

Figure 7. The attitudinal beliefs with their indicators in the model "Excursion" (*: Significant at the p = .05 level)

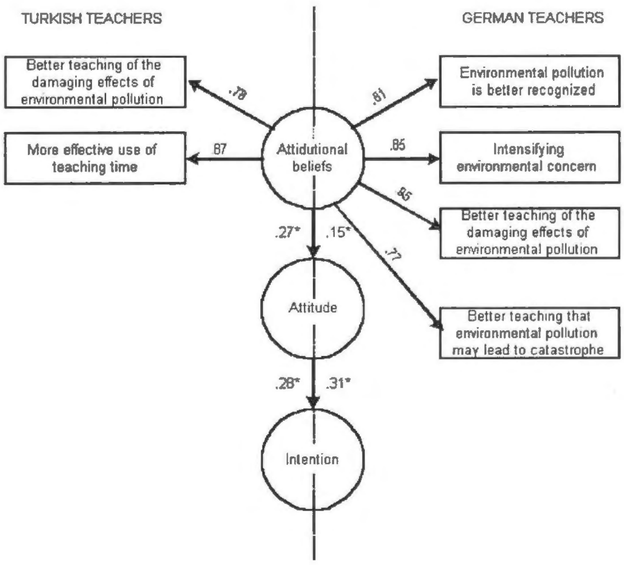


Figure 8. The normative beliefs with their indicators in the model "Excursion" (*: Significant at the p = .05 level)

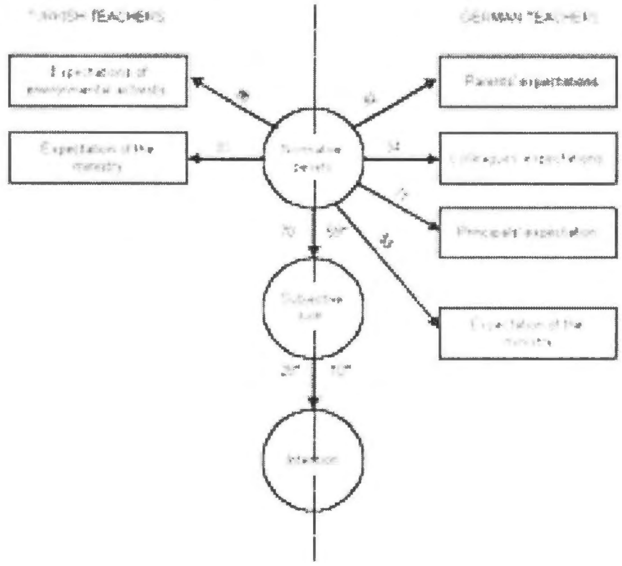
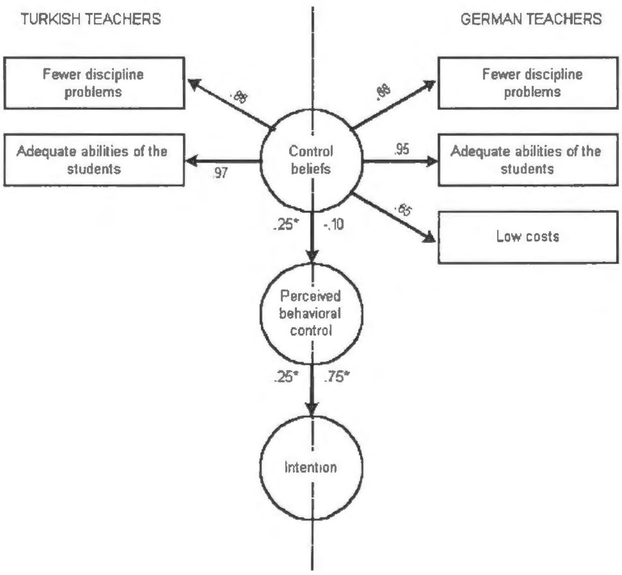


Figure 9. The control beliefs with their indicators in the model "Excursion" (*: Significant at the p = .05 level)



The effects of the normative beliefs on the subjective norm (Fig. 8) are high but only in the case of the Turkish teachers there is a noticeable influence by the subjective norm on the intention. According to the salient indicators the perceived expectations of ministry and environmental activists are of special importance.

Figure 9 shows that only in the Turkish sample do the control beliefs have a low but significant effect on PBC. In the German sample this path coefficient is statistically not significant. Two indicators are present in the Turkish as well as in the German sample: fewer discipline problems and more adequate abilities of the students.

6.2.2 Discussion

For the method "excursion" the effects from the attitudinal beliefs on the attitude (Fig. 7) are similar to the findings reported for practical work (Fig. 3). Thus the same conclusions can be drawn. Because there are only two indicators in the model of the Turkish sample it seems to be necessary to impart to the teachers that there are more objectives which can be realised in environmental education through excursions. A little bit astonishing is the effect of the belief "effective use of teaching time" because this is an argument often used in the opposite way.

If one wants to foster the intention to carry out excursions in environmental education by social pressure, a possible way in both countries may be by orders of the ministry (Fig. 8). However the highest effect would be achieved in Germany through colleagues and parents (the disadvantages of such an approach have already been discussed).

In figure 9 the low relations between the control belief and the PBC in the German sample cannot be explained. To foster the intention of the Turkish teachers to use excursions in environmental education, their skills must be trained in managing discipline problems. The indicator "adequate abilities of the students" has very high coefficients in both the Turkish and in the German sample. But the meaning of this finding is not clear to understand. It may be supposed that the students should know how to behave during an excursion and that they should be able to comprehend the demonstrated (perhaps complicated) facts.

Because in the Turkish sample only two attitudinal beliefs exert a significant effect on attitude, one practical conclusion may be that teachers have to be convinced that excursions have much more useful consequences for environmental education.

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DOES NATURE EXPERIENCE OR OPINIONS OF ENVIRONMENTAL ETHICS INFLUENCE THE PRO-ENVIRONMENTAL BEHAVIOUR OF STUDENTS?

Armin Lude
IPN – Institute for Science Education at the University of Kiel

Abstract

The motivation for this study was the question, whether the decreasing appreciation of nature could be addressed by teaching nature experience or by favouring discussions about environmental ethics. Therefore, a standardised questionnaire was designed to assess types of nature experience, reasons for conservation and pro-environmental behaviour of 14–18 year old students in Germany.
Using Mixture Distribution Models, students were assigned to latent classes according to their patterns of (1) frequencies of different types of nature experience or (2) patterns of appreciation for reasons for conservation.
The subgroups in the models showed differences in their pro-environmental behaviour: Students characterised by extensive experience with nature showed the highest pro-environmental action. Whereas students in a class characterised by infrequent experience (except in the recreational dimension) even had negative correlation to pro-environmental behaviour.
Analysing the reasons for nature conservation, students of a latent class characterised by favouring economic reasons, showed the least developed environmental attitude and were the least environmentally active.

1 Introduction

Even though the history of nature conservation in Germany dates back to 1836 (Plachter 1991: 17), a wider environmental awareness in the public leading also to political action arises only since 1970s (Weidner 1995). Today, teaching about nature conservation is integrated in the high school curricula of all German states (Lude 2001: 14). The curricular aims are to guide students to appreciate nature and to stimulate conservation activity. Despite this, studies observe a decreasing appreciation and abuse of nature among people (Stoll 1999; Rentsch 1988; Schroeren 1997; Langer 1991).
The question is, can this problem be addressed by increased environmental education? The Tbilisi recommendations of 1978 mention, that

environmental education uses a broad range of teaching and learning techniques stressing practical activities and first-hand experience as well as building an environmental ethic (Palmer 1998: 11). Thus in the frame of environmental education, different approaches can be favoured: (1) fostering nature experiences by outdoor activities or (2) thinking and discussing about reasons for conservation.

Conservation NGOs as well as state environmental centres in national parks combat the trend of abusing nature with increased environmental education, especially by a nature experience approach (Erz 1986; Paschowski 1996). Many studies have shown that knowledge has little influence on environmental attitudes and action (e.g. Hines, Hungerford & Tomera 1986/87). Yet not much is known about the influence of nature experiences on this (Bögeholz 1999).

In recent years, discussions about environmental ethics have become more and more popular (Birnbacher 1991; Ott 1998; Elliot 1995; Frankena 1979). The aim is to identify meaningful arguments which support nature conservation and to persuade people to behave in an environmentally conscious way. In the course of this discussion different points of view come up, each of these are favoured by at least one renowned philosopher (Birnbacher 1991: 286). Despite this, it is unknown so far, how these different reasons for conservation are appreciated by 'normal' people. The effectiveness of these reasons for pro-environmental behaviour is also unknown. Which of them will motivate best in order to promote environmentally sound activity?

2 Research design and methodology used

For this study, a standardised questionnaire was designed. It was pre-tested with 120 students. The final version was sent to 50 German high schools taking part in an environmental project along the catchment of the river Elbe (students were aged 14–18). Altogether 780 questionnaires were returned (80%).

The questionnaire comprises items which build rating scales for the following constructs: nature experience, reason for nature conservation and pro-environmental action.

Nature experiences are differentiated according to the specific kind of relationship and perceptions, i.e. appreciating, observing, exploring and using nature. Thus, eight different dimensions were defined: aesthetic, scientific, utilitarian, nature conservation, social, recreational, food production-related and media-related ones (table 1). These dimensions could be proven in a factor analysis (Lude 2001: 74).

Table 1. Items for Assessing the Types of Nature Experience

Aesthetic Dimension • Listening to the murmur of waves at a bank or shore... • Enjoying the bright colours of a landscape when the sun comes out after a thunderstorm... • Sniffing herbs or flowers...
Scientific Dimension • Identifying animal and plant species (e.g. birds, trees, flowers)... • Watching animals and plants... • Exploring seasonal changes of nature...
Utilitarian Dimension • Helping to grow and pick plants (vegetables, flowers, fruit)... • Occupying oneself with animals and plants, which I can use (e.g. fish, herbs)... • Picking wild fruit (e.g. elderberries, blue berries, mushrooms)...
Nature Conservation Dimension • Joining nature conservation activities (looking after toad fences, installing ponds or hedges,...) • Installing nesting boxes for birds or insects... • Leaving wild and untouched places for animals in the garden...
Social Dimension • Playing with a pet (e.g. cat, dog)... • Maintaining a special relationship (e.g. friendship) with an animal... • Looking after ones own pet (e.g. hamster, bird)... • Talking about pets (dogs, cats, birds, ...) with other people... • Reading stories about friendship with pets...
Recreational Dimension • Jogging in the woods or in a park... • Doing 'nature sports' in a natural surrounding (e.g. climbing, canoeing, mountain biking, fast-water canoeing, trekking)... • Swimming in a river or lake...
Food Production-related Dimension • Preferring vegetarian food to meat. • Eating food from a whole-food shop... • Buying regional products at a market...
Media-related Dimension • Watching films or slide shows about the beauty of nature... • Watching films that show how wild animals live... • Looking at coffee-table books about nature... • Following reports about nature conservation activities in newspaper or television... • Reading reports about ecological research...

Secondly, seven distinct dimensions of reasons for nature conservation were taken from reference literature in the field of nature conservation and environmental ethics (Erz 1980; Plachter 1991; Bleckmann, Berck & Schwab 1980, Ratcliffe 1976; Hampicke 1993; Krebs 1996; Birnbacher 1991, 1998; Ott 1998). These are aesthetic, recreational, economic, scientific, bio-centric, holistic and religious reasons to protect nature (table 2). They attribute intrinsic values to different objects (e.g. human beings, living organisms, whole nature). Thus, these objects are thought to have individual value, not only bearing instrumental value for other objects.

Table 2. Items for Assessing the Reasons for Conservation

Anthropocentric-aesthetic Reasons • Sounds and smells of nature are stimulating and relaxing. • Pristine floodplains are delightful. • The sight of a landscape with a diversity of plants and animals is beautiful.
Anthropocentric-recreational Reasons • Unspoiled nature is essential for relaxation. • Nature is the ideal surrounding for sports (cycling, jogging, climbing, etc.).
Anthropocentric-economic Reasons • Protection of useful animals and plants. • Animals and plants are potential raw materials for the development of new medicine. • Fish in the Elbe river are an important basis for life for the people living there (fishing, food).
Anthropocentric-scientific Reasons • Research on ecology requires pristine or good quality habitats. • Freshwater animals and plants are essential objects for ecologists to observe and study.
Bio-centric Reasons • Wild animals and plants have intrinsic values like all living beings. • Animals and plants also have a right to live. • Extermination of animals and plants caused by mankind is irresponsible.
Holistic Reasons • The preservation of natural floodings is important for the functioning of nature. • Floodplains are unique biotopes inhabited by particular fauna and flora.
Religious Reasons • Having respect and a sense of awe for all living beings, because all are God's creatures. • It is our sacred duty to respect and preserve nature. • Any destruction of Nature would not be reconcilable with Christian values.

Finally, pro-environmental behaviour was assessed. To maintain measurement correspondence (Weigel, Vernon & Tognacci 1974; Ajzen & Fishbein 1977; Steel 1996; Kaiser, Wölfing & Fuhrer 1999), pro-environmental behaviour was measured as specifically as the other constructs. It was focused on political activities (e.g. *Taking part in action groups or demonstrations for a National Park*), activities for nature conservation (e.g. *Helping to set up an amphibian protection fence along a frequently used street*) and traffic-related activities (e.g. *Persuading my parents to use the car less often*). Energy consumption, recycling or shopping behaviour were not assessed, as they did not seem to be closely related with nature experience and reasons for conservation.

For analysis, WINMIRA 32, a software by von Davier (1994) for MDMs – Mixture Distribution Models (Rost 1996; Rost & Langeheine 1997) was used. MDMs are statistical methods for finding subtypes of related cases ("latent classes") from multivariate categorical data. These subpopulations are solely defined by their property of being homogeneous in the sense that a particular model holds for this latent class. In particular, latent classes are not defined by manifest variables (e.g. gender, age). Hence the aim of MDMs is twofold: to 'unmix' the data into homogeneous subpopulations and to estimate the parameters for each subpopulation separately (von Davier 1994).

Thus, for each student class membership probabilities are estimated for belonging to each of the different latent classes. The person is then assigned to the latent class with the highest probability. The statistics of these probabilities were used to assess model-fit.

Furthermore, information statistics were also used to assess model-fit (namely the parsimony indices BIC, CAIC). These statistics are based mainly on the value of -2 times the loglikelihood of the model, adjusted for the number of parameters in the model, the sample size, etc. (Rost 1996; von Davier 1996). The main idea is that, all other things being equal, given two models with equal loglikelihoods, the model with the least parameters is better.

Sometimes though, the estimation algorithm may instead converge on what is termed a "local maximum" solution. A local maximum solution is the best solution in a neighbourhood of the parameter space, but not the global maximum. This can be compared to climbing a mountain in the dark. By walking constantly uphill, you will reach the top of whatever peak you are already on. But this does not necessarily have to be the highest peak of the whole mountain-chain. To guard against local maxima solutions, the algorithm was run at least 10 times with different parameter start values (this could be paralleled by different climbing excursions).

3 Results

Students were assigned to latent classes using MDMs like LCA and MIRA (Rost 1996; Rost & Langeheine 1997). The best model-fits were achieved by MIRA (***mi**xed **Ra**sch* Models). As previously mentioned, students belonging to a latent class have an identical (or similar) pattern of answers in common.

First, results concerning students' nature experience were presented. Initially the sample of students was investigated to see if they could be split into different homogenous subgroups ("latent classes"). Then, the students belonging to different classes were analysed to see whether or not they show different pro-environmental behaviour.

Secondly, the opinions of environmental ethics results were analysed in the same way: The possibility of splitting the sample in subgroups favouring different combinations of arguments for conservation was tested. Finally, the pro-environmental behaviour of the subgroups was analysed.

3.1 Latent Class Analysis of the Types of Nature Experience

Analysing the different types of nature experience of students, a mixed Rasch Model with a solution of four latent classes had the highest interpretative value and a sufficient model-fit. Only 0.1% of the student sample was assigned to latent classes by a probability less than 0.400. On the other hand, 77.0 % of the students were allocated by a probability of > 0.900.

To label a class, a type of experience was chosen which distinguished that specific class best form the others. Usually the class scored higher on this feature than any other class. One of the latent classes couldn't be characterised by scoring highest on any one feature, but showed the lowest value in any experience dealing with pets (social dimension, cf. table 1). So, this was chosen to name the class. The labelling is mainly used as a memory aid, because a latent class is characterised by its entire profile based on all types of experience. Therefore, they are *pars pro toto* labels.

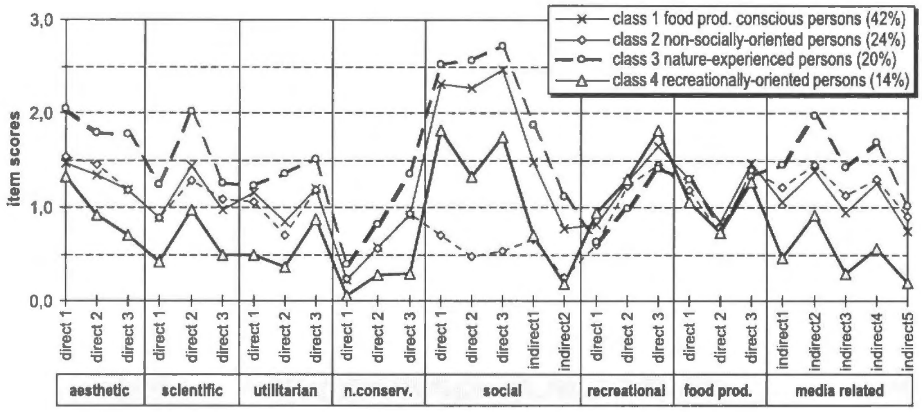
Four different classes could be identified as shown in figure 1:

- Class 1 ("food production conscious persons") is characterised by the highest values in the food production-related dimension (cf. table 1). Furthermore, there are high values in the social and recreational dimension and intermediate values in all other dimensions.
- Class 2 comprises "non-socially-oriented persons" as this class has the lowest values (compared to the other classes) in the social dimension. There are intermediate values in all other dimensions.
- Students of latent class 3 show the highest values in six different dimensions of nature experience: aesthetic, scientific, utilitarian, nature conservation, social, media-related. Only in the recreational dimension,

there are comparably lowest values. Consequently, this class was labelled “nature-experienced persons”.

- In contrast, latent class 4 (“recreationally-oriented persons”) achieves highest values in the recreational dimension. There are intermediate values for the social dimension and the lowest values for all other dimensions. Thus, class 4 is more or less contrary to class 3.

Figure 1. Students assigned to four latent classes by the mixed Rasch Model according to their frequency of different types of nature experience (scale: 0: *I never...* to 3: *I always do this*).



3.2 Pro-Environmental behaviour of the different Latent Classes of Nature Experience

As shown above, four groups of students with a different pattern of nature experience can be differentiated. Do these students also differ in their pro-environmental behaviour? Therefore, a correlation analysis was conducted between the probabilities of belonging to the latent classes and the sum score of pro-environmental behaviour. Table 3 reveals a positive significant relationship only between students of latent class 3 (labelled as “nature-experienced”) and pro-environmental behaviour. Students of class 4 (“recreationally-oriented”) even had a negative significant correlation to environmentally sound action.

Therefore, the students characterised by a generally extensive nature experience demonstrated the highest environmental action whereas the ones with lower experiences showed less actions.

Table 3. Correlation between class membership probabilities for nature experience and pro-environmental behaviour

	probability for latent class 1 "food prod. conscious persons"	**probability for latent class 2** "non-socially-oriented persons"	**probability for latent class 3** "nature-experienced persons"	**probability for latent class 4** "recreationally-oriented persons"
sum score for **pro-environmental behaviour**	**0.05**	**– 0.04**	**0.25** ***	**– 0.30** ***

3.3 Latent Class Analysis of the Reasons for Conservation

As before, LCA and MIRA analysis were calculated. Again, the best model fit was achieved by MIRA modelling. The 3-class-solution was of the best interpretative value and got second best information statistics. Only 0.3% of the persons got a probability of less than 0.400. A probability of greater than 0.900 was achieved by 62.6% of the sample size. These values are slightly less than in the model described above, but still quite good.

The latent classes have the following characteristics:

- Students of latent class 1 (48% of the sample size) reach the highest values in five of seven types of reasons for conservation. Only in the fields of holistic and economic reasons, intermediate values were achieved. As especially high values were scored for aesthetic reasons, this class was labelled as "aesthetically-oriented persons". But – as mentioned above – the class is characterised by its entire profile.
- 35% of the students belong to latent class 2. Highest values were scored for economic reasons, intermediate values for aesthetic, recreational and scientific reasons. Compared to the other classes, lowest values were achieved for religious, bio-centric and holistic reasons. Consequently, this class was labelled "economically-oriented persons".
- The remaining 17% of students belong to class 3, characterised by highest values for holistic reasons, high values for bio-centric and intermediate values for religious reasons. The lowest appreciation was attributed to all anthropocentric reasons (aesthetic, recreational, economic, scientific). Suitably, this class was labelled "holistically-oriented persons".

Figure 2. Students assigned to three latent classes by the mixed Rasch Model according to their appreciation of the types of reasons for conservation (scale: 0: *unimportant* to 3: *very important*).

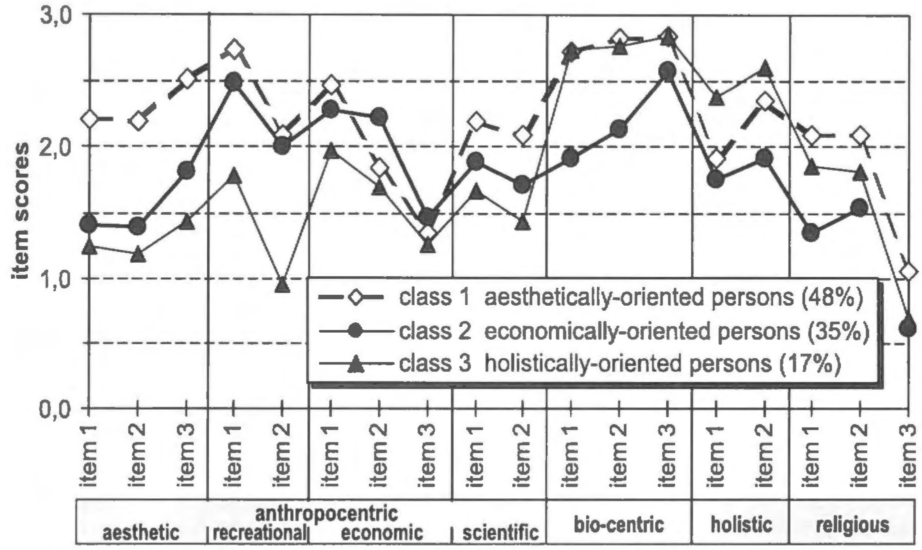


Table 4. Correlation between class membership probabilities for reasons for conservation and pro-environmental behaviour

	probability for latent class 1 *aesthetically-oriented persons*	**probability for latent class 2** *economically-oriented persons*	**probability for latent class 3** *holistically-oriented persons*
sum score for **pro-environmental behaviour**	**0.19** ***	**-0.32** ***	**0.14** ***

3.4 Pro-Environmental behaviour of the different Latent Classes of Reasons for Conservation

Again, the pro-environmental behaviour of the students assigned to different latent classes according to their reasons for conservation was investigated. The correlation analysis in table 4 illustrates a positive significant relationship for both latent class 1 ("aesthetically-oriented") and class 3 ("holistically-oriented"). Students assigned to class 4 ("economically-

oriented") had a negative significant correlation to pro-environmental behaviour.
Therefore, the students characterised by a high appreciation for "week" or "soft" reasons showed the highest environmental action whereas the ones with high appreciation for the "hard" economic reasons were less environmentally active.

4 Discussion

Mixture Distribution Models (MDMs) like mixed Rasch modelling was used to identify homogenous subgroups of students. MDMs become more and more popular for research on pro-environmental behaviour (Kaiser *et al.* 1999; Rost 1996). This is, because only weak *general* relationships were found between variables to explain pro-environmental behaviour (Hines *et al.*1986/87; de Haan & Kuckartz 1998). These can be partially explained by being 'masked' in inhomogeneous groups, whereas 'unmixed' groups reveal different relationships for homogenous subgroups: So one subgroup may have a positive relationship towards pro-environmental behaviour, and another subgroup has a negative one. Analysed together, these relations may not be found.
The 'unmixing' process is also a reduction of complex information provided by the multidimensional assessment of nature experiences and reasons for conservation. But, these 'reduced' person characteristics can be used for addressing students more specifically. Key features for a use of latent classes were:

- Classes had to represent a reduced information of convenient size for the multidimensional assessment. These features were fulfilled as eight types of nature experience could be reduced to four latent classes and seven types of reasons for conservation could be reduced to three classes.
- Sufficient model-fits had to ensure a 'stable' assignment of students to latent classes. Again, this feature was satisfied as can be seen at the high probabilities for the latent classes.
- The information, on which the classes were based had to be relevant for a specific addressing of the target group. Nature experiences can be used for a specific differentiation of students' relationship towards nature (Bögeholz 1999; Lude 2001). Accordingly, the types of reasons for conservation differentiate the students' appreciation of nature (Lude 2001).

What are the practical implications of the results? These can be shown twofold: Firstly, for a specific addressing of students, like in 'ordinary' lessons or on special lessons at outdoor environmental learning centres, it is crucial to 'know' about your target group. Environmental educators should be sensitive to different experiences and sources of appreciation among students. What are their preferences, what is their prior knowledge like, etc.? The latent class analyses provide information about the different experiences and subjects of appreciation of students. Bearing these in mind, pedagogical concepts can be designed.

Secondly, the results can be used to compare and rate the two approaches of environmental education which address the decrease in an appreciation of nature: teaching nature experience or finding reliable and convincing ethical arguments for conservation.

Here, nature experience seems to outrun the reasons for conservation, as there is a higher correlation to pro-environmental behaviour. Thus, favouring nature experience might be more effective than ethical discussions about reasons for conservation. But this does not mean, that it is a decision of exclusion, as both methods were proven to be effective. So, both approaches can (and should) be used in parallel.

Experiencing nature is not only of a positive influence on pro-environmental behaviour (Langeheine & Lehmann 1986; Bögeholz 1999; Lude 2001). Nature experience also stimulates students to increase their experience with nature (Lude 2001: 98). This way, there seems to be a positive feedback loop. This is a stimulating fact for the challenge to develop specific pedagogical concepts for addressing students to strengthen a positive relationship towards nature. Environments had to be created that encourage and enable students to observe, explore, understand, appreciate and experience nature.

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