

RESEARCH IN DIDAKTIK OF BIOLOGY

PROCEEDINGS OF THE SECOND CONFERENCE OF
EUROPEAN RESEARCHERS IN DIDAKTIK OF BIOLOGY
UNIVERSITY OF GÖTEBORG, NOVEMBER 18 - 22, 1998

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EDITORIAL

The Second conference of European Researchers In Didaktik Of Biology (ERIODOB) was held at the University of Goeteborg, Sweden November 18-22, 1998

The aim of the conference has been to give researchers in biology didaktik the opportunity to present and discuss their research work and results on an European level.

The academic committee for the conference was:

Prof.Dr Horst Bayrhuber
Dr Fred Brinkman
Dr Pierre Clement
Dr Ute Harms
Dr Maria Pilar Jimenez-Aleixandre
Dr Gustav Hellden

The local committee was:

Dr Maj-Lis Sjöbeck (chair)
Mrs Gun Mathiasson (secretary)
Dr Mats Hagman
M Sc Jan Landström
M Sc Anita Wallin
M Sc Ann Zetterqvist

The papers and posters of the conference have been reviewed by a team of four:

Dr Fred Brinkman
Dr Maria Pilar Jimenez-Aleixandre
Prof Dr Ulrich Kattmann
Dr Jenny Lewis

The following criteria have been applied by the reviewers:

RESEARCH. Is the proposal about research work?

SUBJECT/PROBLEM. Is the proposal based on a theory?

DESIGN. Is the design appropriate?

DATA ANALYSIS AND FINDINGS. Does the data analysis appear to be appropriate?

GENERAL INTEREST. Does the presentation promise to be of general interest?

The reviewers have recommended 18 of the contributions to the conference for inclusion in the proceedings. They are hereby published.

Möln dal, February 1, 2000

Björn Andersson

Ute Harms

Gustav Helldén

*RESEARCH ON
ATTITUDES AND INTERESTS*

1

*ISRAELI STUDENTS' ATTITUDES TOWARDS AND
INTEREST IN DIFFERENT BIOLOGICAL TOPICS:
A REVIEW OF THE RESEARCH STUDIES OVER
THE LAST 25 YEARS*

Pinchas Tamir

Hebrew University, Jerusalem

Introduction

This conference in Gothenburg is special and distinct from most others. Most professional conferences on education are organized around content areas such as mathematics, language, science, or music. Conferences often feature a specific theme such as homeostasis in zoology or photosynthesis in botany. In this conference the organization level is neither as general as science nor as specific as photosynthesis or homeostasis. Rather, the organization level chosen is that of school subjects, namely biology, chemistry, physics and earth sciences.

How will a conference on biological education differ from a conference on science education? The major difference lies in the nature of experts in these different subjects and its implications. Within biology, the units of studies are at the level of life processes such as respiration or digestion as well as subgroups such as varieties of a particular organism.

When I deliberated with myself about the issues that I would discuss in this conference, I decided to select an area or topic that will be unique to biology. By unique, I mean some issue that relates and integrates with the most authentic attribute of biology, namely life and living.

Purpose

The purpose, therefore, of this study is to review the literature on a) attitudes of students toward science in general and biology in particular; b) the attitudes of students toward the study of biology in school; and c) the relationship between attitudes of various types and achievement in knowledge, understanding and problem solving in the life sciences.

Measures

The following issues and variables were identified and included:

- Interest in science and science learning with special reference to biology
- Curiosity in science and science learning with special reference to biology
- Attitudes of students to the use of living organisms for the study of biology in school
- Attitudes of students to the study of biology a) in class; b) in the laboratory; c) in the outdoors; and d) as a hobby
- Attitudes of students toward the study of plants - animals - microbiology

A review of factors which affect the attitudes was carried out. Effect was found in the following attributes:

1. Gender differences in attitudes related to science education in Israel with special reference to biology (Friedler & Tamir, 1990)
2. The structure of interest in high school biology (Tamir & Gardner, 1989; Gardner & Tamir, 1989, I; Gardner & Tamir, 1989, II).
3. Variables that affect student enrolment in science courses (Milner, Ben-Zvi & Hofstein, 1987; Gardner & Tamir, 1989, II).
4. Attitudes of secondary school students in Israel towards the use of live organisms in the study of biology (Tamir, 1980; Tamir & Sever, 1980; Tamir & Hamo, 1980; Silberstein & Tamir, 1981; Tamir & Shcurr, 1997).

Gender Differences in Science Education in Israel with Special Reference to Biology

General Trends

Research on the differences between the sexes in relation to schooling and learning has received much attention in the last two decades. Girls tend to succeed more in the elementary school and less in high school. The “breaking point” is the beginning of adolescence, and this has caused researchers to explain the phenomenon by the entry into sex roles (Nash, 1979). At this stage, girls show lower cognitive achievement in “masculine” fields (Garratt, 1986) as well as lower aspirations toward future achievements.

There is greater motivation on the part of boys to achieve academically (ensuring superior occupational status) and lower motivation among the girls, together resulting in the formation of an achievement gap at this stage (Kfir, 1988).

The rich information provided by the research has generally confirmed findings of many previous studies which indicate that, in general, boys show higher achievement, are more interested in, and tend to have more positive attitudes towards science. Usually the differences are lowest at age 10 and greatest at age 17. For example, in the First International Science Study, the difference was about a quarter of a standard deviation at age 10, half a standard deviation at age 14, and

three quarters of a standard deviation at age 17 (Comber & Keeves, 1973). An increase in the gap with age is reported also by Johnson and Murphy (1986). In some countries, such as India (Sansanwal, 1983), Singapore (Chy Tin, 1986) and Canada (Ben-Peretz *et al.*, 1985), boys achieve better in all science subjects including biology. In other countries, such as the U.K., boys were found to achieve better in chemistry and physics but not in biology (Johnson & Murphy, 1986).

In most cases and in all ages the largest difference in achievement is in physics and the smallest, if at all, is in biology. These differences in achievement are strongly matched by preferences and interests (e.g. Johnson & Murphy, 1986; Russel *et al.*, 1986; Sansanwal, 1983; Tamir & Gardner, 1989).

Based on the sort of data mentioned above as well as on data pertaining to career choices by boys and girls (e.g. Lesnik, 1983; Tamir & Gardner, 1989) it may be concluded that the behaviour of boys and girls in relation to science is multidimensional and multidirectional. There are indeed differences between boys and girls; however, there is no basis for assuming that all these differences are in favour of boys. Instead, it is possible to identify certain features which clearly distinguish between “boys’ science” on the one hand and “girls’ science” on the other.

In order to be able to understand the meaning and implication of the relationship between attitudes and achievement, the main findings of research are summarized below:

Achievement in Science

The main findings:

1. In all areas and in all ages (with one exception), whenever there exists a statistically significant difference, it is in favour of males.
2. In all age groups the greatest differences in achievement are in physics.
3. Sex differences in achievement in biology and in chemistry either do not exist or are relatively small.
4. The sex differences in achievement in the junior high school are larger than in the elementary and in the senior high schools. The smaller gaps in the senior high school may be explained partially by the fact that the samples represent, by and large, science majors.
5. In the elementary school, males excel in knowledge and comprehension. In the junior high school, males excel in all three cognitive functions; however, the gap in application is largest. In the senior high school, males excel only in application.
6. In high school, boys excel in formal reasoning and in their ability to distinguish between causal and teleological explanations.

Gender and Attitudes

Table 1 compares attitudes and aspirations related to science in general, whereas Table 2 relates to biology.

Whereas in grade 5 there are no sex differences in attitudes towards science, from grade 9 onwards males exhibit more positive attitudes. These positive attitudes are expressed in a variety of ways. For example, in grade 9, when all students follow the same curriculum, 34% of the males, compared with only 28% of the females, prefer the study of science over other subjects, and 20% of the females compared with only 15% of the males like science *less* than other school subjects. A similar situation is found in grade 12 among students who elected to specialize in science, where the standard score difference in favour of males is 0.25.

Table 1. Students' attitudes towards science, science learning and science-related careers by gender

Aspect	Grade level	N	Higher grade	Effect size	Reference
Attitude towards science	5	2500	=		Zuzovsky et al., 1988
Attitude towards science	9	2500	+		Levin, 1988
Importance of science to society	9	2500	+	0.27	Levin, 1988
Aspire to follow science-related careers	9	2500	+		Levine, 1988
Attitude towards science	10	684	+		Novick & Duvdevani, 1976
Scientific curiosity	10	322	+	0.26	Hofstein et al., 1981
Aspire to follow a science research career	10	900	+	0.28	Tamir & Gardner, 1989
Aspire to follow a science teaching career	10	900	-	0.38	Tamir & Gardner, 1989
Attitude towards science	12	2000	+		Tamir, 1988
Importance of science to society	12	2000	+	0.47	Tamir, 1988
Importance of science to student	12	2000	+	0.55	Tamir, 1988
Motivation to study science	12	2000	+	0.21	Tamir, 1988
Like to study science	12	2000	+	0.25	Tamir, 1988
Non-science major in high school	12	500	-		Tamir, 1988
Aspire to follow a science research career	12	2000	+	0.24	Tamir, 1988
Aspire for an engineering career	12	2000	+	0.34	Tamir, 1988
Aspire for a medical career	12	2000	=	0.23	Tamir, 1988

All differences are statistically significant $p < 0.05$; (+) males higher, (-) females higher, (=) equal.
Source: Friedler & Tamir, 1990.

Table 2. Attitudes towards and interest in biology by gender

Area/Aspect	Grade level	N	Higher grade	Effect size	Reference
Human biology	7, 8, 9	991	-		Lazarowitz & Lazarowitz, 1979
Health-related topics	9	2029	-		Blum, 1987
Biology	10	900	-	0.25	Tamir & Gardner, 1989
Human biology	10	900	-	0.48	Tamir & Gardner, 1989
Applications of biology	10	900	+	0.36	Tamir & Gardner, 1989
Biology is difficult	10	900	+	0.24	Tamir & Gardner, 1989
Intend to major in biology	10	410	=		Hofstein et al., 1977
Major in biology in high school	12	2500	-		Tamir, 1988
Interest in biology	12	2500	-	0.30	Tamir, 1988

All differences are statistically significant $p < 0.05$; (+) males higher, (-) females higher, (=) equal.
Source: Friedler & Tamir, 1990.

Another indication is the higher percentage of girls (66%) among students who elect *not* to study any science in grade 11 and 12. (About half of the senior high students take no science subject as a specialized field of study.)

Males also exhibit a higher level of scientific curiosity and appreciate the importance of science in their own lives and for the benefit of society more than do females.

Finally, more boys are interested in following a science-related career, especially in research and engineering. Interestingly, there are no sex differences in aspirations for a medical career.

Subject Preference and Gender

Boys show a higher preference for subjects such as energy, wave theory and electricity, while females have a greater preference for health, human physiology and reproduction. A study of associations with the concepts of equilibrium and regulation reported that girls showed more associations with biology-related subjects, while boys' interests were more related to physics (Jungwirth, 1986).

All in all, it is seen that males are more oriented towards physics while females are more oriented towards biology. Indeed, 60% of biology majors are females, compared with only 31% among the physics majors. In chemistry, half the majors are females. It is interesting to note that in spite of the male orientation towards physics, more females refuse to accept that physics is masculine and that it is biased against females.

Learning in the Laboratory

Table 3 compares the attitudes of males and females as related to the school laboratory. The data indicate that girls consistently exhibit more positive attitudes towards practical work in all the subjects, including physics.

Table 3. Attitudes related to the school laboratory by gender

Aspect	Grade level	N	Higher grade	Effect size	Reference
Observing natural phenomena	10	900	-	0.57	Tamir & Gardner, 1989
Performing applied research	10	900	-	0.60	Tamir & Gardner, 1989
Attitudes towards physics lab	11,12	157	-	0.54	Tamir et al., 1974
Lab is an integral part of the study of chemistry	10,11	505	-	0.24	Hofstein et al., 1976
Attitudes towards science lab	9	2500	=		Levin, 1988
Attitudes towards science lab	12	2500	-	0.21	Tamir, 1988

All differences are statistically significant $p < 0.05$; (+) males higher, (-) females higher, (=) equal.
Source: Friedler & Tamir, 1990

Attitudes and Achievement Related to Plants and Animals

A special reference is made to issues related to plants and animals because there were studied extensively in Israel (table 4). The data show that while both boys and girls equally prefer to study animals (over plants) and to engage in outdoors activities, there are clear indications of botany-zoology gender polarity. Girls have a higher preference for botany while boys have a higher preference and readiness for experiments with, and dissections of, live animals. Regarding achievement, the results of the studies in the 1970s match the attitude polarity as girls achieve better in plant identification and in botany in general, while boys achieve better in zoology. However, in the 1980s the data of the two available studies, while still revealing a higher achievement of boys in zoology, also show a somewhat higher achievement of boys in botany. This does not imply that the general achievement of boys is higher, since girls achieve better in human biology and in genetics.

Table 4. Attitudes towards plants and animals and achievement in botany and in zoology by gender

Aspect	Grade level	N	Higher grade	Reference
<i>Attitudes</i>				
Prefer outdoor over indoor activities	9,10	900	=	Jungwirth, 1973
Prefer indoor activities with animals	9,10	900	=	Jungwirth, 1973
Prefer indoor activities with plants	9,10	900	-	Jungwirth, 1973
Prefer to study animals	7,9,10	300	=	Mayer & Tamir, 1972
Prefer to study plants	7,9,10	300	-	Mayer & Tamir, 1972
Like to identify plants with a key	12	560	-	Tamir, 1972
Care for welfare of animals used in laboratory investigations	7,9,11	450	-	Tamir & Hamo, 1980
Favor use of living organisms in biology studies	7,9,11	450	+	Tamir & Hamo, 1980
Increasing with age the will to use live animals in laboratory investigations	5,7,9,11	580	+	Silberstein & Tamir, 1981
Ready to dissect a mouse	5,7,9,11	580	+	Silberstein & Tamir, 1981
<i>Achievement</i>				
Plant identification with a key	12	560	-	Tamir, 1972
Botany in mainstream matriculation examinations 1969-73	12	1700	-	Tamir, 1972
Zoology in mainstream matriculation examination 1969-73	12	1700	+	Tamir, 1972
Botany in agricultural stream matriculation exam 1970-73	12	1230	-	Tamir, 1972
Zoology in agricultural stream matriculation exam	12	1230	+	Tamir, 1972
Botany in mainstream matriculation examination, 1982	12	1900	+	Tamir, 1985c
Zoology in mainstream matriculation examination, 1982	12	1900	+	Tamir, 1985c
Botany in Second International Science Study 1983-84	12	840	+	Tamir, 1988
Zoology in Second International Science Study 1983-84	12	840	=	Tamir, 1988

All differences are statistically significant $p < 0.05$; (+) males higher, (-) females higher, (=) equal.
Source: Friedler & Tamir, 1990

Discussion

Most of the studies reported were not designed for the purpose of comparing males and females; therefore, it is difficult to find causal explanations for many of the findings. In some cases, for example, attitudes and achievement are positively correlated, while in others they are not. Nevertheless, we shall try to identify general trends. While doing so, we remind ourselves that some of the findings are based on very few studies, hence they should be treated with caution and the

conclusions should be regarded as hypotheses calling for further empirical support. The most obvious case in point is the data pertaining to the elementary school, which are based on one study only: Zuzovsky *et al.* (1988).

The general picture that emerges from this review is the following: in the elementary school, boys and girls are very similar in their attitudes towards science, in achievement in biology, in application, in inquiry skills and in practical work. Yet, even in these early years, boys' knowledge and understanding of physics and chemistry are somewhat better than that of girls. In general, by grade 8 or 9 Israeli girls have more positive attitudes towards school and achieve as well or better than boys (Kfir, 1988). Although by grade 12, girls still have more positive attitudes towards school, their achievement is lower than that of boys (Kfir, 1988). Kfir's results regarding attitudes have been confirmed by Levin (1988) and Tamir (1988). For example, girls devote more time and more attention to homework (Tamir, 1985a; 1988). However, the situation regarding achievement in science is very different from that reported by Kfir.

It appears that the junior high school plays a crucial role in distracting girls and pushing them away from science. The negative experiences during this crucial period may be one of the main reasons why two thirds of the students who stay away from science in grades 11 and 12 are girls.

By grade 10, when students make their choices for specialized fields of study in grades 11 and 12, we begin to see the interaction between sex and the different science disciplines. At this time the biology-physics polarity emerges, with chemistry occupying a place in the middle. This is also the time when another polarity is at work, namely the plants-animals polarity. Thus, on average, males are more oriented towards physics and engineering while females are more oriented towards biology. And within biology females have a higher preference than males for plants, and a stronger reservation from using live animals in the study of biology.

Girls have emerged as showing significantly more favorable characteristics for inquiry and practical work in the laboratory. It may be speculated that if physics would be taught with greater emphasis on inquiry, girls' achievement may improve and the sex-achievement gap would disappear.

It should be noted that girls who decide to specialize in science do not conform to the "slowing down" process described by Kfir (1988). This is evidenced by the equally high achievement of girls in biology and in chemistry. Since the girls who elect to specialize in physics are at least as bright and science-oriented as those specializing in chemistry and biology, their lower achievement in physics compared with boys must be a result either of the nature of the curriculum, which is highly traditional, or of some unknown ecological factor.

Although the underachievement of the 12th grade girls in physics needs attention, the most important implication of this study is the urgent need to improve the

achievement and attitudes of girls at junior high school level. This would require careful examination of curriculum and instruction at the upper grades of elementary school as well as in grades 7 to 9. Such an examination should result in ideas, strategies, activities and curriculum materials which would attract girls, challenge their curiosity and enhance their achievement. With such an invigorating background, significantly more girls may be expected to attempt at least one science subject in grades 11 and 12, where, by and large, they already achieve, on average, as well as boys.

The Structure of Interest in High School Biology

School subjects contain a variety of topics and these may appeal to various groups of students in different ways. Students may also vary in their motivations for learning particular topics, in their interest in different activities associated with a particular discipline and in their preference for various modes of learning.

Purpose

The purpose of the study was to identify the structure of interests associated with the study of biology in high school. More specifically the following questions will be dealt with:

1. What are the dimensions which contribute to the structure of interest in the study of biology?
2. How are these dimensions related to each other?
3. What is the impact of schools on interests?
4. What are the interest differences between boys and girls?
5. Are interests related to parents' occupation?
6. How are interest patterns in grade 10 related to choice of subsequent subject specialization in grade 11?
7. How are interests related to achievement?

Method

Seven measurements of interest were identified and examined in this study. Separate questions were designed, each including 15 or 20 Likert-type items. Following is a brief description of the dimensions:

Interest in science topics (IST). This instrument comprises 45 items representing a broad range of biological topics. In order to decrease administration time the items were divided into groups. For each item, students indicate their interest in learning and knowing more about it.

Interest in scientific activities inventory (ISA). This inventory lists 20 activities associated with the study of science. The items in this inventory assess interest in engaging in various cognitive processes, e.g. observing, estimating, theorizing.

Activity motives inventory (AMI). Fifteen possible reasons for being interested in a certain topic are listed. Students indicate the importance of each reason in determining their level of interest.

Interest in social aspects of science inventory (ISAS). Ten items representing inter-relationships between science and society are listed. Students indicate their interests in participating in discussion of each topic.

Career orientation inventory (COI). These 15 items, representing a variety of science related occupations assess student interest in possibly choosing each occupation as a career.

Attitude towards biology study inventory (ATBS). For these 20 items, reflecting positive and negative attitudes, students indicate the extent of their agreement with each statement.

Learning modes preference inventory (LMP). A list of 15 learning activities is presented. Some involve passive reception modes (e.g. attending a lecture), some active engagement with nature (field trips), others in social instruction (class discussion). Students indicate their preference for each activity.

Background Questionnaire

The following background data were collected: school, gender, whether the parents' occupation is related to science, science topics elected for specialized study in grades 11 and 12, and recent school grades in biology, chemistry and physics.

Subjects and Administration

The subjects were 900 10th grade students from 14 schools, 10 located in Jerusalem and its vicinity and four in other regions of Israel; 12 schools were Jewish and two were Arab.

Data Analysis

The responses to each of the dimensions were submitted to varimax factor analysis. The factors which were obtained served as a basis for constructing subtests to be used in further analyses. These further analyses involved frequency distributions, means, standard deviations, correlations, *t*-tests, analysis of variance.

Findings

The structure of interest in biology is expressed in terms of the various facets which were examined in this study.

Topics

Table 5 is given as an example and presents nine dimensions of topics. Each of these dimensions will constitute a separate subtest as follows:

- Molecular biology and biotechnology (7 items)
- Regulation mechanisms and adaptations (5 items)
- Human physiology and behaviour (4 items)
- Maintaining human health (4 items)
- Applications (3 items)

Table 5. Results of varimax factor analysis of the interest in science topics inventory (N=377)

Topic	Rotated Factor Loadings				
	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5
1. Ways of caring for face skin				0.70	
2. Ways to decrease teeth decay				0.75	
3. Preparing preserved food				0.44	
4. Treating malfunctions of digestive system	0.37		0.37	0.42	
5. Human reproduction and related issues			0.50		
6. Providing first aid to road accident casualties			0.30		0.41
7. Improving athletic performance					0.58
8. Effect of smoking on heart & lung function			0.47		
9. Preventing conception			0.54	0.34	
10. Effect of sedatives on humans			0.74		
11. Molecular composition of snake poison		0.58			
12. Water preservation mechanisms in cactus	0.34	0.73			
13. Factors which affect photosynthesis rate	0.39	0.70			
14. Methods for producing artificial genes	0.58				
15. Adaptations of organisms to life in the Dead Sea	0.48	0.44			
16. Methods of manufacturing new antibiotics	0.67				
17. Reproduction of desert reptiles	0.32	0.59			
18. Inducing mutations in viruses	0.63				
19. Effect of drugs on jet lag	0.49				
20. Conduction of stimuli in nerves & muscles	0.60				
21. Enzymatic decomposition of proteins	0.58				
22. Effect of temperature on rate of reaction	0.44				
23. Effectiveness of chemical treatment on mentally retarded	0.33		0.51		
24. Regulation of flowering time of ornamentals		0.58			
25. Training guard dogs					0.53
<i>Percentage of explained variance</i>	61	20	9		

Source: Tamir & Gardner, 1989

Scientific Activities

The data show four factors which emerged in the analysis. Since three of the items did not load on any factor, they were included on the basis of logical analysis in the most appropriate subtests. Thus the following subtests were created:

- Intellectual inquiry activities (7 items)
- Observing natural phenomena (5 items)
- Exploring the micro world (4 items)
- Carrying out applied research (4 items)

Activity Motives

Four factors emerged; since one item did not load on any of the four factors, it was decided to treat it as a separate subtest. Hence the following subtests were created:

- Utilitarian, instrumental (3 items)
- Independent experiences (6 items)
- Active teacher (2 items)
- Exploring/problem-solving (3 items)
- Logical thinking (1 item)

Science and Society

Three factors emerged and make three subtests:

- Preserving the environment (3 items)
- Moral issues related to intervention in human life (6 items)
- Preventing conception (1 item)

Career Orientation

Four factors emerged. Although one factor loads with three professions all involving close interactions with people, it was decided to separate teaching from the two medical professions. Hence the following five subtests were created:

- Scientific research (5 items)
- Medicine (2 items)
- Applied technicians (5 items)
- Nature field-school or zoo (2 items)
- High school teacher (1 item)

Attitude to the Study of Biology

Four factors were obtained. Since items 10 and 19 did not load on any of the four factors, it was decided to regard item 10 as a separate subtest and to drop item 19 from further analysis. Hence the following subtests were created:

- Enjoyable (7 items)
- Difficult, frustrating, not clear (5 items)
- Boring, not interesting (4 items)
- Not important (1 item)
- Matriculation examination too complex (1 item)

It will be seen that the positive items tend to load on one factor, while the negative items load on other factors. Thus, positive and negative affects are not necessarily bipolar, a phenomenon discussed at length elsewhere (Gardner, 1987).

Preference of Learning Modes

Four factors emerged, each constituting a separate subtest.

- Experiential learning (5 items)
- Reception learning (4 items)
- Studying summaries (3 items)
- Social interaction (2 items)

Level of Interests

An examination of the data reveals the following:

1. Among the nine subject-matter areas the three most interesting are reproduction, human physiology and behaviour, and interrelations of organisms. The least interesting are regulation and adaptation, molecular biology and maintaining human health.
2. With regard to future career, medicine comes out as the most desirable, while high school biology teacher comes last.
3. Among social aspects of science, moral issues are the most interesting.
4. The most interesting activities are exploring natural phenomena and carrying out applied research.
5. Reasons and motives for preferring certain activities over others are, first, instrumental, followed by the way the teacher handles the activities. Apparently all the reasons play an important and quite similar role.
6. Biology for most students is an enjoyable, easy and successful, interesting and important field of study, in spite of the perception of the matriculation examination as being too complex.
7. With regard to learning-modes, experiential learning is by far the most preferred. Social interaction is also highly regarded, while reception learning appears to be only moderately interesting. Not surprisingly, studying summaries and copying them is not something which most students like to do.

Interrelationships

Content areas. The intercorrelations among the different biological areas range between $r=0.42$ and $r=0.65$, with a mean value of $r=0.52$. Although these areas were formed on the basis of factor analysis by which they were separated, these intercorrelations are quite high. It may be concluded that, at the 10th grade, students who are interested in one biological area tend to be interested to some extent in other areas as well.

Content areas and social aspects. The data present the correlations between content areas and social aspects of science. It may be seen that all the correlations are positive, and, with two exceptions, statistically significant. The strength of the relationships is apparently determined by the common ground underlying the pertinent variables. Thus, for preserving the environment the strongest relationship is with regulation and adaptation; for moral issues it is with human physiology and behaviour; and for preventing conception it is with human health as well as human physiology and behaviour. It may be concluded that an interest in a particular biological area is associated with interest in its social implications.

Content areas and career orientations. Aspiring for a career in scientific research is most strongly associated with interest in molecular biology and least strongly with applications. Quite oddly, aspiration for a medical career is only weakly associated with interest in human health. On the other hand, it is most strongly associated with interest in applications, a relationship which makes sense since medicine requires application biological knowledge.

Interest in applied careers (e.g. nursing) is most strongly associated with interest in human health, while a career of a guide in a nature field-school or a zoo is most strongly associated with application. Interest in a teaching career is moderately associated with interest in human health and is not related to interest in the applications of biology.

Social aspects and science career orientations. The correlations of career orientations with science-society issues are smaller than with content areas of all careers except scientific research. Interest in moral issues shows a weak to moderate correlation with all career groups, i.e. students who are interested in a biological career, regardless of what type, tend to be more interested in moral issues.

Content areas and attitudes. There is no correlation between interests and the perception of the complexity of the matriculation examination in biology. The strongest positive correlations are between interests and enjoying the study of biology, while the strongest negative correlations are with perceiving the study of biology as boring. Difficulty and importance are only weakly related to interests in various content areas of biology.

Content areas and learning modes. The data do not reveal great differences either among the different content areas or among the learning modes, with one exception: the weakest correlations are between interests and a preference for studying summaries. Altogether the strongest relationships appear between experiential learning and interests. This means that the more interested they are in various topics, the more these students prefer experiential learning. The fact that other correlations are also positive hints that the interested students remain more interested regardless of the learning mode.

Attitudes and learning modes. Students who enjoy learning biology find all learning modes acceptable; however, they find studying summaries less interesting than other modes. Studying summaries has the weakest correlations with negative attitudes toward biology. Thus, students with negative attitudes toward biology are less inclined to prefer the more involved learning modes and can be satisfied with learning from summaries which may be the quickest way to get this biology over with.

As may be seen, here again the perception of the complexity of the matriculation examination has no relationship to any learning-mode preference.

Interests in activities and their motives. The data present the correlations between interests in activities and the motives students have indicated for these interests. For intellectual inquiry activities, the stronger motives are the seeking of independent experiences, such as spending time outdoors or manipulating equipment in the laboratory, as well as problem-solving.

For observing natural phenomena and carrying out applied research, again the strongest relationship is with the motive to engage in independent personal experiences. For exploring the micro world, the strongest relationship is with the wish to explore the unknown and to solve problems.

Although the remaining correlations are not as high as those mentioned above, nevertheless they are all positive.

The impact of schools. Analysis of variance revealed statistically significant differences among schools in all the topics, in all the social issues, in all learning modes, in all attitudes towards the study of biology and in the perception of the biology matriculation examination. Because of the small number of schools in each sample, it was decided not to attempt to estimate the school impact quantitatively. However, there is no doubt that the school environment exerts substantial influence on the development of interests.

Boys and girls. The results of the data indicate that boys have, on average, a higher level of interest in careers which involve scientific research, in preserving the environment and in the applications of biology. More boys find biology to be boring; the achievements of boys in biology (and in physics) is somewhat higher than that of girls in one of the three samples. However, there were no such differences in the other two samples, either in biology or in physics. Thus, the general conclusion is that by the end of the 10th grade there are practically no differences in achievement between boys and girls. On the other hand, girls reveal a higher level of interest in a large number of areas, namely:

careers: applied technology and teaching high school biology;

biological topics: maintaining health, reproduction, human physiology;

activities: observing natural phenomena;

motives: utilitarian-instrumental, independent experiences;

learning modes: social interaction; carrying out applied research;

attitude: although girls perceive the study of biology and the matriculation examination as more difficult, they at the same time see it as less boring.

The general conclusion that is warranted by the data is that at the 10th grade girls exhibit, on average, a higher level of interest in the content and process of biology. This higher interest does not affect achievement. At the same time, boys are more interested in the applications of biology and in becoming research scientists.

The effect of parents' occupation. As may be seen by the data, students with one or both parents engaged in a scientific occupation are indeed more science-oriented. More specifically, such students are more interested in becoming research scientists, to study molecular biology, to explore and to solve problems; they also tend to perceive their teacher as more active. At the same time they perceive the study of biology as less difficult and less frustrating. They reject the "easy way" of studying from summaries and they achieve significantly higher

standards, both in biology and in physics. Unfortunately, perhaps, they are less inclined to become high school biology teachers. It is worth noting that, in spite of the stronger science orientation of students whose parents work in a science-related occupation, in most areas examined in this study the remaining students exhibit similar levels of interest.

Specialized field of study. The students in all three samples were classified according to their intended specialized field of study into four groups as follows: biology high level, biology low level, physics/chemistry, and non-science. In Israel, senior high school students can elect to take subjects at various levels. The distribution in terms of percentage was 40, 23, 16 and 21, respectively. The large percentage of students who intend to elect biology is noteworthy.

In order to facilitate the comparison, the number of statistically significant differences between the groups is presented. The data indicate that group 2 is quite similar to groups 3 and 4 in achievement and in interests. This means that students who elect low-level biology rather than other subjects take it neither because they are more interested in the study of biology nor because they have a more successful achievement history in biology. In fact, group 3, the physics/chemistry specialists, exhibits a higher level of interest in all the six subtests in which statistically significant differences were found. It may be concluded that group 3 students are more interested in some aspects of biology even though they do not elect to specialize in it.

What about the differences in interests between groups 2 and 4? In one area, the non-scientists (group 4) exhibit more positive attitudes: more of them consider it interesting to work in a zoo or in a nature field school. However, in the remaining eight subtests, group 2 is significantly more positive. The students in group 2, compared with group 4, are more interested in scientific research, agricultural applications, inquiry, exploring the micro world and in problem-solving. They perceive the study of biology as more important and less difficult and more of them consider the matriculation examination in biology to be fair. These eight variables make the interest pattern of students who elect low-level biology distinct from their friends who shy away from science altogether.

Group 3 differs from group 1 in the achievement pattern: the “biologists” achieve better in biology while the “physical scientists” achieve better in physics.

The other differences are also quite congruent with their elected field of specialized study: the biologists are more interested in biology-related careers such as medicine, zoo and nature field school; they are more interested in the study of biology in general and in certain topics such as regulation and adaptation in particular; their interest in certain study activities is more utilitarian and for them the study of biology is less frustrating. However, the fact that for most areas there were no statistically significant differences implies that there is a great deal of overlapping of interests. Perhaps the more decisive factor in determining the different choices of specialized fields of study in these groups is success history.

As may be seen, group 1, the high-level biologists, differs in most areas from groups 4 and 2. It is clearly evident that the students in group 1 are quite distinctive both in their high level of interest and in their successful achievement history.

On the basis of the data it is possible to distinguish between strongly science-oriented students (groups 1 and 3) and less science-oriented students (groups 2 and 4). The first group consists of more than half of the high school student population, and is distinguished by its interest patterns as well as its achievement. Two thirds of the science-oriented students elect to specialize in biology. When these biologists reach the 10th grade they already possess a distinctive interest pattern which is highly congruent with their choice of biology as their specialized field of study.

Achievement in high school. In Israel examination results and end of term grades are reported on a 10-point scale. Typical grades of 7, 8 and 9 represent fair, good and very good performance, respectively. The data relate interests to achievement levels. High achievers are more interested in careers involving scientific research and/or medicine (but not applied technology, nature field school, zoo or teaching). As far as particular topics are concerned, they are more interested in five out of nine topics (but not in inquiry, observing natural phenomena or applied research). Their distinct motive is exploration and problem solving (but not logical thinking, utilitarian, or independent experiences). Also, they do not regard having an active teacher any differently from students at lower levels of achievement.

Their distinct learning modes are experiential learning as well as reception learning (but not studying summaries or social interaction). Their positive attitudes toward the study of biology are reflected in all pertinent variables. And, lastly, most of them achieve better not only in biology but also in chemistry and physics.

To sum up, the high biology achiever is more interested in certain biological topics, aspires for a career in medicine or scientific research, is especially interested to explore the micro world, prefers experiential learning and problem solving, has a positive attitude towards the study of biology, and tends to achieve well in chemistry and physics.

Discussions and Conclusions

The major purpose of the study was to identify interest patterns related to the study of biology in high school. In order to accomplish this task, eight interest dimensions were defined *a priori*. These included one behavioural dimension: the election of specialized field of study, and seven interest domains: topics, activities, motives, social aspects of science, attitudes, learning modes, and career orientations. The behavioural dimension consisted of four options, namely: non-science, physical science, low-level biology and high-level biology.

This dimension revealed that 56% of the students are strongly science-oriented, with two thirds of this group electing to specialize in biology. Of the remaining 44%, about half elect to specialize in low-level biology. The other domains were measured by seven scales consisting of Likert-type items. Factor analysis revealed a number of underlying dimensions within these domains. These dimensions were used to produce subtests as follows: 45 topics were collapsed into 9 subtests; 20 activities into 4 subtests; 15 motives into 5 subtests; 10 science-society items into 3 subtests; 15 career orientations into 5 clusters; 20 attitude items into 5 items; and 15 learning experiences into 4 modes. This reduction of 150 items into 35 subtests allows for a meaningful and manageable analysis and provides, therefore, an important contribution to the study of interests.

The major findings and conclusions of the remaining analyses may be summarized as follows:

1. For the entire student population, the highest levels of interest found were regarding topics which involve human biology, activities which involve exploring and problem solving, social aspects related to moral issues and learning from direct experiences, such as laboratory investigations, field trips and individual projects. The strongest motive for preferring particular activities is their utilitarian and instrumental value, for example, helping to succeed in the matriculation examination or constituting a preparation for a future career. As far as careers are concerned, medicine occupies first priority. And finally, most students perceive biology as interesting, important, enjoyable and successful in terms of achievement.
2. Students who are more interested in one biological area tend to be more interested in other areas as well. Interest in a specific topic is often associated with its social implications (e.g. human physiology and moral issues) as well as with a particular career (e.g. biological applications and medicine).
3. Attitudes towards the study of biology are closely related to interests.
4. Liking to learn biology is positively related to interests for all the learning modes employed in the classroom. However, interest is more strongly related to experiential learning than it is to studying from summaries.
5. A preference for any activity may be related to a number of motives, yet research and investigation are most strongly associated with a preference for independent personal experiences such as spending time outdoors or caring for organisms and manipulating equipment.
6. There are significant differences among schools in the levels of students' interests.
7. Although boys achieve as well as, or better than, girls, and are more interested in applications and in careers as research scientists, girls exhibit higher levels of interest in certain topics (e.g. reproduction and human physiology), certain activities (e.g. observing natural phenomena) and certain careers (e.g. nurse, high school biology teacher). Although girls perceive the study of biology as more difficult, they see it as less boring. They have a higher preference for independent learning and for learning which involves social interaction.

8. Students whose parents' occupation is related to science are significantly more interested in, and more oriented towards, biology.

9. Students who elect to specialize in high-level biology have a distinctively more positive interest profile than all other groups. The closest profile is that of the physical science group, whereas the other two groups, namely the low-level biology and non-science have a much less positive interest profile. Apparently, the election of low-level biology is not based on interests in biology but on other reasons such as convenience or the least undesirable available option.

10. Interests and achievement in biology are strongly interrelated. The high biology achiever is more interested in certain biological topics, seriously considers a career in scientific research or medicine, is especially interested to explore the micro world, prefers experiential learning and problem solving, has positive attitudes towards the study of biology, and tends to achieve well in chemistry and physics.

11. It appears that when students reach the 10th grade, many of them have already developed a clear profile of interests which is associated with achievement, affects their choice of specialized field of study and determines their career orientation.

Variables that Affect Students' Enrolment in Science Courses

Results and Discussion

The results of this study are presented in two parts; in the first, students' reported reasons to enrol (or not enrol) in physical science courses, namely to study or not to study physics, and/or chemistry beyond the required level; in the second, results of a stepwise regression analysis which enables us to find out which of the students' characteristics best predicts his/her choice for enrolment is presented.

Table 6 presents mean ranking of students' reasons to *enrol* and *not enrol* in physical science courses. From this table it is clear that the dominant factors that influence students' decision are those that relate to students personally, i.e. interest, future career and his/her inclination towards the given subject (science or humanities). Extrinsic factors, on the other hand, like the media, parents, teacher and peers are perceived to be less effective concerning students' enrolment. It is suggested, however, that there is a need to explore further the question of whether or not teachers influence students' decision concerning enrolment. The authors of this article hypothesize that since the teacher is the key person concerning activities that take place in the science class, he/she are responsible, at least to some extent, for making the classroom environment interesting and in this capacity influence students' decisions; but the data indicate that students do not perceive that influence.

Table VI. Student ranking of reasons for enrolling (or not enrolling) in physical science courses

	Reasons for enrolling in science		Reasons for not enrolling in science	
	M	SD	M	SD
1. Interest (lack of interest)* in science courses	7.24	1.30	6.62	1.88
2. Interest (lack of interest) in science as a future career	6.49	1.40	6.47	1.44
3. Success in science (humanistic) studies	6.09	1.40	6.42	1.62
4. Science (humanities) is very prestigious	4.18	1.83	3.02	1.92
5. Influence of parents	3.85	1.60	3.59	1.65
6. Influence of friends	2.93	1.44	3.57	1.49
7. Influence of teachers	2.92	1.36	3.45	1.57
8. Influence of media	2.33	1.55	2.71	1.62

*In parenthesis the item presented to students as a reason for not enrolling in physical science courses. Source: Milner, Ben-Zvi & Hofstein, 1987

Results of the Regression Analysis

In this analysis, the number of physical science credit points studied is defined as the dependent variable. Each credit point is equivalent to 90 periods of the subject taught. The maximum credit points the student can take in a given subject is five, one of which is compulsory for all students. The range of this variable is from 2 to 10, which is the sum of credit points taken in physics and chemistry. For example, two credit points cover the compulsory units of chemistry and physics in the 10th grade, while the sum of 10 credit points means five credit points in chemistry, plus five in physics.

The independent variables are:

1. Scales obtained from the *attitude towards school science* questionnaire;
2. Scales obtained from the *attitude toward science* in general;
3. Personal and socioeconomic variables: students' gender, father's occupation and education; father's land of origin.

The results of the stepwise regression analysis is presented in Table 7. Only those variables that contributed significantly ($p < 0.001$) to the total variance were included in the table.

Table 7. Stepwise regression analysis (N=616)

Variables	β of last step	R^2	ΔR^2	F ΔR^2	p
Interest in science studied in school	0.35	0.24	0.24	193.1	0.001
Gender (males, females)	0.25	0.30	0.06	60.0	0.001
Clearance of science (difficulty of science)	0.17	0.34	0.04	28.5	0.001
Father's education	0.14	0.36	0.02	16.8	0.001

Source: Milner, Ben-Zvi & Hofstein, 1987

From Table 7 it is seen that four variables contributed significantly to the total percentage variance (36%) that explains the number of credit points that students took in the physical sciences. The scale that deals with students' interest in science covered 24% of the total variance. This scale originated from the questionnaire that measured students' attitude toward and interest in school science and it consisted of items like: "science classes are fun"; "science classes are interesting"; "scientific work intrigues me."

Summary and Implications

From the literature it is seen that several factors are associated with students' decisions concerning enrolment in science courses. Lowery (1967) in the U.S. and Gardner (1975) in Australia have found association with students' gender. Krippner (1963) in the U.K. found that the decision is associated with students' home background and parental influences. Hofstein *et al.* (1977) confirmed these findings with an Israeli high school population. The present study has clearly shown that the most predominant and influential factor concerning students' enrolment in physical science courses is the one that deals with students' attitudes towards and interest in school science. This finding is in fact a call to those who are involved in science education, to plan and develop science curricula that will be tailored to the needs and interest of students. The authors of this paper hypothesize that by using such curricula students will develop positive attitudes towards science in general and towards school science in particular and eventually this will lead to the increase in enrolment in school science.

An example of such an approach is the development of a chemistry curriculum based on a new text, "Chemistry - A Challenge" (Ben-Zvi & Silberstein, 1981). Recently developed, it is intended to form a sound basis for students who will continue their chemistry studies and also to give the non-science majors an insight into what science is. Much stress is put on the development of scientific models, on links between chemistry and the world outside the classroom and on the "human" side of science. Teachers who have taught this program report that students, even low ability and non-science oriented students have found their chemistry studies interesting.

Attitudes of Secondary School Students in Israel Towards the Use of Living Organisms in the Study of Biology

Introduction

Most of the modern inquiry-oriented biology curricula are based on the firm conviction and belief in the superiority of learning through direct observations and investigations. While much biological observation is divorced from living things and is concerned with physical and chemical processes, there is a growing belief among biology educators that the study of biology "will be of limited value unless combined with careful, thoughtful observation and investigation of living things" (Australian Academy of Science, 1975). In Israel in which the inquiry-oriented

curricula in biology are widely used, special supply centres have been established to facilitate the use of living organisms in classrooms. These centres, located in different parts of the country, operate on a low cost subscription basis, and provide schools with all kinds of organisms such as unicellular animals, micro-organisms, peas and tobacco seeds, *Drosophila*, fish, toads and mice (Tamir, 1976; Blum & Silberstein, 1979). Recently, however, biology experimentation in schools, and especially the use of living animals for study purposes, have come under attack in a number of countries (e.g. Paterson, 1979). There are already signs that in order to avoid legal and social pressures, teachers conveniently abandon the use of living animals altogether (Barker, 1979).

It may be argued that plants and micro-organisms may often serve as an adequate substitute for animals. Many teachers prefer the use of plants for observations and experiments, mainly because plants are easy to use and maintain and, compared with animals, their behaviour is much more predictable (Tamir, 1976). However, there are certain areas, such as movement, adaptation of animals to their environment, the structure and function of animals, and animal behaviour, which are unique to animals and therefore may have no substitutes. In addition, many studies have shown that children of different ages prefer to study, observe, and experiment with animals (e.g. Green, 1958; Blanc, 1958; Jungwirth, 1973; Tamir & Jungwirth, 1974).

Both positive and negative outcomes of using living organisms in the classroom have been reported (Stevens, 1970; Kelly & Wray, 1975; Silberstein *et al.*, 1978). It is therefore extremely important to consider carefully the emotional, ethical and pedagogical aspects involved in using living organisms in order to provide some guidelines to teachers and schools. Within this framework, the study of students' opinions on various aspects related to the use of living animals in their biology studies appears highly desirable.

A pilot study which involved 126 high school students in Israel (Tamir & Sever, 1980) served as a basis for the present study. The rationale for these studies is the belief that if teachers become aware of their students' views, they will be able to take these views into consideration in their planning and in making decisions about their instructional practices.

Purpose of Study

1. To examine opinions and attitudes of students towards various aspects of using living animals in the study of biology.
2. To identify the attitudes of students to the use of different kinds of organisms in their studies.
3. To study the effects of selected background variables (age, sex, and religious affiliation) on the attitudes mentioned above.

Procedure

The subjects were 456 high school biology students who studied in 9 schools in the city of Jerusalem. There were 3 religious (N=150) and 6 secular schools (N=306); 114 studied in grade 7, 144 in grade 9, and 198 in grade 11.

The students responded to the questionnaire anonymously in May 1979. Some of the teachers who administered the questionnaire failed to remind the students to mark their sex on the questionnaire. Consequently, the information regarding the sex of students was obtained in five classes only, which comprised 89 boys and 93 girls. There is no reason to assume that the students in these classes were different from the rest of the subjects. Therefore there is no reason to omit the comparisons made between boys and girls even though the data pertains only to 40% of the total sample.

The questionnaire consisted of 4 parts, as follows:

Part A consisted of 40 statements to which the subject responded on a 5 point scale in which 1= don't agree and 5= fully agree (see Table VIII). The first 10 statements were identical to those used by Tamir and Sever (1980). The other 30 statements were designed following the responses of 126 students to the open question: "What do you think about the use of animals in experiments and dissections while learning biology in school?" (ibid.).

Part B described an experiment in which the fins of a fish are removed in order to study the effect on swimming and to observe the capability of animals to compensate for missing structures. (This experiment was taken from a 7th grade textbook widely used in Israel.) The subjects had to choose one or more out of four possible responses (see below). It should be noted that in the fish Tilapia which is used in the 7th grade program in Israel, when the fins are cut they eventually regenerate.

Part C consisted of a list of 20 organisms, 4 plants and 16 animals, mixed in random order. These organisms were grouped for the purpose of analysis as follows: plants (pine tree, fern, carrot, orange), lower animals (worms, ants, flies), harmful animals (mouse, poisonous snake, bat), "neutral" animals (lizard, frog, rabbit, pigeon), beneficial animals (black snake, chicken, goat), and pets (cat, dog, fish). The subjects were asked to indicate which of these animals they would use in experiments which could cause irreversible damage to the animals.

Part D required the subjects to choose one or more out of four possible responses (see below) to the statement: "You are assigned to dissect a mouse and implant in it an organ taken from another mouse."

The results were analyzed by computer programs yielding frequency distributions, Chi Square, means and standard deviations, correlations and analysis of variance.

Results and Discussion

Table 8 presents the responses to Part A.

Table 8. Means, standard deviations and response distribution in Part A (in percents, N=456)

Statement	Don't agree 1+2	Agree 4+5	X on a 5-point scale	S.D.
1. I like to study biology	5.9	81.4	4.29	0.98
2. The study of plants is more interesting than the study of animals	69.1	11.6	1.97	1.15
3. It is important to observe animals in nature	5.7	78.5	4.33	0.99
4. It is important to make experiments with animals in the laboratory	18.8	65.8	3.82	1.33
5. One may experiment with animals as long as they do not suffer	19.7	61.8	3.76	1.42
6. Experiments with animals are justified even when they involve long-term suffering	72.2	13.6	1.91	1.28
7. Experiments with animals which are essential to human medicine are justified even when they involve long-term suffering	13.8	72.2	4.04	1.19
8. Laboratory observation of animals may be allowed provided that the animals are returned to their natural habitat	10.8	75.7	4.20	1.24
9. Any experiment which involves animals is more interesting and so should be performed.	31.1	44.1	3.1	1.44
10. Students should perform experiments with animals since in this way they learn much more than by reading books	17.3	69.1	3.89	1.34
11. Teachers' demonstrations should be preferred over students' experiments with animals	44.6	41.2	2.91	1.60
12. Experiments with animals increase our scientific knowledge and contribute to the care of animals as well as of people	17.5	66.7	3.86	1.34
13. Information gained through dissection of animals may help the survival of mankind by improving the medical treatment of people	31.1	47.4	8.19	1.47
14. Only animals which have a high rate of reproduction should be used in experiments and dissections	10.7	74.3	4.13	1.22
15. It is not desirable to substitute experiments with animals by demonstrations, films and TV	28.9	73.9	3.28	1.40
16. Experiments with plants should generally be preferred to experiments with animals	19.6	64.5	3.81	1.41
17. Only animals which are harmful to man should be used in experiments and dissections	48.0	32.3	2.67	1.51
18. The use of rare animals in experiments and dissections should be avoided	9.0	85.8	4.45	1.12
19. Experiments on TV and films should be preferred since the damage to animals is restricted to very few ones	26.5	49.8	3.38	1.42
20. Students lack competence and skills and therefore should not perform experiments and dissections of animals by themselves	41.4	39.5	2.93	1.47

Table 8 (cont.)

Statement	Don't agree 1+2	Agree 4+5	X on a 5-point scale	S.D.
21. Experiments with animals may help learning slightly, but the damage to animals is severe; so experiments should be highly restricted	47.3	30.9	2.72	1.45
22. Generally, dissections are not interesting, so why kill innocent animals?	69.3	17.8	2.00	1.36
23. One should not experiment with animals just to make it more interesting for students	27.8	53.0	3.48	1.47
24. The view that one can treat animals as one wishes is fundamentally wrong	19.1	67.7	3.89	1.40
25. Any experiment with animals is cruel, since animals also have feelings and souls	25.0	51.1	3.47	1.36
26. Any creature has the right to live peacefully without interruption	10.3	72.1	4.07	1.19
27. When human beings benefit, the killing of animals is permitted, even by the Torah	38.3	36.2	2.92	1.45
28. People depend on animals, therefore we should be grateful rather than killing them	36.8	32.2	2.93	1.32
29. Only animals which endanger people may be damaged by dissection and experiments	53.3	26.6	2.50	1.50
30. Material learned by experiments with animals is internalized and understood much better	9.4	74.1	4.11	1.16
31. One may deny feeding vitamins to chickens in order to study the effect of this deficiency on their growth	26.7	50.0	3.34	1.37
32. The student should not rely on secondary sources; he should examine and study animals directly	41.2	35.5	2.84	1.44
33. It is acceptable to cause temporary damage, provided that the animals recover their original state	15.3	66.7	3.84	1.29
34. Experiments with animals motivate students to continue and learn about these animals	16.9	65.7	3.77	1.27
35. Reading reports by scientists about their experiments with animals is better than actually doing the experiments	49.8	26.5	3.62	1.40
36. Experiments with animals are exciting and therefore what is learned is well remembered for a long time.	16.6	70.8	3.96	1.31
37. Observations and experiments with animals help me to understand better my relations with my friends	65.4	16.9	2.12	1.31
38. Doing an experiment with or dissection of animals brings about a lot of satisfaction	35.4	43.4	3.11	1.45
39. Fish are sold in the market and many insects are pests -- therefore they may be used for experiments as well	45.2	26.1	2.64	1.38
40. People kill animals anyway (food, hunting) so the use of animals in experiments does not make any difference	64.9	17.6	2.14	1.33

Source: Tamir, 1980

As may be seen, only 6% of the respondents did not like to study biology. Since most of the students liked to study biology, and most of them preferred to study animals (see item 2), the responses to the various questions, even negative ones, should not be regarded as a consequence of a general reservation to the study of biology, but rather as a genuine expression of attitudes towards the specific issues at hand. Items 3 to 40 were grouped according to their contents into seven subtests. For the purpose of saving space, the remaining tables are not presented.

Contradictory Views of Students

The data show that, in general, students regard experiments with and observations of animals to be important. On the average, they also favor the use of animals for instructional purposes and they value the positive motivational effects of such instruction. At the same time, however, they express sincere concern for and affection towards animals. The results show a number of attitudes which, on the surface, appear as contradictory. A few examples taken from Table VIII will be mentioned. While 72% did not agree that experiments that involve long-term suffering were justified (item 6) 72% agreed with statement 7 that such experiments are justified if the suffering were essential to human medicine. The comparison of the responses to items 6 and 7 may be interpreted as indicating that human health has top priority in the values of most students.

There were additional contradictory answers relating to 5 items which reveal that most students express sincere concern for and affection towards animals. Thus, most students believe that it is fundamentally wrong to treat animals as one wishes (one item) and that any creature has the right to live peacefully without interruption (one item) and, therefore, experiments should not be performed just to make the class more interesting (one item). On the other hand, almost 67% of the students agreed that it is acceptable to cause temporary damage to animals (one item). This contradiction may be explained by suggesting that most students care for animals and would avoid hurting them unless there is a good cause which justifies the use of animals. Even then they would attempt to minimize the damage to animals. The conflict between the recognition of the importance of working with animals on the one hand, and the desire to avoid unnecessary damage to them, on the other, is apparent also in their responses concerning learning. Thus, seven items certainly favour learning based on the use of living animals, while eight items show that even students who favour the use of animals are concerned about the possible damages and interference with the lives of animals. This ambivalence of many students, which is symbolically represented by a total average of 3.23 (slightly above neutral) has important implications, to be discussed later.

T tests revealed no statistically significant differences, neither between boys and girls nor between students in secular and religious schools. Analysis of variance revealed a few statistically significant differences by grade level. Thus 7th grade students when compared with 9th and 11th grade students had a lower mean score on the following subtests: Use of animals in research ($F=5.66$, $p>0.01$),

Importance for learning ($F=8.95$, $p>0.01$), and Importance of actual students' performance of experiments ($F=5.79$, $p>0.01$). In the last two subtests 11th grade students had higher mean scores than 9th grade students and the difference as estimated by the Duncan range test was statistically significant at the 0.05 level. It may be concluded that younger children are more sensitive to the use of animals and that as they grow older they tend to value more the use of animals both in research and in instruction.

Student Responses to Fin Experiment

Student responses related to the experiment involving the removal of the fins of a fish were almost identical with those obtained in the pilot study (Tamir & Sever, 1980), namely, more than half of the students were ready to perform the experiment while only 11% declared categorically that they would not perform the experiment. It is interesting to note that significantly more 7th grade students, whose curriculum requires the performance of this particular experiment, voted against it. Seventh grade teachers should take this attitude into serious consideration in their planning and instruction. This particular experiment would not have been permitted in British schools because of the clear-cut avoidance of vivisection in these schools (Barker, 1979).

In the pilot study it was found that students differ in their attitudes to 12 different animals (Tamir & Sever, 1980). The same 12 animals were included in the present study. Two changes and two additions were made as follows: a) instead of snake in the pilot study we have black snake and poisonous snake; b) flies and ants which appeared as one item in the pilot study are separated here; c) bats and fish were added; d) four plants were added to see whether or not the assumption that students have no reservations regarding the use of plants is valid.

Attitudes Towards Different Organisms

Table 9 presents the results for individual organisms as well as for groups of organisms. Of course the groups were formed post hoc for the purpose of analysis. The findings show that 32 to 43% of the students would not favour causing irreversible damage to lower organisms. The table shows that as far as experiments that cause irreversible damage are concerned, students view plants and lower animals to be alike, and about two thirds of them favour such experiments. The fact that about half of the students are opposed to causing irreversible damage to ferns and pines while only a quarter are against using carrots and oranges, may be a result of the fact that the latter are eaten and the former are normally not eaten. The results suggest that even plants should not be assumed to be suitable for any kind of treatment in a biology course.

Table 9. Percentage of students favouring experiments causing irreversible damage to different organisms* (N-456)

Plants		Lower animals		Harmful animals		Neutral animals		Pets		Beneficial animals	
Whole group	63	Whole group	64	Whole group	41	Whole group	43	Whole group	17	Whole group	17
Carrot	74	Worms	68	Mouse	51	Frog	44	Fish	34	Black snake	29
Orange	73	Flies	66	Poisonous snake	46	Lizard	41	Rabbit	18	Chick-en	12
Fern	53	Ants	57	Bat	27			Cat	13	Goat	10
Pine	52							Pigeon	11		
								Dog	8		

*In each group the organisms are arranged by percentage of agreement in descending order

As far as animals are concerned, it is very clear that the use of pets and useful animals should be restricted to a minimum. Students are more tolerant of the use of harmful animals or of neutral animals such as frogs and lizards. The relatively low percentage regarding bats may be a result of the unfamiliarity of many students with this particular kind of animal.

Comparison of the mean response scores regarding different groups of organisms revealed no statistically significant differences between students in religious and in secular schools. As to grade level, students in 7th grade were less inclined than 9th and 11th grade students to cause irreversible damage to plants and to lower animals. (F values obtained were 7.10 ($p > 0.001$) and 2.94 ($p > 0.05$), respectively). Compared with girls, boys had a higher mean score in favour of the use of plants, lower animals, and harmful animals (*t* values obtained were, respectively, 2.13, 2.21, 1.97, $p > 0.05$). There were no statistically significant differences between boys and girls regarding the use of neutral animals, pets, and useful animals.

Differences by Age

It may be observed that while, as mentioned above, younger students had more reservations about the carefree use of plants and lower animals, older students, on the other hand, were less inclined to sacrifice frogs and bats. Students in religious schools were more inclined to sacrifice pines and poisonous snakes, while students in secular schools exhibited more care for ferns. As already indicated, in all cases where statistically significant differences were found between the sexes, boys showed a higher level of readiness to do experiments which involve irreversible damage. Teachers should take into consideration the special sensitivity of girls.

Readiness to Operate on Mouse

The results show that two thirds of the students were willing to perform an operation on a mouse, while one fifth were not. Significantly, more 7th grade students were reluctant to operate. Perhaps one may conclude that even operations on harmful animals are not desirable to a significant proportion of the students and that even if operations and dissections are necessary, they should be postponed at least until students have reached the 9th grade. It is interesting to note that relatively more students in religious schools were not ready to perform the operation. There were no statistically significant differences between boys and girls in their responses to this question.

Summary and Implications

The responses of students reveal a high level of personal involvement on their part regarding different aspects related to the use of live animals in school. This attitude stems from the high level of interest that most children have in animals, as well as from the personal relations that many children develop with animals. Many children possess empathy, a kind of identification with animals, especially pets and farm animals such as cats, dogs, pigeons, and goats. It is interesting to note that while this empathy is very high towards higher and useful animals, many students express empathy also towards lower animals. For example, 45% of the students do not agree to use fish and insects in experiments even though fish are sold in the market and many insects are pests (Table VIII, item 39). As personal feelings and empathy diminish, logical considerations play more and more of a decisive role. This is evidenced by the relatively high level of consent to the use of mice in operations and experiments. While 74% would not concede as a general practice to substitute experiments with animals by demonstrations, films and TV (Table VIII, item 15) 50% would prefer experiments on TV and films in cases in which the experiments cause damage to the animals, because in these cases filming the experiments will reduce the damage to animals (Table VIII, item 19).

Thus, the attitude of students appears to be somewhat ambivalent. On the one hand it is clear that most students are keen on having live animals as part of their studies in school and see in their experiences with animals a means for increasing the motivation as well as the efficiency of learning and retention. This general attitude of students, combined with some unique outcomes related to the study of animals, make a strong case for the use of animals in schools. On the other hand, many students are genuinely concerned about the life and welfare of animals. Thus, teachers should be alert to both positive and negative aspects of experiences with live animals and attempt to emphasize the positive and avoid or diminish the negative. Based on the results, we offer the following recommendations: Whenever animal suffering may be caused, the need for the planned activity should be reconsidered and students may be invited to participate in the deliberation. When a positive decision has been made, careless handling of organisms, including plants, should be avoided. When lower or harmful animals are capable of serving the instructional objectives, their use should be preferred to that of higher and beneficial animals. While the general use of substitutes such as films and demonstrations is not recommended, such substitutes may nevertheless

be utilized under certain circumstances. Generally, students who are reluctant to perform dissections or operations should not be forced to do so. Certain activities such as dissections may be postponed to upper secondary school levels in order not to hurt the feelings of younger students, especially girls, who reveal special sensitivity at the ages of twelve to fourteen.

Administration of questionnaires, such as the one used in the present study, may serve as a basis for class discussion in which important issues related to the use of live animals may be discussed with and by the students. It is hoped that such discussions will make students aware of these aspects and help them to adopt positive attitudes toward live animals and refrain from unnecessary cruelty and other negative behaviours.

Back to Living Animals: An Extracurricular Course for Fifth-Grade Pupils

Introduction

The teaching of science in elementary schools (ages 6 to 12) has always been problematic, since many teachers are reluctant to teach it, often because they have not been adequately prepared. "Even though much is known about what strategies nurture productive problem-solving behaviour, there is evidence that many of the strategies are not implemented into the majority of elementary classrooms" (Barr, 1993).

Two major curriculum reforms have occurred in the last 30 years in Israel and many other countries: the first in the 1960s, emphasized hands-on inquiry and the structure of the science disciplines, and the second in the 1980s, focused on Science, Technology, and Society (STS). Whereas these reforms have achieved significant improvement in some classrooms, the majority of schools have continued to offer traditional textbook-based programs. Teachers, especially in elementary levels, also perceive themselves as lacking the necessary knowledge to teach science (De Rose, Lockard & Paldy, 1979; Donellan, 1982; Weiss, 1978).

Children in elementary schools are rarely taught about particular organisms even though many are interested to know more about living creatures, especially about animals. In fact, it has been found that most children are interested to learn about animals, especially while they can observe and manipulate the animals, the use of animals in the classroom substantially increases motivation and interest (Mayer & Tamir, 1972; Tamir & Hamo, 1980; Kelly & Wray, 1975; Orlans, 1968, 1972; Silberstein & Tamir, 1981; Tamir, 1985b).

On the other hand, however, the study of living animals raises some problems. First, there is a danger that the animals will be harmed. Second, animals need an adequate environment and care that may be difficult to maintain in school, while plants, for example, cause few such troubles. In this context, it has been found that most children, even those who object to manipulating and experimenting with

fish, toads or chickens, are willing to study and experiment with small animals such as snails or insects (Silberstein & Tamir, 1981).

The present study describes the experiences of 5th grade, 10-year old pupils who had an opportunity to study small animals in an extracurricular framework.

Aims

The purpose of this study is to describe the initiation, implementation and evaluation of an extracurricular enrichment course focusing on a variety of animals, with special reference to small animals.

Discussion

As the reason for using retrospective data was that the decision to evaluate the course was made too late when the course had already been started, it is impossible to say whether data collected before the beginning of the course would be any different. Perhaps the advantage of collecting “before” and “after” data simultaneously is that the pupils are actually comparing the two sets, so that the direction of change is more reliably reported compared with two distant administrations.

Our results show the high interest of students in studying living animals. This study of small animals in schools is quite rare. Yet it is much less problematic than the study of large animals as we have found here; children like animals and are, on average, highly motivated to study them.

The special interest in studying animals has been reported in several studies (e.g. Blanc, 1958; Kelly & Wray, 1975; Stevens, 1970; Tamir & Hamo, 1980). Interesting gender differences were found in our study. Females appear to have more positive attitudes to the extracurricular activity. Regarding means of study, before the course, females’ top preference was direct observation of living animals, whereas males’ top preference was class discussion. At the end of the experience, class discussion remained most highly appreciated by males, but the use of videotapes had reached almost the same level of desirability. For females, Observing animals remained the first choice while Building kits and games came second. It should be noted that the extracurricular course took place during the pupils’ free time. Hence, their general positive attitude was not only seen in their verbal responses, but expressed in their behaviour as well. It may be seen that females, on average, were more sympathetic than males to the program: 90% of the females compared with only three quarters of the males were willingly participating in the course. The small (4%) drop in readiness to participate is insignificant. The fact that participation was required and mandatory, and the school was an elementary school similar to most elementary schools which in Israel serve pupils 6 to 13 years of age, implies that such enrichment can fulfil important functions in schools.

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STUDENTS' CONCEPTIONS

A LONGITUDINAL STUDY OF PUPILS' CONCEPTUALISATION OF THE ROLE OF THE FLOWER IN PLANT REPRODUCTION

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Abstract

In a five-year longitudinal study, 25 pupils were interviewed individually at the age of 10y, 11y, 13y and 15 years of age about the role of flowers in plant reproduction. At age 15, each pupil listened to what they had said four years earlier and described how they thought their understanding had developed. All interviews were tape-recorded and the audiotapes transcribed verbatim. Analysis of the interview data and the descriptions of the pupils' differential conceptual development were grounded in Ausubel's theory of meaningful learning. At the beginning of the study the pupils expressed human-centred ideas. They commonly used anthropomorphic and teleological reasoning to explain the flower's role in plant reproduction. Each pupil's conceptual development from ages 11 to 15 could be described by one of four categorisations. Six pupils expressed alternative ideas all of the interviews. Many pupils had undifferentiated ideas of pollination and seed dispersal. Conceptions of the role of the flower in plant reproduction at age 10y were used as a basis for later conceptual development. An early introduction of some scientific concepts can help students develop deeper understandings of ecological processes. It is important to illuminate pupils' expressions and ideas of science phenomena, give them opportunities to reflect on their ideas and encourage them to compare their conceptualisations with other explanations.

Background

In order to create teaching situations during which students' ideas about natural phenomena can be challenged, educators must understand how the students' thinking about different phenomena develop over time. Therefore, I conducted a longitudinal study of students' developing understanding of ecological processes from the age of 9 to 15 (Helldén, 1992; Helldén, 1995). The ecological processes that I focused on dealt with the conditions needed for life, decomposition, and the role of the flower in plant reproduction. I have found that pupils often use anthropomorphic and teleological reasoning when they describe biological phenomena, especially processes in which flowers are involved. I have also found that pupils often have great problems to differentiate between pollination and seed

dispersal when they shall explain the role of the flower in plant reproduction. Therefore, I chose to study pupils' conceptual development of the role of the flower in plant reproduction in connection to my study of their understanding of the conditions needed for life and the process of decomposition. In this paper I report on pupils' understanding of the role of the flower in plant reproduction.

The purposes of this research project were: 1) to describe, at different ages, pupils' ideas about the role of the flower and how their ideas change over time; 2) to study how the pupils' ideas are influenced by experiences of everyday life; and 3) on the basis of these findings, suggest possible ways of challenging pupils' ideas in order to help them develop more scientific understandings of natural phenomena.

As I mentioned above I expected to find anthropomorphic and teleological reasoning in the pupils' explanations of the role of the flower. An anthropomorphic explanation attributes human characteristics to nonhuman beings. Teleological explanations refers to cases in which ends are used as explanations for certain functions. Anthropomorphic and teleological reasoning have not been accepted in science classrooms because such explanations interfere with causal scientific explanations. This conflict is discussed in a recent publication by Zohar & Ginossar (1998).

On one hand, anthropomorphic/teleological formulations have pedagogical heuristic value: they transform long formulations into shorter ones; enhance pupils' empathy toward scientific topics; and helps pupils to organise information along familiar lines. On the other hand, such information may interfere with accurate causal scientific explanations. (Zohar & Ginossar, 1998, p 682)

In the present study I will investigate to what extent pupils use anthropomorphic and teleological reasoning and how these explanations develop between 11 and 15 years of age.

Theory of learning

The predominant currents in psychology, educational psychology and education during the first half of this century concerning learning were built upon a behaviouristic theory that explained learning as a stimulus - response process. Research about human learning as a change in cognitive structure was generally neglected. During the 1920's Jean Piaget began studying children's cognitive development by interviewing children (Piaget, 1982). In 1964, Piaget presented his ideas in the USA during conferences at Cornell University and at the University of California (Piaget, 1964).

Piaget described a child's conceptual development as passing through a series of stages: A sensory-motor stage (birth to two years), a preoperational stage (two to seven years of age, a concrete operational stage (seven to eleven years) and a formal operational stage (eleven plus years). He argued that a child develops

logical-mathematical cognitive structures that are context independent. Research during the last decades has shown that children's possibilities to learn are not restricted to such stages. (Donaldson, 1978; Carey, 1985 and Novak & Musonda, 1991) Young children can think hypothetically and learn much more at an early age than the stage theory would suggest.

Ausubel's theory of meaningful learning is an alternative description to Piaget's stage theory of conceptual development (Ausubel, Novak & Hanesian, 1978; Novak, 1998). Meaningful learning theory focuses on concept learning. Concepts are defined as perceived regularities of objects or events, or of records of objects or events, and designated a label. Meaningful learning occurs when the learner chooses to relate the new concept to a relevant existing concept and proposition in her/his cognitive structure. Cognitive structure is a given individual's organisation of concepts and propositions. The following three prerequisites must be met in order for for meaningful learning to occur:

1. The subject matter to be learnt must be meaningful.
2. The learner must have a pre-existing conception that is relatable to the new information to be learnt.
3. The learner must choose to learn meaningfully. (Ausubel, Novak & Hanesian, 1978)

The cornerstone of Ausubel's meaningful learning theory is expressed in the following quotation:

If I had to reduce all of educational psychology to just one principle, I would say this: The most important single factor influencing learning is what the learner already knows. Ascertain this and teach him accordingly. (Ausubel et al., 1978, epigraph)

Ausubel's idea seems simple, but how do we ascertain what the learner already knows? In order to explain the key principles of his learning theory, Ausubel defined several important concepts.

Meaningful learning occurs when the learner substantively relates new knowledge to concepts that already exist in the learner's cognitive structure. New concepts are assimilated with pre-existing concepts and integrated into a person's cognitive structure. When there are no recognised relevant concepts in a person's cognitive structure, rote learning may occur. Concepts are assimilated and integrated idiosyncratically because each learner's prior knowledge structure is shaped by different experiences.

The process during which new concepts are assimilated into existing cognitive structure is called subsumption and the anchoring concepts are subsumers. Any learning task can be made meaningful if the teacher ascertains the learner's prior ideas concerning the subject matter to be taught, and then uses these ideas as starting points for teaching.

Knowledge is hierarchically organised in a learner's cognitive structure. That means that more inclusive, general concepts are superordinate to less inclusive, more specific concepts and propositions. Cognitive structure can become more elaborate and specific through assimilation of related concepts and the creation of new linkages. The whole matrix of concepts will in that way be modified. This process is called progressive differentiation and starts in childhood and continues throughout life.

When new concepts are introduced they can have a superordinate relationship to concepts that already exist in the cognitive structure. This is called superordinate learning and means that subordinate concepts acquire new meanings.

When new ideas are integrated, pre-existing conceptualisations can be restructured and new meanings can be added to the existing concepts. This is what Ausubel called integrative reconciliation. Integrative reconciliation also occurs when a child begins to recognise that language codes for the meaning of concepts.

In meaningful learning, forgetting does occur but, unlike information learned by rote, meaningful learning and subsequent forgetting does not result in proactive interference of learning of subsequent similar information. On the other hand, fragments of concepts that remain after subordinate concepts or details are lost can facilitate new meaningful learning. To distinguish this 'meaningful forgetting' from forgetting, Ausubel introduced the concept of obliterative subsumption.

Ausubel proposed that new knowledge can be more easily linked to existing relevant concepts in the cognitive structure if advance organisers have been introduced. *In short, the principal function of the organiser is to bridge the gap between what the learner already knows and what he needs to know before he can learn the task at hand meaningfully* (Ausubel et al., 1978, p 171). That means that advanced organisers facilitate meaningful learning only when the material to be learned is meaningful to the learner.

Methodology

A longitudinal study

In order to more fully understand conceptual development, we must stretch the duration of conceptual change research and study the same subject over time (Arzi, 1988; Rudd & Gunstone, 1993; White, in press). The focus of my longitudinal study has been to characterise intra-individual changes in children's conceptions in ecology across time and how their conceptions are influenced by different life experiences. A longitudinal study of the development of students' conceptions in physics has pointed out the great possibilities there are to study such a development by using clinical interviews (Novak & Musonda, 1991).

The clinical interview

As a result of a pilot study, and several projects undertaken by student teachers investigating students' conceptions, I argue that clinical interviews give the best information on children's ideas about processes in nature. The flexibility of the interview makes it possible to repeat questions if the interviewee has misunderstood something. It is easy to follow up the questions carefully. The intimate and relaxed atmosphere makes it easier for a shy and sensitive child to talk. The interviewer can pose questions that open up and challenge the interviewee to think and express her/his ideas freely. The first question is formulated in advance; the first answer is then interpreted and a new question is posed. The interviewer is therefore an integrated part of the research procedure (Bell, Osborne & Tasker, 1985).

The interview procedure

The interviews in the present study were carried out at a small primary school surrounded by mostly private houses and later at a larger secondary school in Kristianstad, a town in southern Sweden. The children were interviewed about the role of the flower in plant reproduction on four different occasions over a five year period. At the start of the study the children were 10 years of age and they were 15 years of age at the study's conclusion. At 10 years of age there were 26 pupils (11 male, 15 female), at 11 years of age 29 pupils (14 male, 15 female) and at 13 and 15 years of age 30 pupils (15 male, 15 female). Twenty-five pupils belonged to the same class from 10 to 15 years of age.

My experience conducting studies in similar classes had shown that it is important to meet the class on many occasions before the interviews start and to let the children become familiar with the purpose of the study. I therefore visited the class regularly during a period of six months before the study and showed the children that I was really interested in their thoughts about different phenomena in nature. Often I had with me organisms of different kinds that I have found in nature. It could, for example, be invertebrates from a pond, plants from a meadow or a dead blue tit found on the ground during the winter. There were many possibilities for investigation and discussion.

During the interviews I made it clear to the children that I was interested in their own thoughts, not whether their ideas were 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?'

Interviews about the role of the flower in plant reproduction

I first interviewed 24 10 years old children about plants in a meadow during a 3-day 'camp-school'. The interviews were carried out in early June in a verdant meadow with many different flowers, such as buttercups and cow parsley. I asked the children, 'Why do plants have flowers?' I then followed up with the question, 'Why do flowers have colours?'

I wanted to know the pupils' thoughts about ecological processes that were different compared with processes dealing with growth and decomposition. The children exposed a rich diversity of interesting ideas. During the following autumn semester, the children investigated flowers of different kinds and were taught about the importance of insects for the reproduction of plants. During the following spring, the pupils cultivated plants of different kinds in pots in the classroom. The pupils also studied plant reproduction at 13 years of age as a part of the curriculum.

I interviewed the pupils at school at the age of 11y and 13y beginning with the question, 'Why do flowers have colours?' At 15y of age I began with the question, 'What is the importance for a plant to have a flower with colour?' During the interviews at 11 and 13 years of age, I had wildflowers in a vase in front of the pupils, and at 15 years of age daisies planted in a sealed transparent box.

Results

Interviews during a 'camp-school'

During the first interviews with the 24 children at 10 years of age about flowers in a verdant meadow, I first asked them why the plants had flowers and then why the flowers had colour. In the children's ideas, there was a common endeavour to see the fitness of the flower. This fitness could be described in relationship to humans, to other organisms, and to the plant itself. The children's ideas of why plants have flowers can be placed in five categories. I. Five pupils established the fact that plants have flowers but did not explain why. II. Nine students explained that the flowers existed for our sake in order to be fine and beautiful. III. Three students said that the flower gives resources to the plant by catching sunshine or water and giving energy and nourishment to the plant. IV. There were four students that said that flowers only existed as food for insects. V. Three pupils' descriptions touched upon the role of the flower as a part of the plant's reproductive system.

The ten-year-old children's ideas of why flowers had colours can be grouped into four categories. I. Five children said that they did not know or only described the flowers. II. Eight children gave alternative non-scientific explanations why plants have colours. For example, Annie said that somebody had painted the flower: *'Once upon a time somebody has dyed the flower with plant dye and then planted it somewhere. Then it has dispersed.'* Oscar had another explanation and said: *'Perhaps the seed takes up a special kind of food and then the flower becomes yellow.'* III. Something purposeful from a human point of view was an explanation that five children expressed. Ruth said, *'Only 'cos they shall look gaily coloured. Cos that had been boring if all plants had been white.'* IV. Six pupils said that the colours of the flowers attracted insects. Even if they did not specifically refer to pollination, there were signs that the children had certain ideas concerning this mechanism. Morgan belongs to this category, *'Perhaps they*

look more attractive for bees and bumble-bees and sort of so they can disperse more easily.'

Interviews at school

When the pupils came back to school after the summer the children started intensive and concrete studies of flowers from different plants. They made colourful illustrations of flowers and how insects visited the flowers. Also, the teacher discussed the flowers' and the insects' role in plant reproduction. During the spring semester the pupils cultivated different plants in pots and followed their development from seed to a mature plant with flowers. The pupils participated in the work with joy. There were interesting discussions going on among the pupils about the flowers' role and the plants' need.

At the end of the following school year, I interviewed the children about the role of the flower's colour. Fifteen of the pupils who were interviewed one year before at the age of 10y, had now made connections between plant reproduction or seed dispersal and the colour of the flower. The previous year, only six pupils made this connection. Six pupils that said the plant had flowers with colour in order to look pretty. Three pupils gave the flowers human attributes that related to happiness and pride. Even if the teaching on plant growth and development influenced pupils' conceptions, human-centred and anthropomorphic ideas were still important for several pupils. The progressive differentiation in their cognitive structure built upon ideas that they had spontaneously developed at an early age.

I also interviewed the pupils about the role the flower's colour when they were 13 and 15 years old. The 27 pupils' development of understanding from 11 to 15 years of age about the role of the flowers' colours can be described as belonging to the following four categories of ideas: I. Anthropomorphic and human centred ideas; II. Ideas about plants getting protection and resources; III. Undifferentiated ideas of pollination and seed dispersal; IV. Towards a more or less complete description of pollination.

I Anthropomorphic and human centred ideas

Three students continued to use anthropomorphic and human centred ideas during all of the interviews compared with six students interviewed the age of 11y. Even at 15 years of age Ruth and Stina said, that the purpose of colour in flowers was to make flowers more visible and nature more beautiful.

At 10 years of age, Anders said, that the purpose of the colour was to make people think that the flower becomes prettier. He had a more detailed description of his ideas at 11, 13 and 15 years of age. At 11 years of age he described human-centred ideas with a practical example from everyday life but also a little about the plants' feelings. He continued to describe the plants' feelings in another dimension at 13 years of age, comparing them with human feelings. Even at 15 years of age, Anders described anthropomorphic ideas from a broader perspective.

It had not only to do with a wish to look nice and be admired but also our way of living including our houses and as company to other human beings.

Anders at 11y

'I think the flowers have 'cos they have colours to make you think they are nice and want to have them indoors. It gives you something to embroider the table with when you have guests. Then the food on the table and then you embroider the table with some brightly coloured flowers.'

Anders at 13y

'I think there is a thought behind it just like we as human beings, that I want to look nice and that I don't want So if you know to put on something, just as human beings put on things. We comb our hair and so on. So I think they have nice colours so that people and others they are nice. Just like we want other people to think that we..., that I look nice. That's what I think.'

Anders at 15y

'Well, actually I've wondered about that too, but I think it's like a human being, they need all this growing around them and the leaves. Life's a bit nicer and not so boring. It is like human beings. We live in our houses. We plant plants and have other things 'cos it makes it nicer. I think that what plays a big part for them to have a flower is that the leaves are not alone. The flower is company for them which makes it nicer for them to grow up. Perhaps it makes them stay on longer. 'They're having a nice time.'

II. Ideas about plants getting protection and resources

Ellen is one of the three pupils that are represented in this category. At 11y she launched the idea that flowers make it possible for plants to get nourishment from wasps. But at 13 years of age she also had thoughts that wasps could do something of more importance. As a 15-year-old she did not say anything about insects. The following three segments are from interviews of Ellen at 11,13 and 15 years of age. (I=Interviewer; S=Subject)

Ellen at 11y

I: 'What is the importance for the plant to have gaily coloured flowers?'

S: 'It gets more nourishment, doesn't it?'

Ellen at 13y

'Cos otherwise ... For example then if the wasp comes, it must give the flower nourishment or it must do something else.... Otherwise the plant dies.'

Ellen at 15y

'Well, there are stamens and pistils in it. And then, the petals protect them in some way.'

III. Undifferentiated ideas of pollination and seed dispersal

All 10 pupils placed in this category of ideas described, at 15 years of age, how pollen or seeds were transported by insects and dropped down to the ground where a new plant would grow. Only one of the pupils talked, at ten years of age, about insects having something to do with the colour of the flower. At the age of 11y, six pupils expressed the idea that insects are attracted to flowers and could disperse pollen or seeds. One student said, *'There is something that fastens on them. Then they fly and drop a little of it and then it'll grow.'* At 13 years of age another student said, *'Such insects come. And perhaps it is so .. , then it perhaps disperses such pollen. It disperses it so new will come.'* These statements are typical for this category of ideas. I think the two processes - pollination and dispersal - have similar features that cause confusion to the students. Both pollen and seeds develop in a flower. The two processes are involved in plant reproduction. The pupils had problems to reconcile these processes. The following interview segments from interviews with Helga at 11, 13 and 15 years of age illustrate how a confusion of the role of the pollen and the seed appears in the different interviews. (I=Interviewer; S=Student)

Helga at 11y

I: *'What use has a plant of having gaily coloured flowers?'*

S: *'It's attracts bees which can take pollen from the flower and then fly away to another flower. Then, such pollen is dispersed, and there will be more plants.'*

I: *'What will it be when the pollen is dropped there?'*

S: *'A plant.'*

Helga at 13y

I: *'Here is a bunch of flowers. Why do the plants have flowers with colour?'*

S: *'To attract bees and they take pollen with them. Then they fly away and other plants will grow there.'*

I: *'Why do other plants grow there? You said that they took pollen with them.'*

S: *'Seeds*

I: *'How does it happen?'*

S: *'And they drop it and then it grows.'*

Helga at 15y

I: *'What is the importance for a plant to have a flower and a flower with beautiful colours? More intensive colours than this one.'*

S: *'It attracts insects which eat something? What is it called? Hm... disperse it pollen and sort of.'*

I: *'How do you think it comes about?'*

S: *'Well, the insects fly to a flower and then pollen is fastened to the insect's feet. Then, when they fly away, they drop it. If the pollen falls down into soil, it stays there and grows up to new plants.'*

IV. Towards a more or less complete description of pollination

At 10 years of age, six of the eleven pupils in this category gave a description of how insects were attracted to flowers because of the colours and how the insects transported pollen from one flower to another.

At 11 and 13 years of age four pupils described how the plants attracted insects, but the pupils confused the processes of pollination and of seed dispersal. This was part of their development towards a more complete understanding of the phenomena. Oscar had a rather curious way towards a complete understanding. He used clearly expressed anthropomorphic and human-centred ideas to explain the role of the flower at 11 years of age, though he used the anthropomorphic ideas as analogies rather than as explanations. Such features in his explanation were still present at the age of 13y. At 15 years of age he had developed a more scientific explanation. He understood the connections between pollination and seed dispersal. An integrative reconciliation occurred.

Oscar at 11y

'In order to attract animals that can then suck nectar from inside there so that they can reproduce or perhaps they can boast to the other flowers and make themselves beautiful and so on in the same way as women powder themselves and so on. If you have them in a garden, perhaps you water them very much more cos they are so pretty.'

Oscar at 13y

S: 'To attract bees and such so it can grow better.'

I: 'What does it mean that it can grow better?'

S: 'That there will be a bigger family. It will be more diluted and not extinct. Nobody wants to have anything to do with an ugly flower but you can try to plant a pretty flower more and so.'

I: 'What role do the bees play?'

S: 'They make it flower. Well, they suck out something. And there is a scale or something like that inside the flower of which they can make honey. And they spray something else in or something like that and it flowers in any case.'

Oscar at 15y

'It's in order to attract the wasps. And then they suck the nectar or something and so the stuff gets stuck, pollin... No, I don't know what it is called. Perhaps that is what it is called and then they take it with them and so it goes on to the next flower. The flower can't be fertilised from the same stamen there down in the seed, it must sort of change flowers. These stick to the wasp and are carried on and go down into the seed. And a new embryo is formed in there which falls out or when it withers, it stays there.'

Discussion

In my interviews with children about flowers in plants, I did not expect to hear such a richness of ideas. During the first interview conducted in a meadow about why flowers have colour, 13 of the 24 of the pupils expressed ideas with human-centred and anthropomorphic features. The children said that the plants had flowers with colours in order to be beautiful, to be picked, to be watered or because they were painted or got the colour from soil. Six pupils said that the colour attracted insects. Four of those referred to the plants' reproduction.

Although the pupils spent the following two semesters at school studying flowers and cultivating plants, only 15 pupils assimilated the plants reproduction to the colour of the flowers in their cognitive structure. The alternative ideas with human-centred and anthropomorphic features were too powerful.

I categorised the children's conceptual development concerning the role of the flower into four categories. In category I three pupils continued to use anthropomorphic and human-centred explanations from 11 to 15 years of age. These pupils developed their alternative ideas without saying anything about plants' reproduction. There seems to be a personal context that appears during the interviews.

The three pupils in category II stated that the flower's role is to protect the parts of the plant or to get resources to the plant. The pupils' ideas in this category have partly anthropomorphic features. In some way the anthropomorphic and human-centred ideas Category I and II seem to be deeply embedded in the pupils' thinking. The lessons on plant growth and development that they received at school appear to have had very little influence on the pupils' ideas. Instead, early life experiences seem to have been very important for some of them, like Anders.

In each round of the interviews from 10 to 15 years of age, there are several pupils who mix the two processes of pollination and seed dispersal. At the age of 15y there were ten pupils who still mixed the processes. It is astonishing that so many pupils had not differentiated their understanding of pollination and seed dispersal, especially if we take into consideration the instruction on plant growth and development they had received at both 11 and 13 years of age. There are aspects of pollination and seed dispersal that are similar. It could therefore be problematic to differentiate between the two processes. They are both involved in plant reproduction, and modes by which pollination and seed dispersal occur can be the same. If such circumstances had been challenged during the studies, it had been easier for the pupils to differentiate between the two processes.

The 11 pupils in category IV had different features in a development towards a more or less complete description of the pollination at 15 years of age. Oscar, for example, had clearly expressed anthropomorphic ideas at 11 years of age. Even if he still had such features at the age of 13, he started to assimilate fragments of ideas about the pollination process, and then developed a more complete understanding of it at 15 years of age. Oscar's reasoning was not like Anders,

deeply embedded in anthropomorphic reasoning. Rather Oscar used anthropomorphic reasoning as a part of his development towards a deeper understanding of pollination. In a parallel research project on the pupils' understanding of ecological processes, Oscar also used anthropomorphic reasoning to describe his thoughts (Helldén, 1998).

The results from this study show that the pupils did not replace one understanding with another one. Marton (1998) argued that in the course of learning, the learner widens the range of possible understanding or increases her/his repertoire of ideas. During this longitudinal study I have also found that conceptual development does not involve the replacement of one idea with another. Rather I observed that many pupils develop their ideas about a phenomenon like plant reproduction under influence from a personal context. Anthropomorphic and human-centred ideas are used by many pupils in order to understand and describe biological processes. I agree with Zohar and Ginossar (1998) that we do not need to avoid anthropomorphic and teleological formulations and explanations in class. On the other hand, it is important to explicitly discuss with pupils what they mean with such formulations or explanations.

Although the pupils spent much time at school studying the role of flowers and other parts of plants, this work had a limited influence on the pupils' conceptual development. Perhaps teaching did not address and challenge their ideas. I argue that it is important to give pupils more opportunities to recognise, discuss and reflect on their ideas in a creative atmosphere.

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DO STUDENTS HAVE AN IMPLICIT THEORY OF ANIMAL KINSHIP?

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Abstract

The alternative students' conceptions of classification of animals are the subject of several investigations. In this research the criteria of classification used by the students themselves were generally neglected. The actual study shows that students prefer to classify creatures along the criteria of habitat and locomotion. They maintain using these criteria even after learning the categories of biological taxonomy. The results do not support hypotheses of concept formation on features or prototypical classification. Instead they lead to the assumption of an implicit theory of natural kinship of animals. Educational consequences to biology instruction from this assumption are drawn especially with regard to biological taxonomy and biodiversity.

Introduction

In constructivistic perspective conceptions and meanings cannot be transferred from the teacher to the students but are constructed by the learners themselves in a way that makes sense to them. Instruction should be built up from the conceptions of the students rather more than is practised today. Presently the knowledge of species and taxonomic categories is becoming more important for biology instruction again, as greater stress is laid on ecological studies and the apprehension of biodiversity (cf. Mayer, 1992; 1995; Mayer & Horn, 1993; Zabel, 1993). Those efforts will fail, if the conceptions of students in this field will go on being neglected. It is the aim of the study to be presented to answer at least the following questions:

- Which criteria of classifying animals are applied by the students themselves?
- In which way do these criteria correspond to those of biological taxonomy?
- Why do the students classify the animals the way they are doing?
- Which opportunities are opened by the personal conceptions of the students for the meaningful learning of biological taxonomy?

Former studies on students' conceptions of animals can be divided in two groups. One set of studies report on attitudes of students towards the animals used in classroom lessons but do not give any information about students' conceptions of animal classification (cf. e. g. Silberstein & Tamir, 1981). The other group of

studies is interested mainly in the presence or absence of the categories of biological taxonomy. Accordingly in these studies the students are asked to use taxonomic categories given to sort a set of living things. The answers are judged by what the authors think to be scientifically acceptable (cf. Natadze, 1963; Ryman, 1974; Trowbridge & Mintzes, 1985; 1988; Mintzes & Trowbridge, 1987; Braund, 1991; 1998).

The study presented here differs completely from this approach. In accordance with the leading questions the interests of the researchers was to investigate how students will classify animals, if they develop and apply their own criteria and categories. Therefore the students are not confronted with biological taxons nor are they asked to use taxonomic categories. Instead they have the opportunity to sort a set of animals in an order that makes sense to them. The "personal taxonomies" of the students investigated are expected to be important means for or hints of learning biological systematic and therefore should be seriously taken into account in biology teaching.

Design and methods

The students' conceptions were investigated by a questionnaire which contains three parts (see appendix):

1. Forming groups of animals and giving names to the groups formed (task 1): A set of 25 names of animals is given. In a pilot study it is confirmed that the names of the animals are familiar even to the students of lower grades. For this reason colloquial names of animals are used, also those which refer to a number of species, e. g. lizard. The task is to sort the animals into groups and to find an appropriate name for every group. The category "single" is provided so that students may not feel obliged to fit every animal into a group. The questionnaire does not include pictures of the animals. So we make sure that the attention of the students is not attracted by accidental features of drawings.
2. Sorting an animal out of a given group (task 2 with 6 items). Each item consists of a multiple-choice part and a free answer part. In the multiple-choice part one animal must be sorted out of a group of 5 animals which – according to the conception of the student – does not belong to the group. The reason for the choice has to be given in the free answer part.
The groups are composed in such a way that the students can find a member which does not fit in the sense of biological taxonomy and another one which fits but deviates either in locomotion, habitat or size from the other members.
3. Sorting an animal into a given group (task 3 with 5 items). Each item consists of a two choice part and a free answer part. The student has the choice to put one of two animals into a group of 3 or 4 animals. The reason for the choice has to be given in the free answer part.

The study was conducted with 536 students of Lower Saxony and North-Rhine-Westfalia. In detail 93 students of grade 4 (primary school, 174 of grade 5 (Orientierungsstufe) and 269 students of grade 7/8 (Comprehensive School and

Gymnasium) participated. The investigation was done in co-operation with 12 teachers, who were familiar with the design and the aims of the study by proceedings of teacher inservice.

Results

Forming groups of animals and giving names

The names of the groups formed by the students and the ranks of the categories chosen are given in table 1. In the following the terms "non-taxonomic" and "taxonomic" are used in the biological sense.

Table 1. Forming groups of animals and giving names to the groups formed (task 1). Included are groups and names which reached a ratio of 10 % and more in one grade. Similar names were comprised (in brackets: percentage of students; N: number of students with evaluable answers). Correlations of ranks (seven first places): grades 4 and 5: $r = .74$ ($p < .05$); 5 and 7/8: $r = .53$ (n.s.); 4 and 7/8: $r = .15$ (n.s.).

Grade 4 (N = 83)	Grade 5 (N = 138)	Grade 7/8 (N = 262)
1. aquatic animals (86,7)	1. aquatic animals (90,6)	1. aquatic animals (66,0)
2. flying animals (69,9)	2. flying animals (45,0)	2. insects (60,7)
3. four- or two- legged animals (65,1)	3. insects (43,5)	3. mammals (51,5)
4. creeping animals (48,2)	3. domestic animals (43,5)	4. birds (43,1)
5. insects (27,7)	5. creeping animals (42,0)	5. domestic animals (34,4)
6. domestic animals (16,9)	6. mammals (23,2)	6. reptiles (31,7)
7. terrestrial animals (15,7)	7. four- or two- legged animals (18,8)	7. flying animals (30,2)
8. large or small animals (14,5)	8. birds (13,8)	8. creeping animals (22,1)
9. fast or slow animals (10,8)	9. large or small animals (12,3)	9. amphibians (18,3)
	10. exotic animals (10,1)	10. vertebrates (14,5)
		11. fishes (13,4)
		12. molluscs (11,5)
- birds (4,8)	- terrestrial animals (8,0)	- four- or two- legged animals (5,0)
- mammals (1,2)	- reptiles (6,5)	- terrestrial animals (4,2)
- reptiles (1,2)		

Obviously in grades 4 and 5 *non-taxonomic categories* are predominant and these categories perpetuate into grade 7/8. Over all grades the rank orders of the non-taxonomic categories are nearly the same. The ratios of non-taxonomic criteria over all grades are given in figure 1.

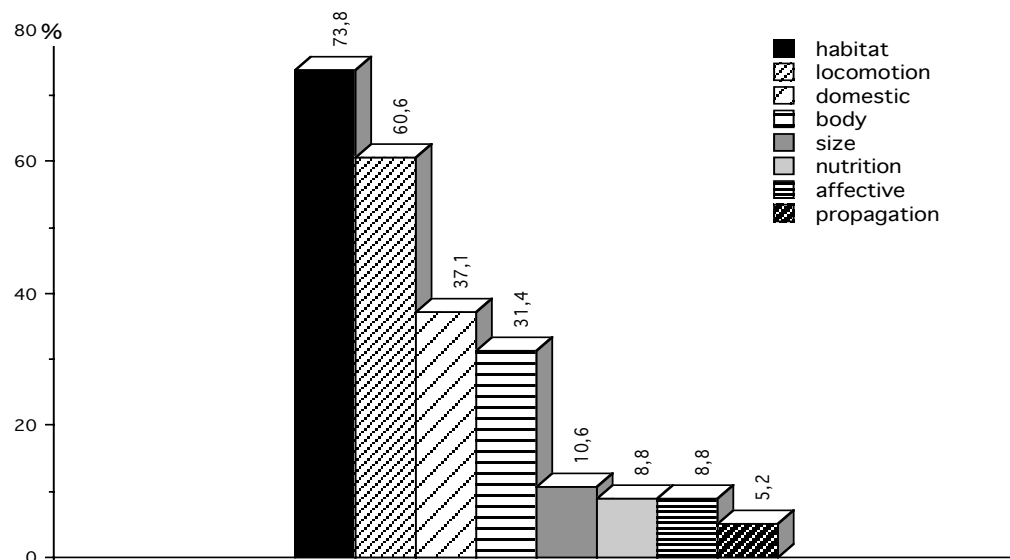


Figure 1. Criteria for forming groups: Percentage of students (all grades) who used the criteria mentioned at least for one of the groups they formed (task 1)

The orientation in classifying along habitat dominates over all grades as well. The category "aquatic animal" has the first rank in all grades. Nearly each student of grade 4 and 5 forms this group and so do even two thirds of the students of grade 7/8.

The second important role is played by the orientation on locomotion (especially flying and creeping). In spite of this, bodily characteristics play a minor role. Only the number of legs is worth mentioning for grade 4. The frequency of this criterion diminishes in the higher grades while taxonomic categories increase.

Number and frequency of taxonomic groups are significantly higher in grade 7/8 than in the lower grades. The forming of taxonomic groups seems to increase continuously, but the frequency is low even in grade 7/8: Only the groups "insects" and "mammals" are formed by more than half the students of this grade.

Sorting animals out of and into a group

The results of the tasks of sorting animals out of a group (task 2) and sorting into a group (task 3) are overall consistent (s. tables 2 and 3):

- with few exceptions the ratio of the taxonomic choices is lower than that of non-taxonomic choices. This is obvious if both tasks are comprised (s. fig. 2).

- Very often the reason for taxonomic choice is inconsistent (i. e. the taxonomic choice is explained through non-taxonomic reasons, s. table 2). In contrast the non-taxonomic choices are generally consistent. Only in 1 % of these choices an inconsistent reason is given.
- The criteria of habitat and locomotion are most frequent (s. fig. 3).

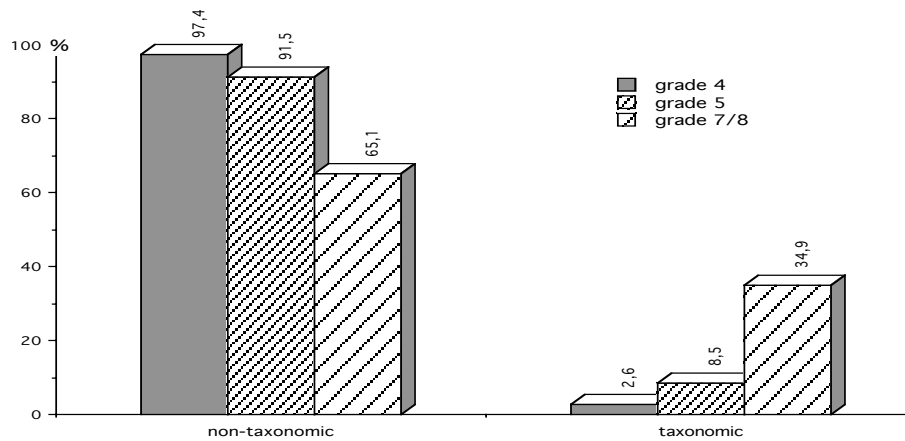


Figure 2. Ratios of taxonomic and non-taxonomic choices in sorting animals out of and into a group (cf. tables 2 and 3)

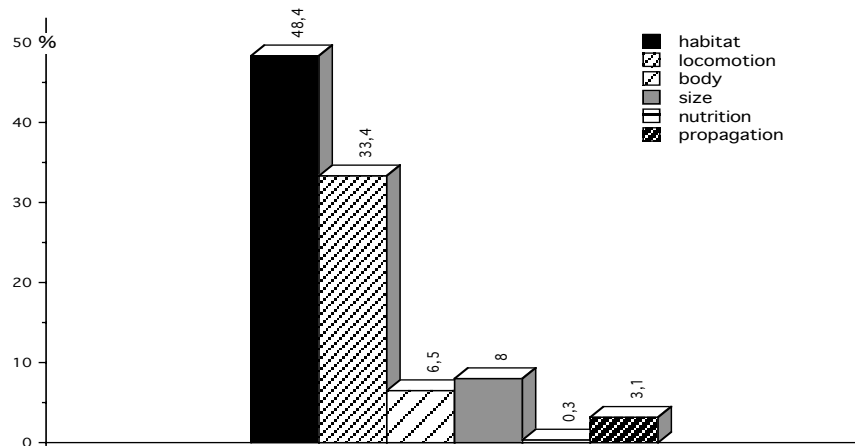


Figure 3. Non taxonomic criteria of sorting an animal out of or into a group (tasks 2 and 3, all grades)

Table 2. Sorting an animal out of a group (task 2). The results for grades 4, 5 and 7/8 are placed in three following rows (N: number of students, evaluable cases). The majority of non-taxonomic choices over taxonomic choices is statistically highly significant even in grade 7/8.

Item	Taxonomic choices		Non-taxonomic choices	
	ratio (%)	frequent reasons	ratio (%)	frequent reasons
2 a N = 93 158 261	2,2 (40,8) * 10,1 (28,5) 40,2 (19,2)	hen ... is a bird ... has two legs ... lays eggs	42,0 (15,0)** 57,0 (4,4) 37,5 (3,1)	camel ... lives in the desert
2 b N = 93 159 255	1,1 (2,2) 6,3 (11,3) 45,9 (6,6)	lizard ... is a reptile ... lays eggs	60,2/33,1 (3,3) 74,2/ 3,1 (5,0) 44,7/ 0,8 (2,0)	elephant ... is larger ... lives in Africa /mole ... lives under ground
2 c N = 92 150 256	4,3 (14,2) 12,7 (12,0) 43,4 (8,6)	seal ... is a mammal ... does not have two ... legs ... does not lay eggs	66,3 (15,2) 68,7 (6,7) 43,0 (4,8)	dove ...does not live in the water ...is able to fly
2 d N = 91 152 252	2,2 (18,7) 11,8 (11,2) 34,1 (4,8)	bat ... is a mammal ... has sonar orienta- tion	71,4 (7,7) 74,3 (2,6) 60,7 (1,0)	duck ... lives in the water ... is able to swim ... eats plants
2 e N = 92 148 257	1,1 (2,2) 14,9 (2,7) 51,0 (3,7)	dolphin ... is a mammal	72,8/21,7 (2,0) 68,9/ 5,4 (8,1) 41,6/ 3,9 (0,8)	goldfish ...lives in an aquarium ...is smaller /shark ... is dangerous
2 f N = 91 160 254	2,2 (7,8) 3,1 (8,2) 33,9 (5,1)	hen ... is a bird ... lays eggs ... is able to fly ... has two legs	85,7 (3,3) 88,1 (0,6) 59,8 (1,2)	seal ... lives in the water

* without brackets: ratio of choices with taxonomicly consistent reasons, in brackets: ratio of choices with taxonomicly inconsistent reasons.

** in brackets: ratio of choices which refer to an animals not mentioned in the table.

Table 3. Sorting an animal into a group (task 3). The results for grades 4, 5 and 7/8 are placed in three following rows (N: number of students, evaluable cases). The majority of non-taxonomic choices over taxonomic choices is statistically highly significant even in grade 7/8.

Item	Taxonomic choices		Non-taxonomic choices	
	ratio (%)	frequent reasons	ratio (%)	frequent reasons
3 a N = 91 153 252	0,0 (3,3) * 3,3 (2,6) 16,3 (4,7)	crab ... is also an insect ... lives in the water	96,7 94,1 79,0	swallow ... is also able to fly
3 b N = 91 155 242	7,7 (16,5) 13,5 (9,7) 29,8 (10,7)	ladybird ... is also an insect ... is also small	75,8 76,8 59,5	snake ... creeps (like the others) ... is also long-shaped
3 c N = 91 152 258	2,2 (3,3) 5,3 (9,2) 30,2 (7,4)	penguin ... is a bird ... lays eggs	94,5 85,5 62,4	bat ... is also able to fly
3 d N = 92 152 263	2,2 (0,0) 4,5 (1,2) 33,5 (1,1)	horse ... is a mammal	97,8 94,3 65,4	frog ... also lives in the water ... is also able to swim
3 e N = 92 155 257	0 (2,2) 5,9 (2,0) 27,6 (1,2)	seal ... is a mammal	97,8 92,1 71,2	ostrich ... lives in the desert ... is a terrestrial animal ... is able to run

* without brackets: ratio of choices with taxonomicly consistent reasons, in brackets: ratio of choices with taxonomicly inconsistent reasons.

Constancy of criteria choosing

The questionnaire makes it possible to test whether the individual student constancy is very different between taxonomic and non-taxonomic criteria (s. fig. 4). The probability of constancy is the same for both categories of criteria. Statistically one should expect that a majority of students will be inconstant in choosing criteria. That is not the case in grade 4. Over all grades more students are constant in choosing non taxonomic criteria although the ratio decreases with higher grades. In grades 4 and 5 no student is constant in choosing taxonomic criteria and only a minority of about 4 % is constant in grade 7/8.

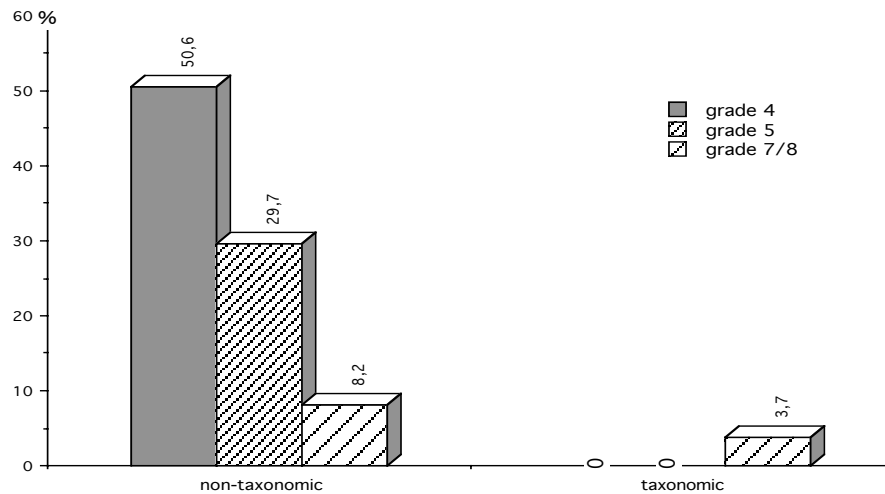


Figure. 4. Constancy of students' taxonomic and non-taxonomic choices (tasks 1 to 3)

Discussion

Coexistence of different taxonomies

The ranks derived from task 1 are able to illuminate the importance of different criteria for students' conceptions. The orientation on the no-taxonomic criteria of habitat and locomotion is not biased, because the sample of animals was large and diverse enough so that students were free to choose any criteria for group forming they wanted. The results of task 2 and 3 may be influenced by the examples of the items. The concurrence with task 1 (group forming) however indicates the importance of the criteria mostly chosen over all items in the conceptions of the students (s. figs. 2 and 3).

The predominance of non-taxonomic criteria (mainly habitat and locomotion) is apparent in grades 4 and 5. Accordingly the students use several non-taxonomic criteria creating their personal taxonomies. The criteria biologists apply while establishing a scientific taxonomy play no or no important role for the students. The problems of students which were found in previous studies of several researchers may therefore be deeper and more comprehensive than supposed by many biology educators. In grade 7/8 taxonomic and non taxonomic criteria are used side by side by most of the students. The greater ratio of taxonomic choices in grade 7/8 shows that taxonomic classification is learnt during biology lessons and partly applied by the students. The criteria of biological taxonomy thus join those of personal taxonomies but do not replace them. The same coexistence of biological and personal taxonomies is also visible in concept maps reported by

Markham, Mintzes & Jones (1994): In the concept map of freshman Kelly the domains of air, water and land serve for classification, the features of bodily structure are only used to characterise the taxon of mammals, which was provided by the researchers.

The coexistence of contrasting conceptions and theories can also be derived from the results of many studies in students' conceptions. The experience of science teachers is that students' every day conceptions cannot be replaced by scientific ones at all. At best they will be added to the alternative conceptions to be placed side by side. This general conclusion does not explain however, why the preconceptions of the students are resistant against change and how they can be used for fruitful and meaningful learning.

What's in a name?

The choice or the use of a taxonomic name does not preclude that the group is formed by the students through non-taxonomic criteria.

The role of names can be demonstrated in the comparison of the use of the term "fish" in English and German.

Students who speak English tend to classify creatures as "fish" if they are called "fishes" like crayfish, starfish, jellyfish (cf. Ryman, 1974; Trowbridge & Mintzes, 1985; 1988). In a study of Trowbridge & Mintzes (1988) the students were asked which of the animals given by pictures are fishes. Strikingly jellyfish and starfish were classified as fish in a high percentage (s. fig. 5). In the study presented here the students formed the group of fishes by their own decision. Those who did included "Seestern" (starfish) and "Qualle" (jellyfish) to a much lower degree. Despite the different methods this result can show the "power of names" (cf. Kattmann, 1992): The German students had the advantage that the German names do not lead to the group of fishes (note that in the case of the crab the percentage of American students classifying aquatic invertebrates as fish is as low as the percentage of German students).

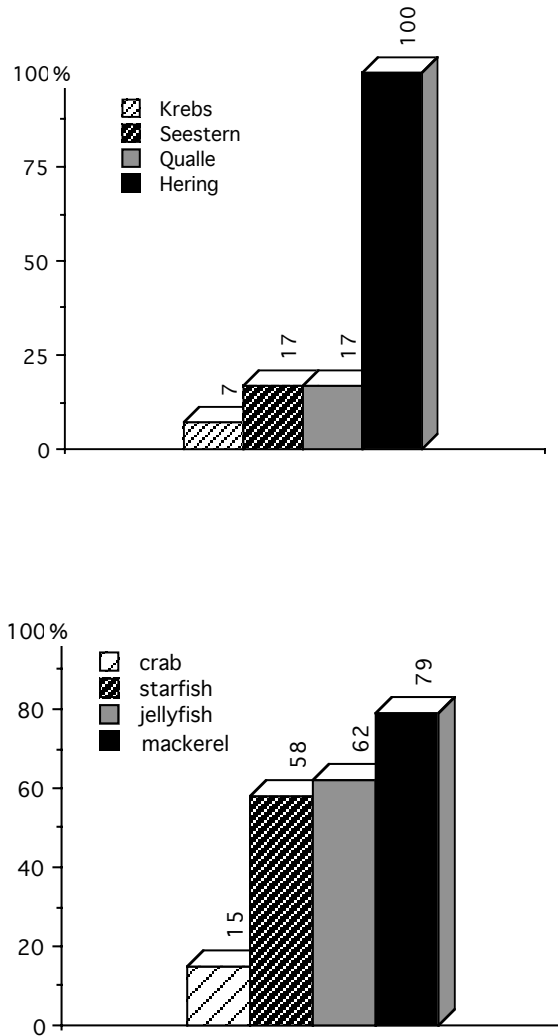


Figure 5. Classifying of animals as "fish": Above: Group formed by German students (grade 7/8, N = 33), bottom: Animals classified as fishes by American students (grade 8, N = 100; after Trowbridge and Mintzes 1988, p. 60)

The power of names is effective in German too. This can be shown in the cases of molluscs and reptiles. 44 students of grade 7/8 formed the group of molluscs, including most vertebrates and also snake and lizard (s. fig. 6). The usual term in German for molluscs is "Weichtiere". The word, which literally means "soft creatures", induces the students to form a group of "softies" while using a taxonomic term which has a biologically restricted sense.

The same phenomenon is observable in the case of one class of vertebrates. For the taxon which lizards and snakes belong to two names are commonly used in German: "Reptilien" (reptiles) and "Kriechtiere" (creepers; cf. Brehme, 1976). 83 students in grade 7/8 formed the group "Reptilien" while 60 formed the group "Kriechtiere". Strikingly those who formed the latter included creeping creatures

(especially snail and earthworm) to a much higher degree into the group than those who formed the group "reptiles" (s. fig. 7).

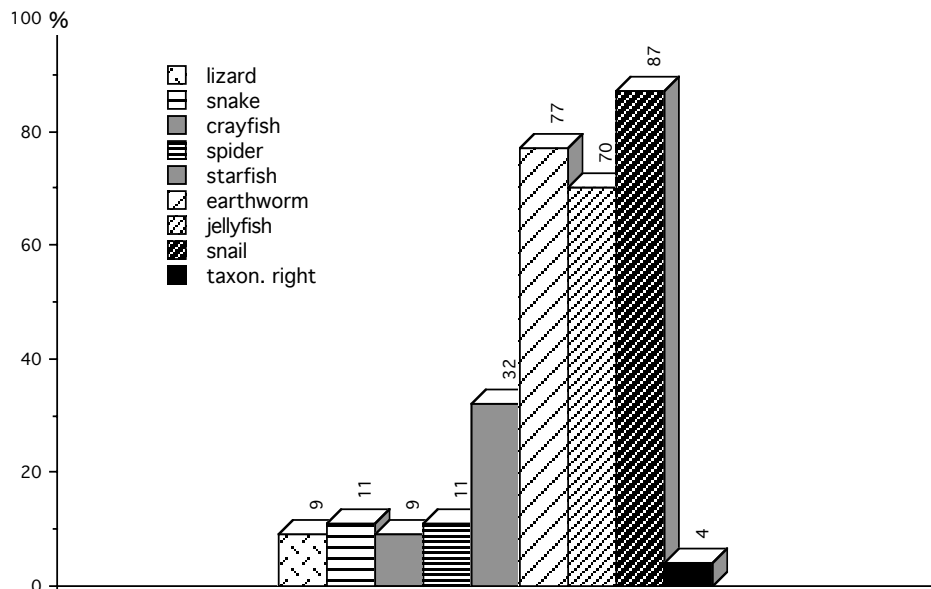


Figure 6. The association of "softies": Members of the group "Weichtiere" formed by German students (task 1); taxonomic right: group formed by members of the taxon molluscs only

Evidence for an implicit theory of kinship

Failure of typological explanations

The differences in classification between the grades cannot be explained by growing skills of classification. The ability of classifying hierarchically is present already in students of grade 4 (age 8 to 9; cf. Inhelder & Piaget, 1973; Markman, 1985). The results of our study do not show an increase of the number of categories, of the differentiation or the consistency in using categories, but only a change of categories used. The findings cannot be explained sufficiently, neither by classical theories of concept forming and logical classification (cf. e. g. Bruner

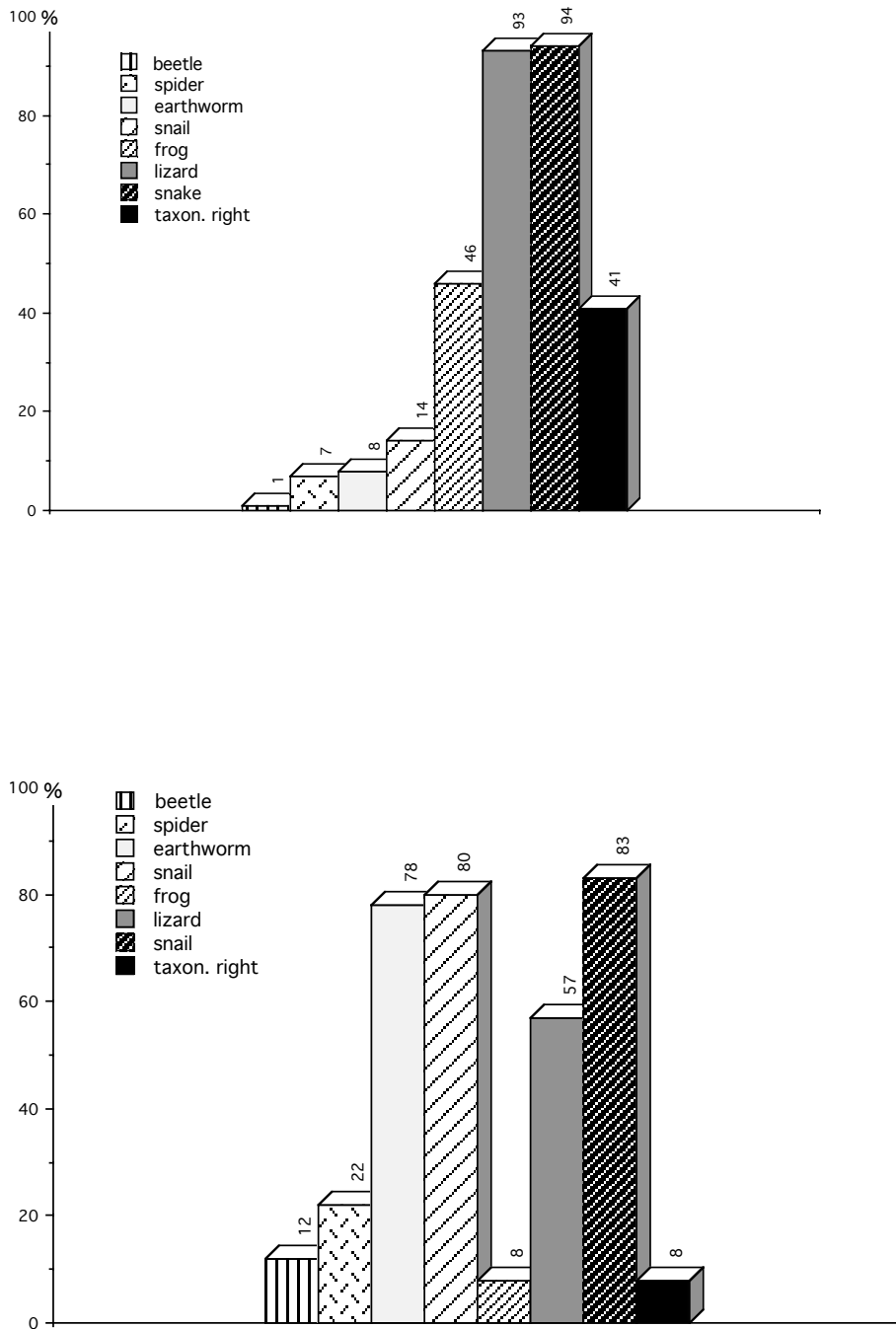


Figure 7. Classifying animals as reptiles or creepers respectively (task 1). Above: The association of "reptiles" (grade 7/8, N = 83), bottom: The association of "creepers" (grade 7/8, N = 60)

Goodnow & Austin, 1956; Clark, 1973) nor by prototypical approaches (cf. e. g. Rosch et al., 1976; Mervis & Rosch, 1981). In the personal taxonomies of the students visible features of the body play quite a marginal role. If birds and flying insects are put together into one group one can hardly speak of a typological approach. Flying is the only visible phenomenon which is common to all the members of the group and which is therefore decisive. Even a habitus cannot be responsible for forming the group, because a similarity of the habitus of a swallow and that of a beetle or a butterfly is not detectable at all. The same is true for classifying the frog with the aquatic mammals only because it spends its life in the water.

The classical and the prototypical solution can only be supported, if it is accepted that a type or a prototype can be reduced to one trait only. In this case the forming of groups investigated in the study must be the result of a rigorous process of abstraction.

Our results do not back this supposition. The tasks of the questionnaire neither require an abstraction from habits or phenotypes of the organisms nor can such an abstraction be deduced from the reason given in the free answer parts. Therefore it can be argued instead that the students' classification is based on categories and criteria which are directly available to them. This assumption is backed by other studies which state that the classification done by young children is more similar to a thematically than to trait oriented classification (cf. Smiley & Brown, 1979; Markman & Hutchinson, 1984; Gelman & Markman, 1986).

In contrast to the suppositions made in former studies (cf. Carey 1985; Atran 1990) there is no evidence that the similarity of animals to humans has any significance for the classification of animals by the students. Accordingly the categories of mammals and vertebrates do not play an important role in the personal taxonomies of the students. None of the categories chosen in task 1 and none of the reasons given in the free answer parts of the questionnaire refer to shared characteristics or to the similarity between animals and humans.

Elementary order of living things

Considering the results of the study one might come to the conclusion that the personal taxonomies are not derived by computing features perceived but constructed systematically on the basis of a comprehensive world-view. In this world-view the environment may be divided into elementary domains which all together represent a wholeness of reality. Therefore it is supposed that students' conceptions of classifying animals are theorylike (cf. Brewer & Samarapungavan, 1991; Carey & Gelman, 1991; Hirschfeld & Gelman, 1994; Hirschfeld, 1995). The classification is supposed to be oriented towards a scheme providing them with explanatory principles for the elementary order of living things. This scheme which the students need not be aware of can be called an implicit theory of animal kinship.

The way students classify animals we therefore call "elementary ordering". The reasons which they give in tasks 2 and 3 indicate that habitat and locomotion are seen only as one and the same group of criteria so that they can substitute one another. Accordingly the criteria used in task 1 can be associated to four large areas of life, which are called "elements":

- water (aquatic animals, swimming)
- air (air living animals, flying animals,)
- ground (creepers, crawling animals)
- land (land living animals, running animals, fourlegs, game and domestic animals).

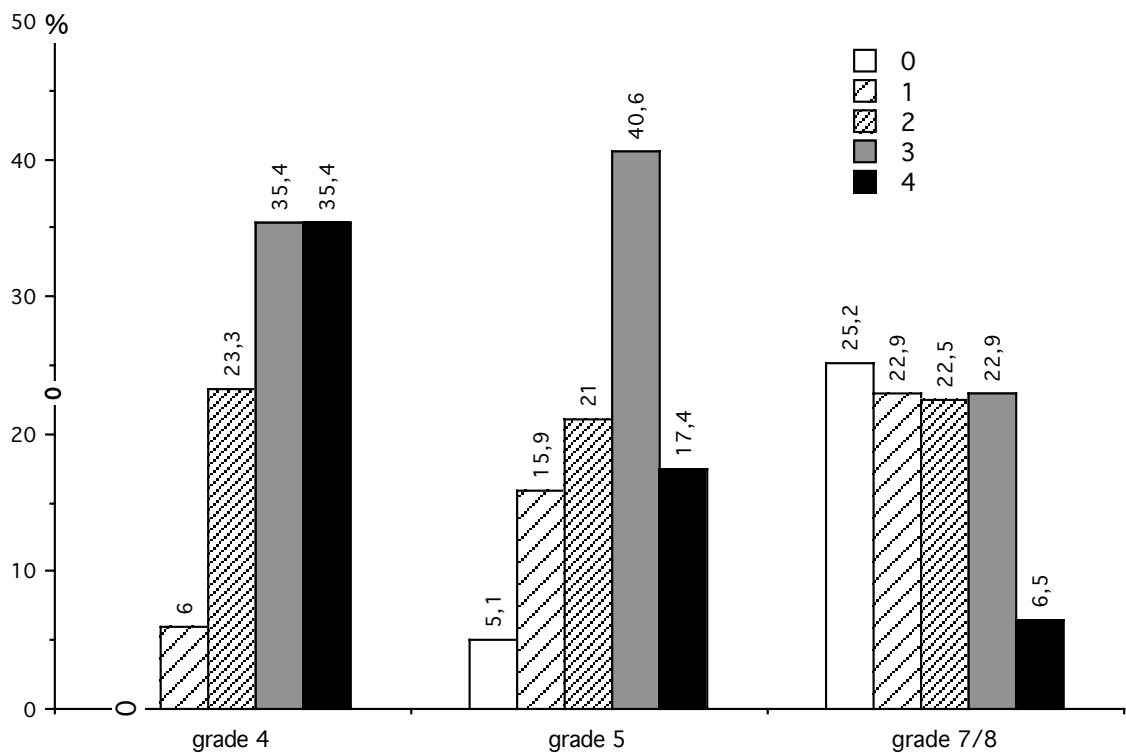


Figure 8. Elementary ordering. Use of elements for forming groups of animals. Numbers indicate how many elements (water, air, ground, land) the students individually use side by side while solving task 1.

The groups of the last "element" seem to be heterogeneous, but this configuration is justified because the members of the groups formed are usually the same.

In grade 4 the first four categories of the ranking (s. table 1) do reflect the four "elements" accurately. If students really use the elements as criteria one should expect that more than one element will be applied in the personal taxonomy of an individual. This is in fact the case (s. fig. 8). In grade 4 and 5 more than two thirds of the students use at least three or four of the elements. The decrease in grade 7/8 is caused by the increase of using biological taxonomic criteria. In this case some taxonomic groups can replace and substitute one element, e. g. reptiles can stand for "ground", mammals for "land". The perpetuation of elementary ordering in grade 7/8 is evident in the group of 55 students who constantly chose non-taxonomic criteria (in the biological sense). 41 of them (i. e. nearly 75 %) used 3 or 4 of the elements in their personal taxonomy.

Further evidence for elementary ordering of animals is given by data from cultural history, history of science, ethnobiology and colloquial language. Documents from these sources clearly show that humans generally tend to order living things along the elements in the same way which is found in the personal taxonomies of the students. (cf. Kattmann & Schmitt, 1996).

Conclusions

The results of the study indicate that students may have an implicit theory of animal kinship which is oriented towards the large areas of living and which can be characterised as elementary ordering. This theory is domain specific. It applies only to a medium level classification which in ethnozoology is called "life form", i. e. the level of larger groups, not of species and genus. The latter are formed by typological or prototypological categories instead, whereas the highest levels (e. g. plant and animal) are formed through abstraction.

Findings of former studies which refer to a medium level of classification (e. g. the classifying into classes or the distinction of vertebrates and invertebrates) should therefore be revisited in the light of the supposed implicit theory of the students. In the studies which concerned the concept of "animal" (cf. Bell, 1981; Bell & Barker, 1982; Tema, 1989) the investigators were interested in the scientific meaning of the term, while the students understood it in the sense of colloquial language, which restricts the term to mammals. Though not intended by the researchers students developed their own categories. When they were asked to give reasons for their classification or characterisation of an organism as an animal, they found they had the task of distinguishing between mammals and (other) creatures. In doing so the students mostly used criteria of habitat and locomotion and number of legs. Only in very few studies the students have had the chance to develop or apply their own criteria and categories (cf. Michon 1982 after Klix, 1976; Jungwirth, 1971; Markham, Mintzes & Jones, 1994). These studies also give some evidence that students primarily use criteria of habitat and locomotion.

Further studies should prove whether the evidence for the supposed implicit theory can be strengthened. Furthermore is necessary to investigate how the coexistence of elementary and biological categories of classification can be considered to improve biology instruction in this field. Instruction which neglects the conceptions of the students will have no success in trying to overcome the difficulties students have to understand and apply biological classification. Those difficulties may not be caused by deficient generalising or logical thinking but can be due to the conflict between biological criteria and elementary ones. This can also explain that whales and dolphins are still classified as fish while the same students were able to point out that their features are those of mammals (cf. Natadze, 1963). To overcome the learning difficulties imprinting of group features or the exercise of the principles of generalisation and logical of classification are proposed by several authors (cf. Trowbridge & Mintzes, 1985, p. 313 f.; Müller & Kloss, 1990; Braund, 1991; 1998). According to the findings of the study presented here, these approaches are of limited value. They even apply better to an instructivistic than to a constructivistic conception of teaching and learning. If implicit theories and personal taxonomies are the students' reasons for classifying animals different views and perspectives should be reflected in order to appreciate their function in different contexts. Thereby students must have the chance to develop and apply their own conceptions adequately to the problem.

Another interesting point of research are the reasons by which students refuse to classify humans as animals or to put them into a group of animals. The conception that humans form a category of their own and the difficulty to perceive humans as animals resulting from it may be explained by another but similar implicit theory of the students, i. e. the forming of categories according social relationships, by which a fundamental distinction between humans and (other) animals is induced (cf. Papadopoulou & Athanasiou, 1998).

As a consequence of the study we developed an instructional unit in which the classification in the biological sense is closely linked to an ecological and evolutionary approach. This allows not only to consider students' conceptions but opens up a new view to scientific theories as well. In considering that the phylogenetic groups of animals evolved in interdependence with the habitat the phylogenetic taxonomy can be seen and worked along this aspect at least for some taxa. This approach is especially useful for the large groups of multicellular organisms (plants, animals, fungi) which can be characterised as major life types (cf. Kattmann, 1991). The same is true for the classes of vertebrates where the criteria of habitat and movement the students of grade 5 are familiar with serve directly to establish the classes in the sense of biological taxonomy in a phylogenetically and evolutionarily adequate manner (cf. Kattmann, 1995; Baumann, Harwardt, Schoppe & Kattmann, 1996).

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Appendix

Which of the animals belong together?

On the following sheets there is a number of tasks for you, but this is not a test. Your answers will help us to improve biology teaching.

There is no right or wrong. We like to get your personal choices and reasons.

1. In this task you will find a number names of animals you certainly know. You will note that some of the animals belong together

Underline all names of animals which belong together with one colour.

Afterwards give an adequate name to each group you formed!

You can also invent adequate names if you like.

dog	cat	butterfly	earthworm	
	wasp	hen	snail	spider
snake	fox	fly	seal	beetle
	hamster	duck	crab	lion
herring	swallow	frog		mouse
	elephant	jellyfish	lizard	starfish

Find a name for each group:

Red:

Green:

Blue:

Yellow:

Black:

.....

If you don't want to include an animal in any of the groups, write the name of this animal into row of "singles"!

"Singles":

**2. In the following tasks five names of animals are given.
Only four of them belong together.**

a) Which of the animals does not belong to the group? Mark its name:

- horse
- rabbit
- pig
- hen
- camel

Please give the reason why this animal does not fit into the group:

.....

b) Which of the animals does not belong to the group? Mark its name:

- mouse
- lizard
- mole
- guinea pig
- elephant

Please give the reason why this animal does not fit into the group:

.....

c) Which of the animals does not belong to the group? Mark its name:

- seal
- duck
- penguin
- swan
- dove

Please give the reason why this animal does not fit into the group:

.....

d) Which of the animals does not belong to the group? Mark its name:

- owl
- duck
- bat
- eagle
- buzzard

Please give the reason why this animal does not fit into the group:

.....

e) Which of the animals does not belong to the group? Mark its name:

- shark
- pike
- dolphin
- trout
- goldfish

Please give the reason why this animal does not fit into the group:

.....

f) Which of the animals does not belong to the group? Mark its name:

- seal
- cat
- fox
- hen
- hare

Please give the reason why this animal does not fit into the group:

.....

3. In the following tasks you will find groups of animals which belong together.

- a) butterfly
fly
beetle
dragonfly

Which of the following animals fits into the group? Mark its name:

- crab
- swallow

Please give the reason, why according to your opinion the animal chosen fits into the group of the other four animals:

.....

- b) earthworm
snail
caterpillar

Which of the following animals fits into the group? Mark its name:

- snake
- ladybird

Please give the reason, why according to your opinion the animal chosen fits into the group of the other three animals:

.....

- c) dove
owl
swallow
eagle

Which of the following animals fits into the group? Mark its name:

- penguin
 bat

Please give the reason, why according to your opinion the animal chosen fits into the group of the other four animals:

.....

- d) blue whale
seal
dolphin
otter

Which of the following animals fits into the group? Mark its name:

- frog
 horse

Please give the reason, why according to your opinion the animal chosen fits into the group of the other four animals:

.....

- e) camel
zebra
elephant
tiger

Which of the following animals fits into the group? Mark its name:

- seal
 ostrich

Please give the reason, why according to your opinion the animal chosen fits into the group of the other four animals:

.....

STUDENTS' UNDERSTANDINGS ABOUT ANIMAL SKELETONS

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Abstract

Surprisingly few studies have looked at people's understanding of skeletons. Most of the work in this field that has been done has only involved children's understanding of human skeletons. This study looks at students' understandings of the structure of animal (including human) skeletons. A cross-sectional approach was used involving a total of 175 students in England from six different age groups (ranging from 4 year-olds to 20 year-olds). Students were presented, on separate occasions, with specimens of a brown rat, a starling and a herring 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 of 'skeletal understanding'. Our analysis shows the extent to which student understanding increases with age and the degree to which pupils know more about human than other skeletons. The findings are interpreted with reference to current trends in English science curricula and pedagogy. We comment in particular on the current inability of most students to see the skeleton as a functional, integrated whole.

Probing students' understandings about skeletons

There are many ways of gathering information about students' understandings of scientific phenomena (White and Gunstone 1992). The great majority of the methods that have mostly been used by science educators rely on students being able to talk about or write about science. Among these are the oral interviewing of students (Osborne and Gilbert 1980), gathering students' written responses (Leach *et al.* 1995), recording students' spontaneous conversations (Tunnicliffe and Reiss, *in press a*) and getting students to construct concept maps (Novak and Musonda 1991). Each of these approaches has its own particular advantages and disadvantages and a useful distinction has been made between phenomenological and conceptually based approaches (Driver and Erickson 1983), though the choice of these labels is perhaps less than ideal.

Phenomenological approaches entail presenting students with events or systems and then asking them to make predictions and give explanations for how things happen. In these approaches, the student, to a large extent, selects the language used to communicate their knowledge and understanding. Conceptually based

approaches entail presenting students with words (rather than events or systems) and then asking them to perform specific tasks with them. While conceptually based approaches are of value, they suffer from a fundamental limitation:

'Although this approach allows inferences to be made about the meaning that individuals ascribe to the language and ideas of science, it is not possible to make inferences about the way in which they construe phenomena in their own terms. For example, it is not a logical conclusion that a 13-year-old student from a Nigerian farming community who cannot remember the meaning of the term 'ecosystem', has no ideas about the relationships between organisms.' (Leach *et al.* 1995, page 723)

However, although phenomenological approaches (*sensu* Driver and Erickson 1983) avoid some such language problems, they still rely on words. In this study we report on students' understandings of the structure of animal skeletons. We decided on a cross-sectional approach in which students of different ages would simply be presented with different animal specimens and asked to draw what they thought was inside the animals when they were alive. While we emphatically do not wish to imply that this approach is necessarily superior to others, one advantage is the way in which it does not require students to use language unless they so choose - for example by labelling the structures they draw. Other advantages include the non-threatening nature of the task to many pupils and the comparative ease with which a rich mass of data can be obtained. In addition, there is perhaps a certain appropriateness in asking subjects to represent (albeit in two dimensions) anatomically the anatomy (albeit the internal anatomy) of a specimen (albeit viewed externally) presented (albeit it three-dimensionally) in front of them.

Perhaps surprisingly, given the central significance of the endoskeleton for the chordates and the inclusion of the skeleton in many science curricula, comparatively few studies have investigated pupils' knowledge about animal skeletons (Driver *et al.*, 1994). Most in depth work has been done only on human skeletons (Gellert, 1962; Williams, Wetton and Moon 1989, Osborne, Wadsworth and Black 1992, Guichard 1995, Cox, 1997) while work on the skeletons of other species has involved a range of interventionist methodologies. In particular, Caravita and Tonucci (1987) and Caravita (1996) presented 7, 9 and 12 year-old Italian school children with a variety of activities designed to explore their understanding of the structure and functioning of parts of the skeleton. For example, after a rabbit's leg was dissected, the pupils went on to build a model of the rabbit's leg.

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), a herring (*Clupea harengus*) (fresh) and an edible crab (*Cancer pagurus*) (fresh). On each occasion the students were then asked to draw what they thought was inside the specimen when it was alive. Students were not examined under formal examination conditions but were told not to copy one another'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. The teacher wrote labels on the drawings for children if they requested it, particularly with the 4 and 5 year-olds. A note was also made by us of the gender of each student.

This paper concerns itself only with the information provided by the students about the vertebrate skeletons - i.e. the two mammalian skeletons (rat, human), the bird skeleton (starling) and fish skeleton (herring). Our findings about what organ systems (e.g. the gut, the circulatory system, the reproductive system) the students thought were inside the animals will be reported separately as will our findings about what the students thought the skeleton of the crab (the only invertebrate we used) was like.

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. 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 20 undergraduates (aged 18 to 22). 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 20 undergraduates studied were all biology specialists with 18 of them intending to become primary teachers specialising in Science.

Analysis

A total of 572 drawings were made. After one or other of us had collected them, we jointly and repeatedly sorted through them, attempting to arrange them in a ranked order which we felt reflected different levels of biological understanding. Our ranking was informed both by previous work in the field (especially Osborne, Wadsworth and Black 1992, Guichard 1995 and Cox 1997) and by our own knowledge of anatomy and English biology curricula. No notice was taken of the student's ages in determining this ranking. Eventually, we agreed on the following order:

- Level 1 No bones.
- Level 2 Bones indicated by simple lines or circles.
- Level 3 Bones indicated by 'dog bone' shape and at random or throughout body.
- Level 4 One type of bone in its appropriate position.
- Level 5 At least two types of bone (e.g. backbone and ribs) indicated in their appropriate positions.
- Level 6 Definite vertebrate skeletal organisation shown (i.e. backbone, skull and limbs and/or ribs).
- Level 7 Comprehensive skeleton (i.e. connections between backbone, skull, limbs and ribs).

The two of us then separately and independently scored all the drawings. In those cases where our scorings differed, we then discussed each such drawing until we agreed on the level to be awarded. (We agreed on the great majority of scorings. There were literally just two or three cases where we initially differed by more than one level.) Data were then entered into Minitab and Excel for analysis. All statistical tests are 2-tailed.

Results

The significance of student age

As one would expect, older students attain higher levels, on average, than do younger ones. In all there are six different age categories: Reception (Yr. 0), Yr. 2, Yr. 3, Yr. 6, Yr. 9 and 1st year undergraduates (Yr. 14). Table 1 shows how the average level attained increases when students are drawing themselves (i.e. humans) from 2.06 for Yr. 0 students to 5.85 for Yr. 14 students. Standard errors of the mean are provided allowing statistical analyses to be performed. For example, a t-test comparing the levels of Yr. 0 and Yr. 2 pupils gives $t = 3.61$, $df = 35$, $p < 0.001$, whereas a t-test comparing the levels of Yr. 2 and Yr. 3 pupils gives $t = 0.21$, $df = 52$, $p > 0.5$.

Table 1. The levels attained by students of different ages when drawing themselves. Levels equate to the 1-7 scale for understanding of the skeleton as described in the text. Yr. 0 students are Reception pupils (aged 4-5 years); Yr. 14 students are first year undergraduates specialising in biology. sem is the standard error of the mean; n is the number of students in each age category.

Year	Mean level	Median level	sem	n
0	2.06	2	0.21	16
2	3.43	3	0.31	21
3	3.52	3	0.27	33
6	3.84	4	0.31	32
9	4.75	5	0.19	24
14	5.85	5.5	0.23	20

Table 2 shows the same data as table 1 but for the rat; table 3 shows the data for the starling and table 4 for the herring. In each case it is clear that age has a significant effect on the level attained. Common sense suggests that in those case where t-tests fail to demonstrate a significant effect of age (e.g. Yr. 2 versus Yr. 3 pupils drawing their own skeletons, as described in the above paragraph), the lack of a significant difference is simply due to scatter and the proximity of the ages. For example, for all four animals, there are very significant differences between the levels attained by Yr. 0 and Yr. 6 pupils (human: $t = 4.75$, $df = 46$, $p < 0.001$; rat: $t = 2.96$, $df = 38$, $0.001 < p < 0.01$; starling: $t = 6.49$, $df = 46$, $p < 0.001$; herring: $t = 5.72$, $df = 45$, $p < 0.001$). For three of the four animals, there are very significant differences between the levels attained by Yr. 2 and Yr. 9 pupils (human: $t = 3.59$, $df = 43$, $p < 0.001$; rat: $t = 5.55$, $df = 48$, $p < 0.001$; starling: $t = 8.30$, $df = 55$, $p < 0.001$; herring: $t = 0.63$, $df = 32$, $p > 0.5$).

Table 2. The levels attained by students of different ages when drawing the rat. Headings as in table 1.

Year	Mean level	Median level	sem	n
0	2.78	3	0.28	9
2	3.28	3	0.22	25
3	3.71	4	0.24	35
6	3.87	4	0.24	31
9	4.80	5	0.16	25
14	5.16	5	0.23	19

Table 3. The levels attained by students of different ages when drawing the starling. Headings as in table 1.

Year	Mean level	Median level	sem	n
0	1.47	1	0.19	17
2	2.82	3	0.19	33
3	3.60	3.5	0.22	30
6	3.61	4	0.27	31
9	4.63	5	0.12	24
14	3.94	4.5	0.41	18

Table 4. The levels attained by students of different ages when drawing the herring. Headings as in table 1.

Year	Mean level	Median level	sem	n
0	2.53	2	0.21	17
2	3.14	3	0.28	14
3	3.52	4	0.18	31
6	4.30	5	0.23	30
9	3.45	4	0.41	20
14	4.94	5	0.10	17

The significance of the animal being drawn

The identity of the animal being drawn, while it has some effect on the level attained by the students, is less significant than the age effects revealed by tables 1 to 4. Analysis of the data in table 5 shows that while there are no significant differences between the overall levels attained on the rat and human ($t = 0.30$, $df = 288$, $p > 0.5$) nor between the herring and the human ($t = 1.27$, $df = 273$, $0.2 < p < 0.5$) students score significantly lower on the starling than on the human ($t = 2.91$, $df = 297$, $0.001 < p < 0.01$).

Table 5. The overall levels obtained by students drawing themselves, the rat, the starling and the herring. Other headings as in table 1.

Animal	Mean level	Median level	sem	n
Human	3.94	4	0.14	146
Rat	3.99	4	0.11	144
Starling	3.40	4	0.12	153
Herring	3.71	4	0.12	129

Such overall comparisons fail to take into account age-related differences. More nuanced comparisons, though with necessarily smaller cell sizes, can be made within age groups between (i) level on human and level on rat; (ii) level on human and level on starling; (iii) level on human and level on herring. These comparisons are provided in table 6 which shows two things. First, where there are significant differences (on four occasions), students score higher on the humans than on the other three animals. Secondly, only among the undergraduates (Yr. 14) are there strong differences between how students perform on the various animals.

Table 6. Values of *t* obtained by making *t*-tests within year groups between the levels attained by students when drawing themselves compared with, separately, the rat, the starling and the herring. *df* in brackets.

Year	Human and rat	Human and starling	Human and fish
0	-2.04 (23)	+2.05 (31)	-1.55 (31)
2	+0.39 (44)	+1.66 (52)	+0.69 (33)
3	-0.56 (66)	-0.25 (61)	0.00 (62)
6	-0.07 (61)	+0.56 (61)	-1.19 (60)
9	-0.19 (47)	+0.55 (46)	+2.89*** (42)
14	+2.10* (37)	+4.06*** (36)	+3.57*** (35)

* $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$.

The significance of gender

Overall gender differences between the levels attained for each animal are shown in table 7. The undergraduate data have been excluded from this table as all 20 undergraduates were female (meaning that their retention in table 7 would distort the 'true' mean for females upwards relative to that for males). The sex ratios for the other year groups are less biased: Yr. 0 - 11f, 10m; Yr. 2 - 19f, 19m; Yr. 3 - 18f, 18m; Yr. 6 - 14f, 21m; Yr. 9 - 14f, 11m.

Table 7. The overall levels (excluding Year 14) obtained by females and males drawing themselves, the rat, the starling and the herring. Other headings as in table 1.

Animal and gender of drawer	Mean level	Median level	sem	n
Human f	3.54	4	0.17	67
Human m	3.75	4	0.24	59
Rat f	3.70	4	0.16	64
Rat m	3.93	4	0.18	61
Starling f	3.12	3	0.18	69
Starling m	3.55	4	0.17	66
Herring f	3.53	4	0.18	57
Herring m	3.51	4	0.19	55

None of the comparisons of female and male scores for the four animals are statistically significant (human: $t = 0.73$, $df = 124$, $0.2 < p < 0.5$; rat: $t = 0.98$, $df = 123$, $0.2 < p < 0.5$; starling: $t = 1.74$, $df = 133$, $0.05 < p < 0.1$; herring: $t = 0.07$, $df = 110$, $p > 0.5$). More fine-grained analyses - viz. between sexes within age groups within animals - are rendered problematic by the small cell sizes but it seems clear that statistically significant gender differences are likely to be infrequent and/or of low power.

Pupil consistency across different animals

Is there any pupil consistency across different animals? In other words, are individual pupils who score highly, for their age, on one animal likely to score highly for the others too? This question is investigated by calculating Pearson product moment correlation coefficients within the six year classes for (i) level on human with level on rat; (ii) level on human with level on starling; (iii) level on human with level on herring. Seventeen of the 18 correlations are positive (highly significant on a sign test) and there are six significant correlations, all positive. In other words, although there is considerable scatter, there is a significant tendency for students who score highly on their drawings of humans to score highly on their other drawings.

Discussion

The two previous studies we have found in which authors discussed how children's drawings of the skeleton develop are those of Caravita and Tonucci (1987) and Guichard (1995). Each of these, like ours, is a cross-sectional rather than a longitudinal study. Caravita and Tonucci, who worked with Italian children aged 7, 9 and 12 years of age, found five categories:

- A Outer frame type
- B Stuffed in-type
- C Semi organised pieces of bones-type
- D Iron wire core-type
- E Organized pieces or bones-type

and provided drawings to illustrate each of these (Caravita and Tonucci 1987, pages 71-72).

Guichard, who worked with French children between the ages of 3 and 12 years, also found five categories:

- A Bag of bones
- B Fish knuckle-bones
- C Stick members
- D Chain of knuckle-bones
- E Correct diagram

and provided drawings to illustrate each of these (Guichard 1995, pages 247-248).

Both Caravita and Tonucci and Guichard's categorisations have similarities with ours. Yet there are sufficient differences to make us think that international

comparisons using a common methodology might produce some very interesting findings. We have striven to provide an objective categorisation which covers all possible drawings and which could be used by other researchers.

We believe that there is more of a need for researchers to trace the sources of student's knowledge and understanding of skeletons. A particular concern of ours is the increasing loss of knowledge among UK pupils of organisms other than humans. In a related study (Tunncliffe and Reiss, in press b) we have shown that schools are significantly less likely to be cited by UK 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.

In this study the differences between the knowledge shown by the students of their own skeletons and those of a rat, a starling and a herring are perhaps smaller than might have expected (tables 5 and 6). Nevertheless, we are struck by the fact that the starling proved particularly problematic, especially for the undergraduates. We suspect that students of a range of ages are mostly able to translate their knowledge of the human skeleton to that of the rat (another mammal) and it may be that students are more likely to come across entire fish skeletons (notably whilst eating) than entire bird skeletons. It may also be the case that fish skeletons feature more frequently than bird skeletons in Tom-and-Jerry-type cartoons.

We found it salutary to note how few of even the biology undergraduates reached level 7. Eight out of 20 did on the human drawing; 2 out of 19 did on the rat drawing; 0 out of 18 did on the starling drawing; and 0 out of 17 did on the herring drawing. And yet all that was required for level 7 was to draw a skeleton - however limitedly artistically - with connections between backbone, skull, limbs and ribs! We strongly suspect that far too many students, however well they do on formal biology examinations, have only an atomistic knowledge of parts of the skeleton (cf. Lucas 1995, Braund 1998). Regrettably, English 'developments' in biology 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.

However, there are some positive signs, even in England. While the National Curriculum (Department for Education 1995), the Requirements for Courses of Initial Teacher Training (Department for Education and Employment 1997), the official exemplar scheme of work for 5 to 11 year-olds (Qualifications and Curriculum Authority 1998) and revision guides (e.g. Peacock 1998) reward an atomistic knowledge about human skeletons, a number of successful children's books about skeletons provide far richer and more integrated accounts of the skeletons that both humans and other animals possess (e.g. Treays, Fox and Reiss 1997, Llewellyn 1998).

We are also encouraged by the fact that some quite young pupils produced some very fine drawings. One Yr. 6 boy scored a 7 for his drawing of the human

skeleton, a 7 for his drawing of the rat, a 7 for his drawing of the bird and a 6 for his drawing of the fish. Unlike, for example, many of the undergraduates, it was apparent that he had a vision of the skeleton as a functioning whole.

And that leads onto the final point we wish to make. Our belief is that too few of the students, whatever their age, had any overall genuine understanding of skeletons, even their own. There are a range of teaching approaches which would facilitate such a holistic overview. One possibility is that students could assemble paper or cardboard cut-outs of skeletons with pins and staples for movable and immobile joints. Another possibility is that meat-eating children could be asked, as an out-of-class exercise, to draw the skeletons of any fish or chicken they eat, though we acknowledge that few students nowadays eat whole fish or come across whole roasted or boiled poultry. A further possibility is that pupils could not only dissect owl pellets but assemble the bones they find into at least partial skeletons. A final possibility is that far greater use could be made through visits of the skeletons in museums as these provide rich educational opportunities (Tunncliffe, in press). In all cases discussion with students about the mental model(s) they hold (Gilbert 1997) should be an integral part of the teaching they receive.

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*WHAT HAPPENS TO THE FOOD WE EAT?
CHILDREN'S CONCEPTIONS OF THE STRUCTURE
AND FUNCTION OF THE DIGESTIVE SYSTEM*

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Abstract

This paper is concerned with children's conceptions of the structure and function of the human digestive system with a view to contributing to our understanding of how biological knowledge is structured by children. It is based on data from a qualitative investigation carried out with 45 children between the ages of 4 and 10. These were divided into 4 groups according to educational level, from nursery school to final year primary school children. They were interviewed one to one using Piaget's clinical method. The results indicated that at the age of 4, as opposed to at the age of 10, children do not explain the phenomena of digestion in physiological terms, since the biological functions are not considered. At the age of 4, children represent the abdominal area as an empty space, where all food intake is preserved in small pieces (as a result of the process of mastication), with the same chemical constitution it had when masticated. Children above the age of 8 represent the belly as a space full of organs. The food intake goes through different organs, in each of which it is transformed. We concluded that: (1) from the age of 4 children possess biological knowledge as an independent knowledge domain; (2) the acquisition of the concept of digestion leads to a conceptual rupture and subsequent enrichment; (3) the concept of transformation can constitute an obstacle to comprehension of the scientific model of the functions of the digestive system. We suggest that to create viable teaching strategies, transformation (and in particular chemical transformations) must be focused on and that teaching in biology at an early age is not only possible but also desirable.

Background

The objective of this study was to identify children's ideas about the structure and function of the digestive system in order to contribute to our understanding of the genesis of biological knowledge. There is little and contradictory research about how biological knowledge is structured by children. For example, Carey (1985) described how an intuitive biology emerges from an intuitive psychology between the ages of 4 and 10. In contrast, Keil (1992, 1994) has claimed that biological knowledge constitutes an autonomous domain from the beginning, although he cannot be sure where this biology domain comes from. Recently, Hatano and Inagaki (1997) suggested that children's biology is gradually constructed through daily experience in the early years, and indicated that the socio-cultural context in

which children are exposed to biological information is critical in the acquisition of an advanced biological knowledge system.

According to Hatano and Inagaki (1997), these different pronouncements on the origin of children's biological knowledge imply different orientations to the teaching of biology. They refer to Carey's claims (1985) that young children have no form of biology, and have to be taught as if biology were a new subject. However, to Hatano and Inagaki (1997), pre-school children have already acquired a form of autonomous biology. They therefore believe starting teaching in biology at kindergarten or in the lower elementary grades is possible and can be effective.

This limited amount of research and its contradictory conclusions regarding the origin of children's biological knowledge is reason enough to justify investigation. Studies that contribute to our understanding of how biological knowledge is organized by children before formal teaching would therefore seem to be productive, and would contribute to increasing our understanding of human cognition. As a result, we would have a basis for rethinking how to facilitate children's cognitive development. Specifically, understanding the origins of biological knowledge could have a significant impact on the direction of biological education, since our understanding of how such knowledge is structured by children can direct the content and methods of teaching.

Method

Participants

Forty-five children, between the ages of 4 and 10, from the same private school in Recife in the Northeast region of Brazil, participated in this research. They were divided according to educational level into 4 groups, ranging from nursery school to final year primary school children. They were picked according to random criteria from each class list. In each group of subjects, the children had attended school for the same number of years and had not had any formal instruction in digestion. (Table 1)

Table 1. Distribution of Sample

	Nursery Group Age 4	Literacy Group Age 6	Second Year Age 8	Fourth year Age 10
Male	7	6	3	6
Female	5	6	6	6

Procedures

The children were interviewed one to one using Piaget's clinical method of interview. All the interviews were recorded. At the beginning of the session, the researcher welcomed each participant and told him or her that they were going to

talk about the inside of the human body. Each child was given a bar of chocolate, a pencil and a piece of paper with the outline of a human body printed on it. The child was asked to eat the chocolate and draw on the paper the parts of the body through which the food would pass. After doing this, the child was asked to name any drawn organs, describe how they worked, say what happened to the food as it passed through each organ and what it looked like at each stage.

Data Analysis

The interviewees' answers were analysed according to two aspects of the digestive system: structure and function. Under the structural aspect were considered the organs that children related to digestive processes and their physical features (form, location and constituent elements). Under the functional aspects, the transformations that these organs promoted on ingested nourishment and its trajectory were examined. This focus on the structure and function of the digestive system, as if these are independent of one another, is a strategy for the analysis of detail. In fact, both aspects are connected. The process of transformation of ingested nourishment is related to the mechanisms responsible for that transformation. Both functional process and structural mechanisms are presupposed in the development of organs in which transformation occurs. Furthermore, the nourishment is modified in each organ, or associated organs that it passes through.

Results

The structure of the digestive system

The organs mentioned by the children as parts of the digestive system were grouped into four areas: mouth, pharynx-oesophagus, abdomen and anus. The subjects asserted that food is put into the mouth and passes through the interior of the body to the abdominal area - although some subjects aged 4 did not mention the pharynx-oesophagus area. The abdominal area was given various names. At age 4, the name 'tummy' predominated, while older children used expressions from the scientific vocabulary: 'stomach' or 'intestine'. Reference to the anus was more frequent among children aged 10 than children aged 4: 25% of children aged 4, 67% of the group aged 6, 100% of the group aged 8 and 91% of those aged 10 referred to it. The anus was named "bottom" in all groups.

The majority (89%) of children at the age of 4 represented the abdominal area as an empty space, where all food intake is preserved in small pieces (as a result of the process of mastication), with the same chemical constitution it had when it was masticated. For these children, the only possible means by which intaken food can leave the tummy is through gravitational movements such as walking and bending the body from the waist. In the first case, the food leaves the tummy in the direction of the end of the legs, where it accumulates, resulting in the stretching of the body and consequently increasing the child's height. Analogous reasoning is applied when someone bends the body from the waist: the food falls down into the arms, stretching the body, promoting growth (see the child's drawing below).

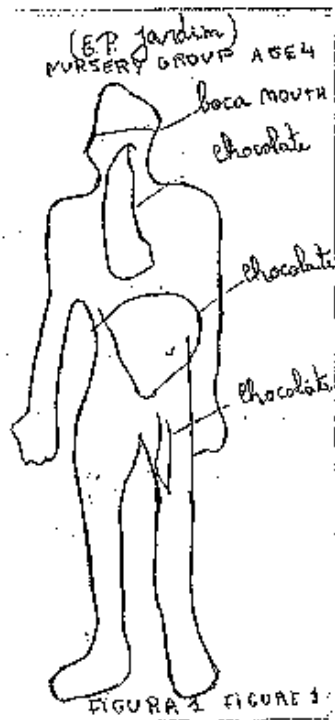


FIGURA 1 FIGURE 1

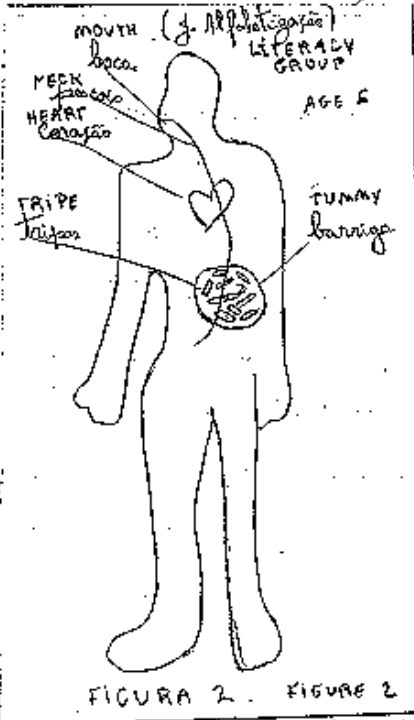


FIGURA 2 FIGURE 2

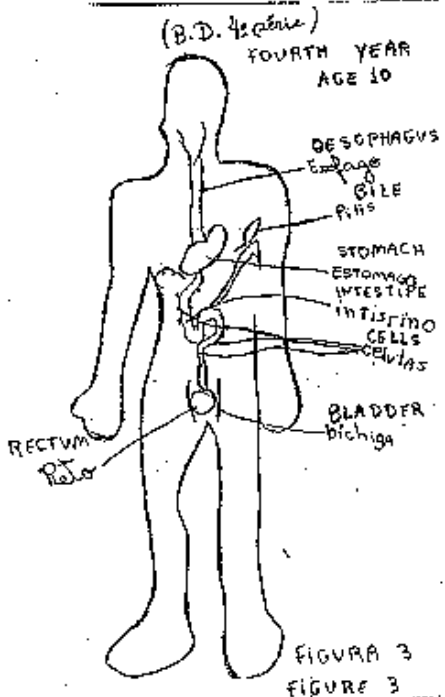


FIGURA 3 FIGURE 3

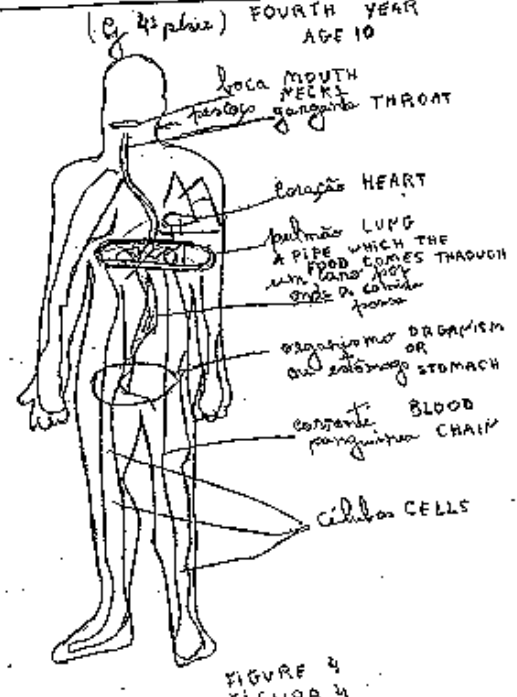


FIGURE 4 FIGURA 4

For 11% of children aged 4 and 25% of children aged 6, the abdominal area is a space predominately empty but with a few divisions. Children aged 8 and 10 drew and described the digestive system as a tube.

The function of organs and the transformations they perform on the ingested nourishment

Three trajectories of food through the inside of the organism were described: ingested food remaining entirely in the body (the predominant idea among the nursery school interviewees, aged 4); all the ingested food subsequently leaving the body (the predominant conception among the literacy class group and the second year primary school interviewees, aged 6 and 8); and a part of what is ingested staying in the organism while the rest leaves (this was indicated by most of the final year primary school children, aged 10)¹.

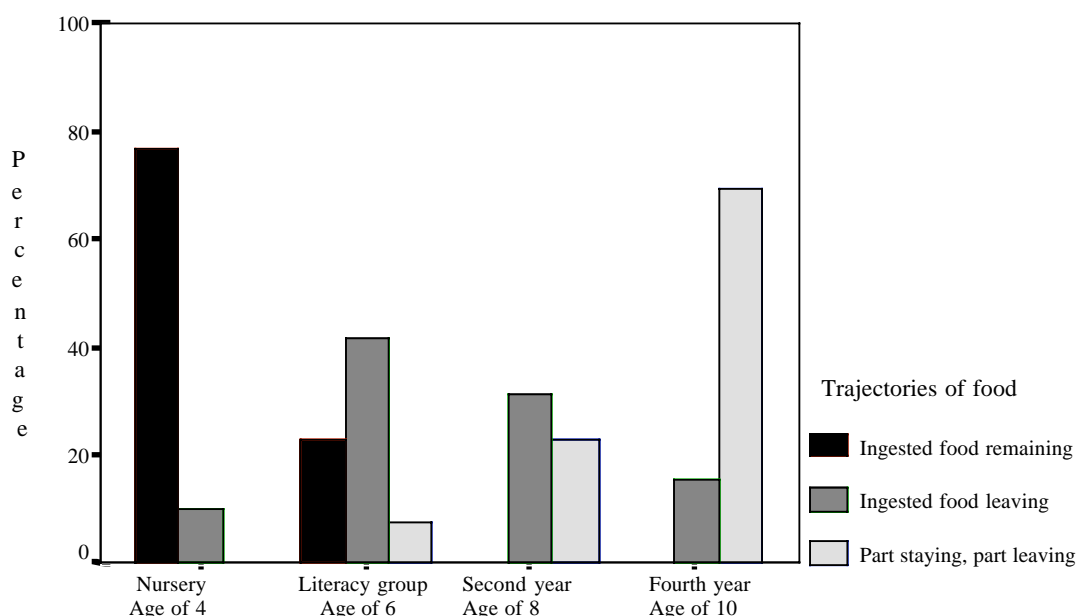


Figure.1. Children's perception of food intake and its destination

First model: Ingested food remaining entirely in the body²

(C)- Then when the tummy is full we don't eat any more. No, we can eat only one thing. When the tummy is full, the food has to go away for us to eat more.

¹ The data were treated according to discourse analyses. Each of the two thematic topics (structure and function of the digestive system) was read according to the protocols of each informant in order to generate categories within each topic. Once the categories were generated, two independent judges read each protocol in order to categorise the responses. Disagreements about the response classification were classified as an ambiguous answer. The level of agreement between the judges was 98%.

² (C) indicates a child, a subject, (E) the interviewer

(E) - *Where does it go away to?*

(C)- *Well, it goes to here. (He bends his right arm and with his left hand, points at the muscle)*

(E)- *What is this called?*

(C)- *It's the arm. Then when the food comes to this part (the muscle) then it stays above the other foods because this is tall (he indicates the arm muscle). After it will be hard. Here it is a little soft (he touches his thigh).*

(E)- *Does the food go to the leg too?*

(C)- *It does. You can see how it's getting big here. (He touches his thigh)*

(E)- *And from the leg does it go to another place?*

(C)- *Yes? It comes to here. (He touches his legs from the thigh to the forelegs), to here (He touches the forelegs down to the toes). My foot is getting big and strong. Look how it is getting,*

(E)- *Yes, it is getting big.*

(C)- *Only here it is not growing (he points at his heel). (J.G., nursery, at age 4.)*

Second model: All the ingested food subsequently leaving the body

(E)- *Will it (the food) go out from the tummy or will it stay in the tummy?*

(C)- *It goes out through the bottom" (J.G. Literacy class group year)*

(C)- *After it (the food) goes to the stomach then it is kept there.*

(E)- *Is it kept in the stomach? Is it only kept in the stomach or does something else happen to it?*

(C)- *We do a pooh then it goes out (R. Second year, at age 8)*

Third model: a part of what is ingested staying in the organism while the rest leaves

(C)- *It (the stomach) changes (the food) into blood what is good. What is not good goes down to the intestine. The heart transforms it (the food) into blood, then pumps it through the body.*

(E)- *Then tell me, is the food transformed into blood and will it be pumped through the body?*

(C)- *Yes.*

(E)- *What about the bad food in the intestine? What will happen to it?*

(C)- *It will go out with the pooh. (I. Fourth year, at age 10)*

The model in which ingested food remains entirely in the body suggests an understanding limited in detail about what happens to nourishment inside the organism. It does not make any link between what was taken in and what will be excreted.

(C)- *... it will not go out from the tummy.*

(E)- *No? Will it be in the tummy for the rest of your life?*

(C)- *Yes.*

(E) *Tell me, Where does pooh come from?*

- (C)- *It comes from the bottom.*
 (E)- *But how did it appear inside us?*
 (C)- *I don't know.*
 (E)- *Is the food changed into pooh?*
 (C)- *No.*
 (E)- *Is there any chance of the food being changed into pooh?*
 (C)- *No. (J. Literacy class group, aged 6)*
- (E)- *Then will the food go out from the tummy to some other place or it will stay in the tummy?*
 (C)- *It will stay in the tummy.*
 (E)- *Tell me C., Do you pooh?*
 (C)- *Yes.*
 (E)- *Where does the pooh come from?*
 (C)- *From the tummy.*
 (E)- *But the food is in the tummy, isn't it?*
 (C)- *Yes, but the pooh is behind the food?*
 (E)- *How can it be behind the food?*
 (C)- *Look, the food is here. Like this. This hand is here, the other hand is here (she bends one hand, covering the other), then the pooh is behind this hand (She refers to the covering hand).*
 (E)- *Oh yes, but how does it appear?*
 (C)- *It comes behind, it comes like this (she gestures again, bending one hand with the other)*
 (E)- *Tell me: You'll eat this chocolate, does it have pooh behind?*
 (C)- *No.*
 (E)- *How does it appear?*
 (C)- *Like this, like my hand (Again she gestures, bending one hand over the other).*
 (E)- *Yes.*
 (C)- *Then the pooh goes round and it comes through our body.*
 (E)- *But how did it come to be inside our body?*
 (C)- *Ah! When we were born, it was inside our tummy.*
 (E)- *Was it? Was it inside our tummy when we were born?*
 (C) *Yes.*
 (E)- *Ah! I understand. Then it stays behind the food. Why?*
 (C)- *Ah, Because, do you know why? Because it was. I don't know why it was that.*
 (E)- *Is the food changed into pooh?*
 (C)- *No. (C. Nursery age 4)*

According to the model in which ingested food remains entirely in the body, the organism is similar to a container. The mouth is the opening of this container.

- (E)- *But will it stay only in the arms and legs? Won't it leave our insides?*
 (C)- *No. Because people can't spit out the food that came into the tummy.*
 (E)- *Ah, then if food comes in, it can't go out, is that it?*
 (C)- *Yes. (J.G. Nursery 4 year)*

(E)- I eat. Then, will the food go into my tummy? Will it come out of my tummy?

(C)- No.

(E)- No? Will it be there all my life? Won't it ever go away again?

(C)- No.

(E)- If the food stays there all the time, won't you get a big tummy since you keep putting food inside it?

(C)- Yes.

(E)- Then, what will happen? What can we do to avoid it getting too big?

(C)- Don't eat so much. (M.B. Nursery age 4)

Those subjects using the model of the organism as a container understand that food is broken down through the process of mastication. It gets smaller, but retains its identity. In other words, what is intaken is transformed in size but conserves all its original properties.

(C)- If you cut the foot, food will come out. (M.A. Age 6)

(E)- What does the inside of our tummy look like? How does it seem to be?

(C)- There is meat, pasta, fruit, pears, apples". (M.B. age 4)

(C)- When we eat, the food stays in our tummy.

(E)- Does it? What does it look like? Does it seem to be dough, like it was when it left the mouth, or does it change?

(C)- When we chew it, it turns to dough. (C. Age 4)

The subjects who said that the ingested nourishment remains in the organism do not talk about nourishment being broken down by chemical substances (e.g. saliva, gastric juice, etc.). They also do not talk about peristalsis or circulation. When they say that the food from the abdominal region goes in the direction of the arms and legs, or that from the mouth it goes in the direction of the whole body, it could be imagined that they are talking about circulation as a result of the circulation system. This is not, however, the case. The trajectory of the nourishment through different parts of the body is explained by analogy with gravitational action.

(E)- M., will the food go out from your foot? Will it go to any other place?

(C)- When we do this then it jumps.

(E)- Ah! When the foot beats the floor, the food jumps, is that it?

(C)- We are like this, aren't we? Then we beat, beat, beat (She beats her foot against the floor, after jumping)

(E)- Then, will it go out only if we move?

(C)-If we jump like this (she jumps more quickly). (M.A. Literacy class group, age 6)

(E)- What happens to the food in your tummy?

(C)- It gets down to here. It drops.

(E)- Where does it drop to?

(C)- Well, it drops down (He draws an arrow).

(E)- Ah, there is an arrow here, isn't there?

(C)- It's only to tell you that the food is falling down.

(E)- Is it? Then you drew the arrow just to show me, did you? There isn't an arrow in the tummy, is there?

(C)- Yes. Because here, when I am eating , that is when I finish eating, then it (the food) goes to the hole, then it drops here" (J.G.Nursery, Age 4)

The second description of the trajectory of nourishment through the inside of the organism, in which all the ingested food subsequently leaves the body, was given by subjects from all groups. In this model there is a concept of quantity conservation, in keeping with Piaget's description of the quantity conservation model; that is, independent of what happens between the intake of the nourishment and its leaving the body, there is the belief that the quantity is not changed. Therefore, the quantity that was put in will be taken out.

Belonging to this second model is the idea that ingested food will be moved through the inside of the organism by peristalsis and blood circulation. Transformations are attributed to physical factors such as mastication (already mentioned in the model of the organism as a container) and the movements that the nourishment is subjected to while going through the inside of the organism (e.g. peristaltic movements).

Subjects know about changes in the aspects of the appearance of nourishment, the modifications that can be verified. But they do not give evidence of recognising alterations in the structural properties of food, in other word in its identity. In the subjects' view the physical qualities of the ingested food are transformed: it gets smaller, liquefies and comes together in the shape of excrement, albeit remaining the same with regard to its chemical properties. It keeps its initial identity except for its physical aspects plus its smell and colour.

The third model of the trajectory of nourishment through the inside of the body, in which a part of what is ingested remains inside the organism while the rest leaves, was presented by one child aged 6 and more children of higher ages. It is the most complex model found. Subjects seem to be considering qualitative aspects of what was ingested, recognising that in the food intake are elements necessary to the organism, but also that there are physical limitations - the organism cannot absorb everything it ingests.

For some children presenting this third model, nourishment is made up of diverse elements, some of which are not good for the organism. According to them, the process of breaking down nourishment consists in make it smaller, resulting in the isolation of its elements. Then, elements beneficial to the body are kept inside, while useless elements are excreted. Other children said that, while the ingested

food is going through the body, a series of transformations take place, until food arrives in a part of the body where some of it is transformed into blood or cells. This part of the food stays in the organism while the rest leaves.

These explanations of the separation of what is good and what is not good for the organism vary in their level of complexity. The first description is elementary compared to the second. From the first description, the notion of chemical transformation is missing. In the second description, chemical transformation is mentioned, but the children explain neither how the liquid resulting from the transformation of nourishment passes through the body modified in the blood nor why some elements of the ingested food are not good for the organism.

Four children talked about the nourishment thus: “*dough for a kind of water*”, “*receive a black thing*”, “*receive a liquid*”, “*receive an acid*”. This suggests children hypothesise that there are some substances which can modify others. They acknowledge changes in chemical identity since, for them, after the nourishment comes into contact with these substances, it is changed into something with a chemically different form. Three of these four were age at 8 and one was 10.

Two children aged 10 suggested a transformation in chemical identity -one said that what is good for the body is transformed into blood, the other that what is good is transformed into cells. However, they did not relate these transformations to other substances as did the other four. To sum up, only 6 children - 3 aged 8 and 3 aged 10 - suggested deep transformations of what was ingested, the latter relating the digestive system to the circulatory system.

Considering the Results

The children put food in their mouths. Thus, they have empirical evidence as to where the digestion processes begin. However, the end of these processes are not so obvious. The ingested food is transformed, so it is not easy to conclude that what is excreted “*by the bottom*”, as the children put it, has any link with what is ingested. These difficulties explain the increased mention of the bottom among the older children.

To understand the relationship between the ingested nourishment and the excrement, it is necessary to have some ideas about what mediates this relationship. The intermediary processes are not visible, although there are some clues suggesting where the ingested food goes. For instance, when the food is taken in, it is possible to feel the movement around the neck, which explains any mention of the pharynx-oesophagus area. Some of the sensations related to food intake come from the abdominal area: the muscle movements and intestinal sounds, the feeling of being full, the pain of any digestive disturbance. These sensations, as well as the adult explanations listened to by children, can help the subjects to infer that the abdominal area receives the ingested nourishment. Familiarity with these sensations explains why the abdominal area is one of the parts most referred to by the subjects.

The expressions used by the children to refer to the abdominal area indicates that, with increasing age, scientific vocabulary is preferred over the more usual words. Yet, it was found that children aged 4 refer little to particular parts of the inside of the body. This suggests that knowledge about specific parts inside the body is acquired in the long term. Representation of the digestive system is associated with how the process of nourishment transformation inside the body is explained. Thus, accounts of the divisions of the interior of the body vary according to the children's understanding of what happens to food inside the body.

Use of the model in which ingested food remains entirely in the body was most frequent at age 4. It was described by some subjects at the age of 6, but was not used by children aged 8 or 10. Children at the age of 4 referred to the belly as if it was a big empty space. This description was also presented by a few subjects aged 6. If the organism is understood as a container where the intaken food is conserved, then it is understandable that this receptacle does not need internal divisions. The internal divisions in the scientific model are called organs. They are responsible for transforming the ingested nourishment. In conformity with the first described model (ingested food remaining entirely in the body), mastication is the only transformation of the food. Thus, according to this model, organs are not necessary.

In the groups where the model in which all the ingested food subsequently leaves the body predominated, the majority also represented the abdominal area as a predominantly empty space, with a few divisions connected to each other. Analysing this model, it can be remarked that what is eliminated is not exactly the same as what was ingested, i.e., the organism is not seen as a mere container. Transformations happen inside it, specifically, when the nourishment goes through parts located in the abdominal area. The few internal divisions of the body represented in this conception can be explained by their function; that is, in these divisions, the appearance of the food taken in is changed. For example, when food arrives in the abdomen, there is no transformation, therefore divisions are not needed in this area: it is an empty space.

According to the third model, a part of what is ingested stays in the organism while the rest leaves, thus part of the ingested food is absorbed by the organism, while another part is not. The subjects who described this trajectory for the nourishment represent the interior of the digestive system as a tube beginning inside the deep part of the mouth and ending in the abdominal area. This tube has interconnected divisions. This model describes transformations which require an organic explanation, displaying distinct parts, each of which has a specific function. It is a more sophisticated model than the two previous ones, where the abdomen was represented either as an empty space or as a predominantly empty space with a few divisions.

The data provide evidence that the development of the notion of chemical transformation is complex: only 6 children older than 8 indicated that there are substances in the body that can modify others. The ingested food, having

encountered such substances, is changed into something different from what it was. Its chemical structure is converted and so it has a new identity. Alterations relating to changing properties are mentioned by all children. From the age of 4, children know that nourishment is broken down in small pieces by chewing. Its appearance and size are altered. Some children said that the food softens, or melts. Others described small pieces of food coming together with others. It can be said that all interviewees are sure that ingested food will change in physical aspect, but most of them believe that, despite this modification, the food will keep the same chemical properties it had at the beginning.

Chemical transformations imply alterations of structural properties: new chemical and sometimes new physical properties are generated. There is a new product with properties distinct from those of the previous product, which therefore has another identity. The chemical transformations are complex and as a result are more difficult for children to understand. This difficulty affects children's explanations about the function of the digestive system; for instance, they do not know how the food became either blood or excrement.

Discussion

The ideas of children aged 4 to 10 regarding the structure and function of the digestive system were examined. There is evidence that their models are determined by beliefs which provide the children with a set of related explanations. If this set is analysed according to the logic of the children's arguments, it is possible to consider these models as coherent and cohesive. This set of beliefs has been called 'theory' (Keil 1985, 1991; Carey 1985, 1991).

There is no consideration of biological function by children aged 4 when explaining the function of the digestive system. Gradually, there are changes in their theory, so that by the age of 10, it is found that the function of the digestive system is explained in terms related to the function of the organs. In other words, the explanation of the function of the digestive system has a biological basis.

The age differences suggest that children's theory is built on the application of empirical knowledge. For instance, for some children, nourishment is eaten then falls to the legs or moves through the body due to movements such as walking. Effectively, they are applying their knowledge about the way matter falls to the bodily functions. When children say that, after some time, food will rot in the abdomen and become excrement, they are also applying empirical knowledge: they have seen food putrefy. These findings indicate, as noted by Hatano and Inagaki (1997), that biological knowledge is constructed from inferences drawn from daily experience, an application of empirical knowledge to related contexts.

There are disagreements among researchers about the origin of the biological domain. Carey (1985) claimed that the biological domain emerges from the psychological domain. Keil (1992, 1994) stated that young children's initial biological theory is an independent domain from the beginning. According to

Hatano and Inagaki (1997), biological knowledge is constructed through daily experience, thus it is not totally free from the influence of knowledge from the psychological domain. The findings of this present study give support to Keil's claim that biological knowledge is distinct from other domains of knowledge. They suggest that biological knowledge is an autonomous domain from the beginning.

If children at the age of 4 possess biological knowledge as an autonomous domain, then "starting instruction of biology at kindergarten or in the lower elementary grades is possible and can be effective, but the instruction must enhance restructuring of it" (Hatano & Inagaki 1997, p.126) through strategies that promote enrichment of biological knowledge and conceptual change.

In order to design an effective biological teaching programme, it is important to recognise that the same utterances about bodily function do not imply the same representation of the inside of the body; and also that the same representations do not imply a similar understanding of function. Thus, it is important that teachers explore students' theory and are not limited by the terms that the pupils use. Having the children draw, then describe what they had represented in their drawing proved a useful technique in investigating children's theory. Considering the findings, it is suggested that particular attention must be given to children's notions of transformation, especially chemical transformation, and their notions of the digestive system as a system related to others.

The validity of this suggestion is open to investigation, as is our understanding of how daily experience is related to the genesis and evolution of biological knowledge.

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*PUPILS' CONCEPTIONS OF
FOOD IN CONTAMINATED AREAS*

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Introduction:

The concept 'food' in the context of Chernobyl-contamination

Chernobyl

Following the explosion of one of the reactors of the nuclear power plant of Chernobyl on April 26, 1986, and the extensive civil operation that followed, the exposed population still experiences all kind of health problems. Most (70%) of the radiation fell down on the Republic of Belarus. Only 10% fell down in parts of Russia and 20% on Ukraine (where Chernobyl is located). Therefore, we investigated the local conditions and beliefs of people in Belarus focussing upon their conceptions about food, food cycles and contamination.

We are participating in an EC-founded research-project: *Living in contaminated areas*. This project will pay attention to the continuing confrontation of the population with contamination as with the countermeasures.

A number of foods is contaminated with Caesium (Cs) 137, a long living (half-life 30 years), gamma-emitting isotope. Cs circulates via several food cycles in the contaminated areas. Mushrooms are an extreme example, both because they accumulate Cs 137 and because they are favourite folk-food for free. This holds also for berries.

Seeing the food behaviour of the people in the contaminated areas, they are not aware of the continuous circulation of the radioactive matter that is maintained. Therefore we took 'food' and 'food cycles' as concepts to investigate which ideas people, especially younger people at school age, hold on these topics. These ideas

we will use to construct together with teachers lesson materials for the school curriculum that hold these ideas.

A teaching strategy and pupils' conceptions

David Ausubel (1968, Ausubel et al. 1978) indicated the importance of pupils' conceptions for teaching in his well known statement: "If I had to reduce all of educational psychology to just one principle, I would say this: The most important single factor influencing learning is what the learner already knows." He adds: "Ascertain this and teach him accordingly." We wanted to bridge this gap between 'what the learner already knows' and new subject matter, by developing lessons that are based upon prior knowledge of pupils with applications in local situations. This implies that the truly effective teacher must not only know the subject matter well enough to be able to present all of the puzzle pieces and the pattern that will enable the students to put those pieces together, but must also know the contradictory patterns that the students may bring to class and how to open their minds so that they become willing and able to wrestle successfully with the alternatives and the evidence. Only then will students gain scientifically appropriate conceptual knowledge and the procedural skills to evaluate old and perhaps inappropriate ideas and allow the process of equilibration to proceed. In other words the primary goal of instruction is not merely to teach concepts and conceptual systems but to teach students how to change old concepts and conventional systems and invent new ones when it is appropriate to do so (Lawson, 1994).

Alternative conceptions are tenacious and resistant to extinction by conventional teaching strategies (Ausubel, Novak & Hanesian, 1978). But not all alternative conceptions are tenacious. It is important to differentiate between the concepts that might require high-powered conceptual change strategies and those that are equally likely to yield to well-planned, conventional methods (Wandersee et al. 1994). The concepts of food and foodcycles are found to have a tenacious character.

Brinkman and Van der Sluys (1993) found that approximately 99% of the pupils enrolled in a lesson series in a lower secondary education course were unable in post-course interviews and paper- and pencil assessments to apply adequately the concept of cycles, esp. the role of microbes (reducers) in the cycling of nutrients in nature. Brinkman and Achterstraat (1991) found no increase in the understanding of the function of nutrients in human food after teaching this subject matter in secondary education: nutrients and food are exchanged easily and the contribution of nutrients to energy and movement is denied.

To go from alternative conceptions towards a conceptual change intervention strategies are used mostly primarily exploratory. Studies designed to measure the conceptual change resulting from an intervention need to employ assessment techniques sensitive to subtle changes in students' understanding. Several such techniques have been developed, including interviews about instances and events and concept mapping (Wandersee et al. 1994). Moreover the development of

interventions based upon pupils' misconceptions has proven to be a powerful communication tool between teachers and researchers in education (Brinkman et al 1992; Maier et al. 1994).

The relevance of the concept 'food'

'Natural food' is one of the main ideas pupils from Eastern Europe bring forward when they are asked to give their ideas about health (Kievits et al. 1997). Cs 137 in the natural food is never mentioned. Previous studies in the field of health and nutrition have focussed on children's understanding of concepts and beliefs related to food, diet, health and environment including food choices and preferences (e.g. Turner, 1997).

Few studies have investigated peoples' knowledge and understanding about the importance of singular nutrients in the diet (Turner et al. 1997) nor have the understanding that teachers and public informers have about such topics been examined. Research with teachers suggests that they require knowledge and confidence to teach about nutrition and health (Turner, 1997; Brinkman et al 1992).

Education and information about the relationship between nutrient-consumption, including contamination and health is an important one in the context of developing a rehabilitation programme to reduce health-risks when living in contaminated areas (EUR 16534 EN, 1996). In-service education programmes for teachers are an important element of professional development throughout Europe. Innovative projects in science have encouraged teacher participation in research that has explored children's understanding of scientific concepts (e.g. Boschhuizen et al. 1995).

The findings from such studies have been used to develop in co-operation with teachers resource materials on health topics on food and nutrients (Brinkman et al. 1992), cancer (Maier et al. 1994) and environment (Boschhuizen et al. 1995). The outcomes of these projects highlight the importance of teachers, teacher educators and researchers working collaboratively. In the scope of public information a similar co-operation with public informers, journalists, health educators seems important as well.

The above lead us to the following research questions:

Which conceptions about food do pupils have in secondary education in Belarus?
Which consequences for teaching food cycles can be derived from these conceptions?

Research method

The design of this study

In a strategy for teaching, the determination of associative frameworks of the pupils deserves an important place. In recent years in biology teaching the emphasis has been placed on the idea that biological knowledge is not an objective in itself, but that it has to be applied to (everyday) contexts. In the orientation phase the teacher uses the associative frameworks of the pupils to discuss the differences and similarities mentioned and to focus on the new concept. In the information phase the teacher discusses the more specific meanings of the new concept with, for example, the inquiry and/or other strategies. After the information phase the newly-acquired knowledge is tested within new (everyday) contexts: application phase. After application the pupils return to their associative frameworks and discuss what they have learned (reflection phase).

In this paper attention will be focussed on pupils' conceptions and on the consequences for teaching activities in the orientation and information phase.

The information needed was obtained in several ways:

The Hierarchical Concept Mapping Test (HCT) (Boschhuizen et al. 1991) with the stimulus word 'food' was done. Next to the HCT, drawings were made and clinical interviews were held.

Local teachers in science, biology and other disciplines, participated by giving information about health and environment curricula in Belarus and by participation in lessons in which pupils' conceptions have been determined. The contribution of teachers to the project will be reported elsewhere.

The pupils

The study was carried out with pupils in Belarus in May 1998. Three schools were involved in this project: one in Minsk, one in Kostyokovichi and one in Belaya Dubrova. The pupils, both boys and girls, were 12 – 14 years old. In total 84 pupils participated.

The hierarchical concept mapping test

The Hierarchical Concept Mapping Test (HCT) procedure includes the following successive steps:

- the pupils are asked to write down words which they connect with a stimulus word (in this case the word food);
- the pupils are asked to arrange their associations into coherent groups (clusters);
- the pupils are asked to give a number to each of their clusters (the cluster label) and to describe the relation of each cluster label with the given stimulus word (food) in one or two sentences (statements).

The 84 pupils carry out this test individually.

The interpretation of the data from the HCT

Data were categorised, based upon the statements of the pupils into a categorising system of a higher order by putting similar statements together in one category. The problem of the interpretation of data is an important one. The outcomes of the methods can be described objectively, but they have to be ordered. This entails a process of interpretation. This process of interpretation is fundamentally subjective. In the HCT the pupil orders his/her own associations and the process of ordering can be monitored by the researcher. The fact that this makes the HCT more objectives is the reason for our choice of this test. Results were assessed through inter-collegial discussions.

The drawings

After the HCT all the pupils were asked make a drawing and to explain ‘the way the food goes in your body’. The drawings were analysed by making an inventory of the various body-parts that were presented either by drawings or by written names. In the clinical interviews that followed, the individual drawing of the interviewed pupils functioned as a starter.

The interviews

The clinical interview is one of the oldest methods for exploring children’s thoughts (Sutton, 1980). A clinical interview is initiated by asking the pupil a question about some concrete phenomenon: often the questions asks the pupil to predict, describe or explain something in relation to a concrete phenomenon. The response to the question is judged by the interviewer to be either relevant or irrelevant; if relevant, the question is restated to elicit a relevant response. When a response relevant to the phenomenon is elicited, further questions are asked (Steward, 1980). The interview can also be conducted in a more open way.

We applied this approach by making use of the following interview grid:

- What kind of food do you like?
- Describe the way the food goes through your body, by using your drawing.
- What is the function of food?
- If you drink milk, what way is the milk going?
- If milk contains radioactive elements, what is happening with those elements?

The interviews were held after the HCT and the drawing-activity. Interviews took place with two pupils together (mostly boy and girl) and were tape recorded and later transcribed. We interviewed 32 pupils (10 from Minsk, 12 from Kostyokovich and 10 from Belaya Dubrova).

Results and conclusions

The hierarchical concept mapping test

During teaching, the teacher has to bear in mind the most dominant (frequent) statements of pupils about the concept he teaches. We therefore registered the frequency of the pupils' associations for each category as a percentage of the total number of statements. Table 1 lists some examples of pupils' statements for each category. In table 2 the pupils' associative frameworks concerning the stimulus word 'food' and the percentages of the total number of statements (n = 936) are shown per category.

As can be seen in table 2 pupils' statements about the stimulus word 'food' have been classified into categories of 'foodproducts', 'preparing food', 'food values/feelings', 'function/importance', 'feeding' and 'rest'. In the 'rest' category we placed statements from the categories 'hygiene', 'nutrients', 'definition', and '?'.

Table 1. Examples of pupils' statements per (sub)category of 'food'

Category	Examples
Foodproducts	Fruit, vegetables, meat, fish, juice, eggs and bread shows what kind of food exists. Potato, onion, carrots, cucumbers, tomatoes are vegetables that grow in our garden.
Preparing food	In a pot and a frying pan you cook food. Shop and market are places of getting products. With a spoon and a fork you get the food into your organism, with a knife you cut it. Bread, fat and meat we can prepare at home.
Food values/feelings	What feeling a person has while eating (tasty). Food, it's a pleasure.
Function/importance	Minerals, this is necessary food for a man to eat. You should eat these fruits to have a lot of vitamins. Due to food we have strength and with the help of food our brain works better. Juices and drinks we need so that man is not thirsty any more.
Feeding	Time of heaving meals (breakfast, lunch, dinner and supper).

Table 2. Pupils' associative framework on the stimulus word 'food' and the percentages of the total number of statements (n = 936) per category.

Category	%
Foodproducts	56
Preparing food	16
Food values/feeling	10
Function/importance	9
Feeding	5
Rest	4

Conclusions

Different foodproducts were often mentioned, especially all kinds of fruits and vegetables. Drinks like coffee, juice and water were also seen as foodproducts. In the category preparing food we found a lot of statements related with cutlery and crockery. Not mentioned were nutrients and digestion. The possibility of contaminated food was also never mentioned.

The drawings

The drawings have been analysed by counting the parts of the digestive system drawn by the pupils (table 3). Also the written explanation in the drawings are sampled (table 4). In table 5 the parts drawn as well as named are mentioned. In total 80 pupils made the drawing.

Table 3. The body parts that were drawn most by the pupils. (n = number of pupils; 100% = 80 pupils)

	Drawn	n	%
1	One channel	47	59
2	From mouth – stomach	44	55
3	Mouth	29	36
4	No exit	15	19
5	Unknown exit	14	18
6	Stomach	13	16
7	Exit from the stomach	12	15
8	Exit behind	10	13
9	Intestine, gut, bowels	9	11
10	Two channels	6	8

Table 4: the bodyparts that were named most by the pupils. (n = number of pupils; 100% = 80 pupils).

	Named	n	%
1	Digestion	37	46
2	Teeth, chewing	7	9
3	Unknown exit	5	6
4	Food dissolves	5	6
5	Throat, neck, swallowing	3	4
6	Organism	3	4
7	From mouth – stomach	2	3
8	Mouth	2	3
9	Exit behind	2	3
10	Anus	2	3

Table 5: the bodyparts that were drawn as well as named most by the pupils (n = number of pupils; 100% = 80 pupils).

	Drawn and named	n	%
1	Stomach	62	78
2	Mouth	36	45
3	Intestine, gut, bowels	22	28
4	Gullet	19	24
5	Liver	17	21
6	Exit behind	16	20
7	From mouth – stomach	15	19
8	Teeth, chewing	14	18
9	Straight gut	9	11
10	One channel	8	10

Conclusions

The stomach plays an important role in the food processing of the body; 78% of the pupils has drawn and mentioned the stomach (table 5), while 16% only drew it (table 3). Other digestive parts are mentioned in far less amount. A way (tube) from mouth to stomach is drawn en/or mentioned by 77% of the pupils: 55% of the pupils only drew this way (table 3), 3% named it (table 4) and 19% drew as well as named it (table 5). In 59% of the drawings (table 3) there was drawn one channel. The exit for the (digested) food is not often indicated. There is an exit from the stomach. If there is an exit it's behind.

Digestion is named by 46% (table 4) of the pupils. However the absorption of small molecules (digested food) in the blood through the intestinal wall is never mentioned.

The interviews

Favourite food

At the questions what they liked to eat most of the pupils answered fruit or vegetables, like:

- *apples*
- *peach and pears*
- *potato*
- *orange.*

Function of food

The function of food is unknown by most of the pupils. We heard sayings like:

- *So when you eat you fill your body, you don't feel hungry;*
- *It is tasty;*
- *Fill my stomach;*
- *For fun, it is for fun. And it's also necessary.*

Milk seems to be healthy because:

- *it contains vitamins;*
- *Milk, I think, is useful for your stomach.*

The way food passes the body

The stomach plays a dominant role in the way the food goes through the body:

- *It goes to the stomach. A part of it stays there (digests) and a part of it goes out;*
- *Potato goes to stomach; I think it digests and then it goes through guts and then goes out;*
- *Potato first it goes to throat, then it goes to stomach, then it is digested in stomach and than it goes out in the way of waste;*
- *Vitamins are digested in the stomach;*
- *Well, I eat it (potato) and it goes to everywhere through stomach.*

The way milk passes your body

The difference in the way of the food and the way of the milk is only the exit:

- *(waste of) food goes out at the backside;*
- *(waste of) milk goes out in front.*

The pupils were ashamed to pronounce the right words for it; they were only laughing. We found a similar behaviour with teachers during discussion of this subject.

Radioactive elements

If milk contains radioactive elements, what is happening with those elements?

- *The radioactive material will stay in the organism.*
- *They stay somewhere in your lungs or in the stomach somewhere or around the stomach.*
- *They settle down these elements in our body. They get to stomach.*
- *They go to stomach first. So first of all they digest everything that is inside the stomach. And they start eating cells of our body.*
- *I think it will stick somewhere and it will gather in one place and bad process will start.*

-

Radioactive elements can leave the body:

- *only if you make an operation;*
- *you need to throw out;*
- *you do a blood transfusion.*

-

Sometimes confusion with radioactive elements and bacteria is made:

- *I learned that there are very many bacteria in the milk even if it is fresh milk there is some radioactive in it;*
- *The body absorbs them they are very dangerous. And these radioactive bacteria they became old and after 30 years they disappear.*

Conclusions

Pupils mentioned different kinds of fruits and vegetables as favourite food. The function of food is unclear even as the process of digestion. The stomach is the only digestive organ in function. Once you eat food contaminated with radioactive elements, these elements will stay in your body. There are only few ways mentioned in which radioactive elements can leave the body. The fact that the elements can leave your body by urine is not mentioned. Some pupils see radioactive elements as bacteria. There is a taboo on poop and piddle; pupils were laughing and were ashamed when they had to use the words poop and/or piddle.

General conclusions

Pupils have an endangering view on radioactive contamination in their body. Once you are contaminated, the contamination will stay in your stomach. This in contrast with the reality; Cs 137 can leave the body by urine. The biological half-life time of Cs 137 is about 100 days.

The great lines of the process of digestion are not shown, in the concept maps, drawings and interviews.

The idea that food and contamination is stuck in your body, can mean that pupils are not aware of a ecological food cycle and may not be aware of the continuous circulation of radioactive matter.

Consequences for teaching

The purpose of intervention by the teacher is to bring pupils' conceptions to fit criteria such as, to promote conceptual 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). Teachers can make use of our results for the orientation phase. In the first place the teacher can make use of the main categories found in the HCT, drawings and interviews. The differences and similarities between the main categories can be discussed to make it possible to focus on the new concept. In the second place the teachers have to show that it is not possible that all of the food stays in the body (moreover the stomach). In the information phase information should be given about the function of the food, digestion, radioactive contamination of food and the way of removing radioactive elements from the body. In the application phase pupils can be asked to apply their newly-acquired knowledge in a local situation.

In co-operation with Belarussian teachers we have developed lesson materials about 'food' and 'cycles'. The lesson materials take into account the local context and the conceptions found. A try-out of the materials is accomplished in September 1998. We hope that conceptual change could be achieved by these materials in Belarussian classrooms.

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*GENES, CHROMOSOMES,
CELL DIVISION AND INHERITANCE –
DO STUDENTS SEE ANY RELATIONSHIP?*

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Introduction

Over many years a number of different studies have shown that the concept of biological inheritance is, in general, poorly understood. This literature has been reviewed twice in recent years - by Wood-Robinson (1994), from an educational perspective, focusing on school children's understandings and by Turney (1995) from a more general 'public understanding' perspective - and a number of misunderstandings have been identified. These include a belief in acquired characteristics, the belief that parental contributions are unequal (for example, that girls will inherit their mother's characteristics and that boys will inherit their father's characteristics) and a lack of awareness that there is a real, physical, entity passing from generation to generation. While understanding of probability is generally good, the ability to apply it within the context of inheritance is variable.

With recent advances in gene technology and rapid progress on the Human Genome Project, genetic screening is becoming available for an increasing number of inherited conditions. As a result, this limited and confused understanding of inheritance has become a matter of some concern to health care professionals and those interested in the public understanding of science. These concerns focus on :

- the extent to which consent to screening is 'informed';
- the extent to which people are able to interpret the results of screening, and the personal implications, correctly.

In Britain, at present, the results of genetic screening are usually discussed with a genetic counsellor. Given the rapid increase in number and availability of genetic tests, and the limited resources of the National Health Service, it is unlikely that this can continue. In addition, some tests are already available mail order, without

the counselling support normally provided by clinics. There is a growing awareness of a mismatch - even within genetic counselling sessions - between the information which professionals provide and the information which the non-specialist feels they need and of the need to bring about a better shared understanding. In particular, a need to identify what it is that people need if they are to give consent which is informed, interpret the results of screening correctly and come to an informed view as to what, if anything, they should do in response to those findings.

Biological inheritance can be defined, briefly, as the transfer of genetic information from parents to offspring and the interpretation of that information within the offspring, as reflected in its characteristics. However, it is a complex concept, underpinned by a number of more basic concepts relating to:

- the nature of the information;
- the ways in which that information is transferred:
 - a) from cell to cell (within one individual);
 - b) from parent to child;
- the way in which that information is interpreted.

Some understanding of these basic concepts is needed if a useful understanding of human inheritance is to develop. This would include some understanding of the relationship between the structures and processes involved.

In England and Wales the first National Curriculum was introduced in 1989. For the first time, science became a compulsory part of the curriculum for all school students up to the age of 16. One reason for this was the perceived need to increase the general levels of scientific literacy within the population (NCC, 1993). Defining what might be meant by 'scientific literacy' is open to debate but if the 'utilitarian' argument (Millar, 1996) is accepted, it might be reasonable to suppose that such a curriculum would prepare young people for the impact of gene technology on their everyday lives. This paper reports on findings from a study of young people, nearing the end of their compulsory science education, relating to their understanding of the basic concepts which underpin an understanding of biological inheritance. The implications of these findings (in terms of the understanding of inheritance which these young people are likely to have) are considered and the implications of this (in terms of a science curriculum for all, designed to increase public understanding of science) is discussed.

Methodology

This study was designed to investigate young people's understanding of, and attitudes toward, gene technology as they came to the end of their compulsory science education. It was assumed that this would be the knowledge and understanding which they would take with them into adult life and which they would draw upon and build upon, should the need or wish arise. Our interest was in their understanding of the concepts rather than their ability to recall content knowledge. For fuller details of the rationale for, and design of, this study see Wood-Robinson *et al* (1995).

Data on young people's knowledge and understanding of genetics was collected through written probes requiring individual written responses. These written probes contained a mix of fixed and free response questions and were designed to probe the student's understanding of cell division, reproduction, the location and function of different cell structures and the relationship between these structures. Analysis of the free response questions was ideographic, using a coding scheme based on the student's responses rather than the scientific explanation. The coding scheme developed, through an iterative process of reconsideration and discussion, so that all responses could be included. Fixed response questions were analysed by calculating the frequency with which each of the possible responses was selected.

When analysing and coding written responses there is always an element of interpretation. To validate these interpretations, and to probe the students' reasoning in more depth, a number of small groups interviews were undertaken. Each group (3-4 students) was presented with a mythical animal. They were told that the cheek cells in this animal contained just three pairs of chromosomes and they were provided with a drawing of these. They were also told that the chromosomes in this animal behaved in exactly the same way as human chromosomes. They were then asked to draw the chromosomes that they would expect to find in a range of other cells within this animal (nerve cell, sex cell, fertilised egg, unspecialised embryonic cell and finally, a cheek cell from the fully developed new individual) and to compare the genetic information within each of these cells. For each task their reasoning was probed further by the interviewer. Each group discussion was audiotaped and later transcribed for analysis.

When working in small groups in this way, it is not possible to follow individual lines of reasoning, since these may change or develop as a result of group discussion. The group was therefore the unit of analysis for these data. Ideas and concepts expressed within the group were identified and the frequency and consistency of their use was noted. The frequency of different types of response, based on the individual drawings of chromosomes, was also noted.

The main survey sample was drawn from 8 co-educational comprehensive schools under local authority control. They were all located in the West Yorkshire area of England and covered a range of urban, suburban and rural catchment areas. Within each school teachers were asked to select 3 classes (top set, middling ability and low achievers) to represent the range of ability within the school. In total, 482 school students aged 14 - 16 responded to these written questions. All students had been taught to the 1991 curriculum (DES, 1991). For the majority (72 % of this sample) teaching about genetics had been completed. The remaining 28% had been taught about the structure and function of the cell, variation and its environmental and genetic causes, the transfer of information between generations in the form of genes and the basic principles of selective breeding. They had not completed work on cell division, the monohybrid cross (dominant and recessive

relationships) or the molecular structure of genes (DNA replication, protein synthesis and the genetic code).

A sub set of 35 students, drawn from just 3 of these schools, took part in the discussion task. Teachers selected one discussion group from each of the three classes (top set, middling ability and low achievers) giving a total of 9 groups drawn from 9 classes from across the ability range.

Findings

Although each individual in the sample was asked the same set of questions, not all individuals responded to each question. In addition, some gave tick box responses but did not offer any reasons for their ticked response. When students failed to respond to questions it was sometimes because they had run out of time. More often, it appeared to be because they were unsure how to answer the question. For this reason, findings are presented as a proportion of those responding and, where appropriate, as a proportion of those asked.

A. Understanding of the nature of the information

Data were collected using the probes '*Size Sequence*', '*Living Things*' and '*Biological Terms*'. Details of these can be found in Lewis *et al* (1997).

While the majority of the sample identified genes as the source of inherited information very few had any clear understanding of a gene as physical entity with a specific location on a chromosome. There was also confusion and uncertainty about the relationship between genes and genetic information.

In response to the question '*Why are genes important?*' 73% of responses [60% of the sample] indicated determination of characteristics. A further 14% of responses [11% of the sample] indicated transfer of information. Interview data supported these findings.

The students were less clear about the location of genes. About half of the responses to the question '*Where are genes found?*' [39% of the sample] indicated that genes were found in cells. A further one quarter of the responses [20% of the sample] thought that genes would only be found in specific cells, for example the reproductive system [38 responses]. Interestingly, while many of these responses explicitly mentioned the male reproductive system, none explicitly mentioned the female system. Only 11% of responses [8% of the sample] explicitly located genes on or in the chromosomes. Evidence from a number of sources suggested widespread confusion between genes and chromosomes (see '*common confusions*' below).

There was also confusion about the term '*genetic information*' and what it might mean. In response to the question '*What is meant by genetic information?*' 58% of responses [33% of the sample] suggest that it was related, in some way, to characteristics but there was uncertainty as to what this relationship might be. For

example, students did not appear to see a direct link between genetic information and genes. When probed about the transfer of genetic information, in the context of cell division, up to 9% of responses [5% of the sample] didn't appear to locate genetic information within cells. When, under the heading '*Living Things*', the students were given a list organisms and asked to indicate whether or not each one contained genetic information, those saying 'yes, it does contain genetic information' ranged from 92% to 50% of the sample, depending on the organism.

B. Understanding of the transfer of information (between cells; between generations)

Written data were collected using 3 probes – '*Cells*', '*Cell Division*' and '*Reproduction*'. Findings from the discussion tasks supported the findings from these written probes.

There was widespread uncertainty as to how genetic information is transferred from cell to cell within an organism. Only a minority of students clearly distinguished between somatic and sperm (or sex) cells and most were unclear as to the distinction between mitotic cell division and meiotic cell division. Given this, it is not surprising that while many were aware that the newly fertilised egg should have equal amounts, or matching sets, of chromosomes they were unclear as to how this is brought about or why it might be necessary. There was widespread confusion between fertilisation - the process by which genetic information is transferred to the next generation - and the mechanisms which bring fertilisation about.

'Cells'

When asked to compare the genetic information in cells of different types from one individual, only 60% of the sample gave a response for all 4 comparisons (cheek cell with cheek cell; cheek cell with nerve cell; cheek cell with sperm cell; sperm cell with sperm cell). Of these, 60% believed that cells only contain the genetic information they needed in order to perform their function. 14% appeared to believe that every cell contained different genetic information (possibly arising from the belief that genetic information is shared out at each cell division; see '*alternative conceptions*'). Only 20% of responses [12% of the sample] held the basic belief that all cells from one individual will contain the same genetic information.

59% of responses made no distinction between somatic cells and sperm cells. This failure to distinguish between the two fundamental types of cell was also apparent in the responses to the '*Cell Division*' probe (see below).

Just 7% of responses [4% of the sample] showed a clear understanding of the transfer of information between cells within an individual and clearly distinguished between somatic and sperm cells.

'Cell Division'

The difficulty in distinguishing between somatic and sex cells noted above was also apparent in the responses to this probe. 28% of the sample made no distinction between meiosis and mitosis in terms of chromosome number and 36% of the sample made no distinction in terms of genetic information. In contrast, 18% correctly distinguished between the two types of cell division in terms of chromosome number and 22% correctly distinguished between them in terms of genetic information.

When asked about mitotic cell division, less than half the sample [46%] were aware that the chromosome number would remain unchanged but almost two thirds [65%] believed that the genetic information would remain the same. This difference may have been related to the belief that cells of the same type (in this case skin cells) contain the same genetic information. Only 29% of the sample recognised that mitotic cell division only occurs in somatic tissues. Reasoning related to mitotic cell division tended to be very general. 16% of the sample [21% of responses] recognised that chromosomes were copied and shared and 22% of the sample [34 % of responses] recognised that genetic information was copied and shared. However, when discussing mitotic division in plants, 33% of the sample [48% of responses] indicated that mitosis was important for growth, repair and replacement.

When asked about meiotic cell division, 31% of the sample were aware that the chromosome number would halve and a similar number [34%] were aware that genetic information would be different. One quarter of the sample [25%] correctly indicate that meiosis only occurs in the gonads. However, this understanding of meiosis was not very secure, since less than 20% of the sample accurately distinguished between meiosis and mitosis in terms of chromosome number.

This was reflected in the reasons which they gave in justification of their answers. Less than one fifth of the sample showed a scientific understanding of the distribution of chromosomes and genetic information during meiosis - 8% recognised that the purpose of meiosis was to reduce the number of chromosomes in preparation for fertilisation and 15% recognised that different genetic information would be needed in order to ensure variation in the next generation. When asked about meiotic cell division in plants, 15% of the sample recognised that meiosis was important for reproduction.

'Reproduction'

Responses to this probe indicated that about half of the sample [45%] recognised that the egg and the sperm contained equal numbers of chromosomes. More than half of these [30% of the sample; 52% of responses] recognised the need for matching sets or equal contributions. Almost half of these [13% of the sample; 23% of responses] explicitly said that this was needed in preparation for fertilisation.

The finding that 19% of the sample thought that a sperm cell would need more chromosomes than an egg cell, while only 8% thought that a sperm cell would need less chromosomes than an egg cell may have been an artefact of the question (since there were twice as many choices indicating more chromosomes). However, 9% of the sample [4% of responses] were explicit in their belief that sperm cells would need more information, though there was little indication as to why.

Slightly less than half the sample [42%] correctly recognised that the fertilised egg would contain double the number of chromosomes found in sperm. When asked to explain their reasoning about this 24% of the sample recognised the need for matching pairs or equal sets of chromosomes but there was no indication that the implications of this, in terms of inheritance of characteristics, was understood.

However, when asked about the purpose of sexual reproduction 12% of the sample [44% of responses] did recognise the importance of sexual reproduction in terms of increasing the mix of genes.

There was a widespread difficulty in differentiating between the process of fertilisation (the fusion of egg and sperm) and the mechanism which brings this about (in animals, copulation). This became very apparent when the students were asked about reproduction in plants. 43% of the sample recognised that sexual reproduction occurred in plants. The most common reasoning [21% of the sample; 35% of all responses] indicated an awareness of the existence of sex cells and/or a mechanism. Of those who did not accept that sexual reproduction could occur in plants, the most common reason was that they could not identify a mechanism [27% of the sample; 44% of the responses]. The absence of discernible movement was a major factor here. 7% of the sample [12% of the responses] were aware of pollination but did not recognise it as a means of bringing the sex cells together. Instead it was seen as evidence of asexual reproduction. A further 3% of the sample saw the production of seeds as evidence of asexual reproduction.

D. Common confusions

A number of confusions were apparent, across a range of questions.

1. The relationship between genes and chromosomes

There is considerable confusion about the relationship between genes and chromosomes. Genes were frequently considered to be larger than chromosomes but the proportion of the sample expressing this view varied, depending on the context and format of the question. At times the two terms appeared to be used interchangeably.

In responding to the 'Size Sequence' probe 25% of the sample considered 'gene' to be bigger than 'chromosome'. A similar finding emerged from the 'Biological Terms' probe. In response to the question 'What are genes made up of?' 25% of the sample [39% of the responses] suggested chromosomes. However, when

asked (within the same probe) ‘*Where are chromosomes found?*’ only 10% of the sample [17% of responses] said that chromosomes were found in genes.

In the ‘*Living Things*’ probe 11% of the sample were not aware that chromosomes contain genetic information.

2. The concept of ‘cell’

While this study did not set out to investigate young people’s understanding of cells, it soon became apparent that a minority of the sample had some problem with the concept. While the extent of this confusion is not easy to quantify, examples of it occurred in response to all probes. The term itself was regularly used interchangeably with ‘chromosome’ and even ‘gene’, there was a lack of awareness that all cells have a common basic structure and a lack of awareness that cells are the basic ‘building blocks’ which making up an organism.

Depending on the form of the question, upto 6% of the sample confused cell and chromosome.

3. The role of chromosomes

When asked, in the ‘*Biological Terms*’ probe ‘*Why are chromosomes important?*’ only 40% were able to give an answer. The most common response indicated determination of characteristics [63% of responses, 25% of the sample] and of those who were more explicit, the majority [6% of the sample; 15% of responses] indicated determination of sex. A further 11% of responses [5% of the sample] mentioned the transfer of information.

Responses to the ‘*Cell Division*’ and ‘*Reproduction*’ probes suggested that there was a low but regular confusion about chromosomes in relation to sex determination [upto 4% of the sample, depending on the question]. In these cases all chromosomes were considered to be either male or female and during meiosis or fertilisation the distribution of the chromosomes was related to the sex of the chromosome and depended on the type of sex cell (egg or sperm) and the sex of the newly fertilised egg (male or female). This finding was confirmed in the discussion tasks, when a number of students clearly illustrated this view with coloured diagrams of chromosomes.

4. The terminology of cell division

This was evident, across a number of questions, in upto 6% of the sample. These students seemed to have difficulty with the contradictory terms which are used to describe the process of cell division in terms of chromosomes and genetic information - terms such as divide, replicate, copy, share, split, reproduce and multiply. This confusion was compounded by their uncertainty about the relationship between cells and chromosomes already noted above.

5. distinguishing between processes

In responding to questions about cell division and fertilisation, up to 5% of the sample seemed to be confused as to which process they were being asked about and responded inappropriately for that particular question.

D. Alternative conceptions

Other than the widely held belief, documented above, that the genetic information in a cell depends on its function, there were very few alternative conceptions.

1. Chromosome number is related to the condition of the cell

Examples of this occurred in responses to questions in the 'Cell Division' and 'Reproduction' probes, with up to 2% of the sample believing that the number of chromosomes in a cell would depend on the age or the health of the cell.

2. At cell division, chromosomes and/or genetic information are shared but not copied

This may have arisen from the confusion about terminology noted above, but examples of it occurred in response to many questions, with up to 9% of the sample holding this view in relation to chromosomes.

E. Understanding of how the information is interpreted

Despite numerous opportunities, in response to a range of different questions, not one student noted that there is a product associated with a gene.

When asked about alleles only 12% of the sample responded. Of these only 12 [$<3\%$ of the sample] explicitly recognised that there were different forms of a gene.

Students were not asked explicitly about the extent to which characteristics are determined by genes or about the effect of environmental factors, but a number of responses to other questions suggest that some students believe that all characteristics are determined by the genes - including behaviour and personality.

Discussion

It is clear from the findings that these students had a poor understanding of the relationship between genes, chromosomes, cell division and inheritance. They had little understanding of the nature of the information, were confused about the process by which that information might be transferred and had very limited awareness of the mechanisms by which that information might be interpreted. It is unsurprising, in view of these findings, that students have difficulty in understanding the concept of inheritance.

Of greater surprise and concern was the level of confusion about basic biological structures such as cell, chromosome and gene. It seems that these students were poorly equipped with even the most basic understandings on which to develop a

better understanding of genetics and inheritance in adult life - despite their compulsory science education.

One possible explanation for this is the nature of the compulsory science curriculum. There has been a difficulty in defining an appropriate 'science for all' curriculum - both in terms of content and in terms of purpose. This has been exacerbated by the tension between the need to train future scientists and the need to provide a science curriculum which is appropriate and relevant to all, regardless of specialist interest or ability.

These findings suggest that if we want a more effective, appropriate and relevant science curriculum for all and if we want to increase the general level of understanding of science within the population, then it would be better to provide our students with a basic knowledge of structures and concepts together with some opportunities to apply this knowledge to real and relevant social situations. In this way students would be able to see the relevance of the science to their daily lives and would have the opportunity, through using that knowledge, to develop their understanding of the science. Research into the opinions and attitudes of these young people toward various uses of gene technology showed that after a brief but carefully designed teaching intervention of about 30 minutes most students were able to engage with the issues and come to a reasoned view (Lewis *et al.* 1997).

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STUDENTS' VIEWS AFTER THE BIRTH OF DOLLY THE SHEEP

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Why was the birth of Dolly such a media sensation ?

The idea of cloning through cell nucleus transfer was first put forward by Speeman as far back as 1938, on the premise that assuming that all genes are present in the genetic make-up of a given somatic cell from a whole organism, then it should be possible to regenerate a complete individual by transplanting the nucleus of that cell into an egg. From the outset, interest focused on transferring the nucleus of a somatic cell from an *adult* individual. Di Berardino brought this early premise into question in 1980, as it appeared that the likelihood of cell nucleus implants developing into a normal individual decreases with greater differentiation in the cell tissue from which donor nuclei are taken - which would apply *a fortiori* to adult cell tissue. The idea was that once a protein adheres to a gene, the expression of certain genes may become totally inhibited since the differentiated cell then loses its 'totipotency' - its ability to regenerate any tissue in the organism. In other words, not all genes in a differentiated cell would be "awakened".

Research on embryo cloning in domestic mammals has been proceeding along three parallel lines: embryo scission, blastomere separation and cell nucleus transfer. In each case, until 1997 - in other words until the birth of Dolly - cloning was carried out with embryos, not with differentiated cells from adult individuals.

Cloning experiments using differentiated cells

In 1996, Ian Wilmut's team at the Roslin Institute in Edinburgh succeeded in obtaining two ewe lambs, *Megan* and *Morag*. These differed from all previously obtained animals in that they developed from a cell culture from nine day old sheep embryos, which therefore already contained about one hundred and twenty cells. At this stage, the cells were already becoming differentiated into three distinct tissue types : the endoderm, mesoderm and ectoderm.

The cells from which the nuclei were taken were cultured over several months from 9 day old embryo cells (redivided 6 to 13 times during the process), which made it possible to obtain several thousand genetically identical cells. The cells

were induced into a state of quiescence before they were transplanted into enucleated oocytes by reducing the serum concentration in the culture medium. Wilmut hypothesised that the nuclei of these now quiescent cells - where multiplication had been halted at the G0 stage - would be reprogrammed more easily by the receptor oocyte since there would be no need for the latter to inhibit nucleus activity before reactivating it. Moreover, in sheep, transcription of an embryo genome does not begin before the 8-16 cell stage (as opposed to two cells only in mice). The first cell divisions are therefore dependent on the cytoplasm in the oocyte. In theory, this means that reprogramming of the transplanted nucleus can take place over at least two division cycles. Therefore, in this experiment, the cultivated cells retained the full genetic potential of young embryo's genetic material. According to Wilmut, cell differentiation would then reflect changes in gene expression rather than the loss of any specific chromosomal areas.

Wilmut sees two potential applications for this new technique. Firstly, transgenesis may become possible while donor cells are still being cultured. According to Wilmut, current transgenesis techniques are very primitive in that, at best, they will only allow a single gene to be introduced but with no way of knowing what place it will take up in the genome, so that it may interfere with existing genes. "Gene targeting" techniques would allow much greater precision in genetically modifying an existing gene or in adding a new gene. Selection techniques could then be applied to identify those transgenic cells of potential value as donors of nuclei which are still being cultured. Secondly, cloning would improve animal breeding efficiency by ensuring uniformity, provided that breeders raise different batches of clones to reduce risks in the event of a clone being susceptible to a particular infection.

The births of Megan and Morag gave researchers new hopes of obtaining clones of adult individuals. The most dramatic turn of events occurred in February 1997 when Wilmut announced the birth of *Dolly*, cloned by his team from an adult ewe. Dolly grew from the nucleus of a somatic cell taken from the mammary gland of an adult ewe and transplanted into enucleated oocyte. The embryo thus obtained was transferred to the uterus of the surrogate ewe which gave birth to Dolly.

The research team grew three populations of donor cells. The original cells were taken from 9 day old embryos, from 26 day old foetuses (fibroblasts) and from the mammary gland of a 6 year old ewe in the last three months of gestation. Eight surrogate ewes carrying the reconstituted embryos gave birth to live lambs which developed from the three cell populations.

Dolly is the first mammal ever born after transfer of the nucleus of an adult cell. The initial culture mainly contained epithelial mammary cells (over 90 %) together with other types of differentiated cells including myoepithelial cells and fibroblasts. However, the research team could not say with complete certainty that the cells did not include a small proportion of undifferentiated cell lineage which may have been capable of regenerating the mammary gland during gestation...

The birth of Dolly shows that during the development of the mammary cell from which she grew, there was no irreversible alteration of the genetic information needed to bring an embryo to full term. Dolly thus brings the initial research hypothesis on cloning up to date, by showing that when adult differentiated cells are reinserted into a suitable medium they will regain their full genetic potential. Cloning an adult individual is therefore a feasible proposition. But as to whether Dolly is really an identical copy of her "mother", this cannot be maintained with the same degree of certainty, because of the maternal heredity associated with the cytoplasm of the receptor ovocyte. Moreover, some scientists have recently questioned whether Dolly is actually a true clone of an adult ewe ³.

And we should not overlook the fact that of the 277 embryos reconstituted from mammary gland cells, only Dolly survived ...

The birth of *Polly* at the Roslin Institute was announced in July 1997. What the research team obtained was a "live synthesiser" capable of producing a human protein. The value of this achievement stems from the fact that bacteria, the agents most widely used in gene manipulation, cannot manufacture human proteins with a similar structure to the protein sought, while cells from the higher animals are capable of doing so. The fact that these proteins can be collected in large quantities in a biological fluid such as milk adds considerably to the potential value of developing large transgenic mammals.

Producing large transgenic mammals is still extremely difficult, as evidenced by the fact that the Scottish firm, PPL Therapeutics, obtained only nine transgenic calves from the 22 000 embryos they manipulated... and that this was seen as an extraordinary achievement! However, cloning may improve yields in the production of large transgenic mammals, and the birth of Dolly opens up new horizons in this area. Polly was the first ewe obtained from a cloned cell into which a human gene was introduced, enabling a human protein of pharmaceutical value to be expressed and synthesised in her milk. The method used to obtain Polly was the same as for Dolly, with one exception : the human gene was first injected into a cell from the "original" ewe. The nucleus from this modified cell was then introduced into a previously enucleated ewe's ovocyte. The embryo thus obtained was then transplanted into the uterus of the surrogate ewe which gave birth to Polly in July 1997, on a farm belonging to the Roslin Institute and PPL Therapeutics.

³ Vittorio Sgaramella, from the University of Calabria in Cosenza (Italy) and Norton Zinder, from Rockefeller University in New York, raised doubts on this in a letter published on January 30th 1998 in *Science*. They maintain that Dolly was cloned from a mammary cell from a gestating ewe, and that the cell culture may have been contaminated by a foetus the ewe was carrying. In the same issue of *Science*, the Edinburgh research team declared that tests were under way to establish Dolly's true "age". Griffin declares that: *'statistically, it is infinitely improbable that foetal cells, which are extremely rare in blood, could have become dominant in the mammary gland culture within such a short time. Dolly is a true clone of an adult ewe.* In July 1998, the polemic is achieved : 2 British teams have analysed the genetic patrimony of Dolly and concluded she was the copy of her mother.

The race for clones and transgenic species was on. In January 1998, George and Charlie, two cloned and genetically modified calves were "created" by Robl & Stice at the University of Massachusetts. PPL Therapeutics also announced that they would now be cloning transgenic cows. Mr. Jefferson, a calf cloned from an adult individual, was born on the 16th February 1998. In France, a female cloned calf named Marguerite was born on the 20th February 1998 at INRA (the national institute for agronomic research), having developed after the transfer into an enucleated ovocyte of a nucleus taken from a muscle tissue cell of a 60 day old foetus obtained from a slaughterhouse. To verify the importance of the state of quiescence of the donor nucleus (as maintained by Wilmut's team), INRA compared the development aptitude of embryos reconstituted from cells treated in two different ways, by inducing quiescence and by maintaining the cell division process, respectively. The number of blastocysts obtained was the same whichever treatment was used, and gestation was established in both cases. Further developments are awaited ...

Are knowledge and attitudes among Ministry of Agriculture and Fisheries students influenced by events receiving such intensive media coverage as the birth of Dolly ?

This is what this study set out to establish. To do so, a comparison was made between data obtained before and after the birth of Dolly, in a diachronic approach lasting from 1993 to 1997. The surveys carried out in 1993 and 1995 on knowledge and attitudes among students in France were presented at the symposium on "Young People's Knowledge of and Attitudes to Gene Technologies" in Rome at ESERA (1997).

Like Lewis et al. (1997), we have used the term "*opinion*" to designate values attached to specific issues in a specific context, and the term "*attitude*" as referring to more general values. For example, on the issue of transgenesis in animals, an "*opinion*" would be the view that manufacturing transgenic cows capable of producing humanised milk in industrialised countries is not acceptable, while the view that manufacturing transgenic animals is ethically unacceptable under any circumstances would be an "*attitude*".

In the last three months of 1993, a survey was carried out among ninety Ministry of Agriculture baccalaureate (A level) students. The aim was to check the understanding of several biological terms (such as oocyte, blastomere) likely to be used in an information document, and to check whether basic notions (such as non-unpermeability of the nucleus membrane, chronology of meiotic divisions, and the stages of embryo development) necessary to the understanding of work on cloning had been assimilated. This investigation aimed at identifying the level of formulation accessible to this kind of public.

It seems that biological knowledge needed to understand the stages of the cloning procedure is not memorised by everyone. This in itself creates a problem. Jacobi

(1986) suggested the term *chronotopic* to describe accounts which retrace the evolution of a biological entity or the sequences of an elaborate physiological process. At the moment of fertilisation, the biological entity known as an *oocyte* changes its name and its nature. The following chronotopic series then appears : oocyte \Rightarrow ovum \Rightarrow egg \Rightarrow embryo. Even if 93% of students give an exact definition of an oocyte, this does not mean that they understand the above-mentioned chronotopic series. It appears that the order and terminology of this series are not in fact clearly understood by the students. The risk is that difficulties occur in learning about cloning which includes manipulations of these different biological entities.

30% of students correctly identified the instant and the products of meiotic division. Half the students know that embryo cells are also called blastomeres, and the same proportion can recognise the morula stage. This part of the questionnaire reveals gaps in the biological knowledge needed to understand the method used in cloning by nucleus transplantation ; these gaps may constitute conceptual obstacles to knowledge acquisition.

The cloning principle has been defined by these students without clear identification of the procedure itself, which is an indeterminate process enabling identical individuals to be obtained. We have observed that the nucleus transplant method, although the one mainly used, is poorly retained ; students are more likely to envisage oocyte or embryo splitting, or even blastomere transplant. According to each case, they retain a simple, but incorrect method (oocyte splitting), or an out-dated method (embryo splitting), or one which has been discarded (blastomere transplant). From an educational point of view, this should lead to an insistence on the reasons for abandoning a method, or on why it is currently impossible to use it. For instance, the following could be developed : limiting factors encountered, the importance of the presence of the pellucid zone in the course of embryo development and the difficulties encountered in in vitro oocyte maturation in cattle.

A lack of scientific knowledge does not prevent students from envisaging the advantages and disadvantages in using this particular biotechnology. The abundance of confused notions and concepts in biology used by students to explain cloning reveals the existence of numerous conceptual obstacles. Their scientific training has equipped them with a scientific vocabulary which is unfortunately misused. This analysis reveals the variety of fields of reference that students associate with cloning, and the state of confusion reigning in the scientific facts students use to explain cloning.

Knowing the basic principle of cloning is sufficient to enable students to form an opinion. What is memorised is the socialisation of knowledge, that is, the range of real or imagined repercussions. Constructing an opinion is based on the key-stone of social representations. Whether these are influenced by the socio-cultural group to which they belong, or by the implicit objectives underpinning the education they receive, they lead to the forming of strongly-held opinions. Can they be used

as anchor-points in the acquisition of new knowledge ? Confronting the contradictory points of view between students, and also written and spoken testimony by supporters and opponents of cloning may create socio-cognitive conflicts likely to stimulate knowledge acquisition.

In 1995, to test this further, interviews were conducted with 10 fifth-year secondary school students. These took place at the beginning of the school year to avoid any bias associated with recent lessons on the topics in question. The study showed that the gaps in students' knowledge tended to confuse the issue, and that what they were expressing opinions rather than knowledge. They get more or less anxious according to whether or not it relates to plants, animals or human beings.

Student reactions after the birth of Dolly was announced

The cooperation of twelve zootechnology teachers working for the Ministry of Agriculture and Fisheries in different parts of France was asked. Five of them gave their assistance by collecting the information analysed here from their students (173 altogether). The study depended on voluntary assistance from the teachers, who were teaching different classes of different sizes. Although we do not claim to be analysing a representative sample here, the fact that the variables of gender, class and school had no significant effect does allow us to maintain that an observation was made of trends in the knowledge, opinions and attitudes of Ministry of Agriculture and Fisheries school students.

The quantitative data used in the study were processed through Sphinx software. Calculations were based on quotations from the students, who were questioned during the weeks which followed the announcement of the birth of Dolly, the cloned sheep. These students have not been taught about the experiment of Dolly.

The data were collected in three ways.

- An open questionnaire on animal cloning aimed primarily to assess the state of students' knowledge (what procedure was used, what difficulties were encountered by researchers, knowledge of other animal cloning procedures, what results have been obtained, what are the applications considered). Two additional questions aimed to elicit attitudes and opinions.
- A multiple-choice questionnaire, in the form of an opinion poll, were devised to narrow down students' opinions on animal cloning. The introduction to the questionnaire was as follows : "*You are being asked in an opinion poll to give your views before the authorities decide to invest large sums of money in a research programme on animal cloning.*"
- Finally, a questionnaire made up of mainly closed questions was used to ascertain students' opinions on animal transgenesis.

Students' knowledge on animal cloning

How is cloning done?

After Dolly's birth had been announced, embryo scission was no longer the method most frequently mentioned (described by six of the students). Eleven students mentioned embryo cloning by cell nucleus transfer. 56 students mentioned the very recent method which involves cloning a cell from an adult individual by nucleus transfer. The individual providing the cell from which the nucleus is taken is the "mother" of the clone. Twelve students mentioned the stage in which the "mother's" cells are cultured. Some of the recent media discourse on Dolly appears piecemeal in students' responses : 27 students mention *mammary cells* or *mammary tissue* or *udder cell*; 17 mention ewes, whereas in 1993, most students referred to cattle as the object of cloning ; five students offered a synopsis, as published by various popularising scientific articles (ewe A is the cell donor, ewe B is the ovocyte donor and ewe C carries the embryo); five students took up the idea that "*males will become superfluous*" as suggested in the more sensational media headlines.

Four students thought that *genes* or *chromosomes* were involved : "*it's done with genes, they extract genes to duplicate them in an animal*" ; "*they mix up chromosomes from one individual with another to make two identical individuals*". Two students mentioned *blood*, as a life-giving fluid: "*scientists do it. I think they do it with blood from the person that's being cloned. With the blood, they can create a double*" ; "*they use blood taken from an animal to reconstruct the DNA*". As in 1993, but for eleven students only, cloning involves the *division* or *multiplication* of a cell, an ovule or an egg. Four students explain that two cells are mixed together : "*you only need one individual, for instance a cell from the udder and an ovule. Afterwards, the two cells are mixed together to make a single cell. Then they place the cell inside the mother in which it will go full term*".

29 % of the students gave an accurate description of the principle underlying the method used by the Roslin Institute. However, many responses show a lack of clarity in students' scientific knowledge, which was particularly evident in the incorrect differentiation of biological and physico-chemical entities (cell, chromosome, ovule, ovocyte, molecule, DNA, etc.) and an imperfect grasp of animal physiology : "*they take molecules from the animals*"; "*they take a cell from an ovule and one from the teat*" ; "*they take a chromosome from an animal and transfer it to another animal*" ; "*they take a teat cell from an animal. Then they take an unfertilised ovule from an animal and transfer it to an embryo. Then the embryo develops until lambing*" ; "*the DNA and the tissues are divided*" ; "*they take a living cell from an animal and reproduce the same animal from it*" ; "*I think they take cells from an animal and implant some of them in the reproductive organs of a female of the species the cells were taken from*" ; "*they take a female cell and a male cell and change the genetic codes to get exactly the same animal*" ; "*they take a cell from a living creature then they reproduce the creature. The cell develops and grows to make a living creature*". Seven students

thought that clones could be produced through cell culture alone : *“it's fairly simple. You take cells from the udder of a donor ewe, put them in a culture medium and leave them to develop”*. One student described crossing two different species : *“they take cells from one animal and cross them with cells from another species. Then they're assembled to make a new breed”*.

What difficulties are encountered by researchers?

Eighteen students thought that researchers did not encounter any difficulties and fully understood the method. The others thought that the difficulties encountered were technical (32 responses), financial (31 responses), ethical (28 responses), to do with public opinion (19 responses), with biological factors (14 responses), diseases (14 responses), legislation (10 responses), genetics (7 responses), politics (6 responses), religion (6 responses), the appearance of anomalies (5 responses), nature (5 responses), mistakes (5 responses), risks of human/animal deviation (4 responses), the media (4 responses), incomplete scientific knowledge (3 responses), the decline of biodiversity (3 responses), clandestine experiments (3 responses), the elimination of males and men (2 responses), traditions (1 response) and time (1 response). But responses also included : *“they're crazy”*, *“they don't really know if they've got everything under control”*, *“cloning shouldn't be used for personal reasons”*, *“and what about mad cow disease!...”*, *“and viruses”*, *“and the craze for technology!”*, and *“they may be able to create doubles. But can they create a mind? They might not know what mind a clone would have”*(this response seems to derive from students' familiarity with comic strips or mangas).

Do you know of any other animal cloning techniques?

64 % of the students said they did not know of any other animal cloning techniques. 10 students admitted they did not know. Embryo transplants were mentioned by four students, embryo cloning by three, artificial insemination by one, plant cloning by one, egg or cell splitting by three, bi-section by three, embryo division by one, sexing by one and xenotransplantation by one.

What are the results of animal cloning to date ?

In students' responses, results are either the product obtained, or the consequences of cloning. The product obtained is a ewe (39 responses), Dolly the ewe (10 responses), Dolly (12 responses), a sister who is its mother's twin (referring to Dolly) (1 response), a sheep (8 responses), two sheep (3 responses), sheep (5 responses), a breed of sheep (1 response), ovines (2 responses), a goat (1 response), a cow (1 response), cows (5 responses), Limousine and Holstein cows (1 response), frogs (6 responses), monkeys (14 responses), an animal (6 responses), animals (9 responses), two animals (1 response), individuals (2 responses), creatures (3 responses), a (female) twin (1 response), a clone (3 responses), and even humans (3 responses), and animal and plant cloning (1 response).

Consequences are the disappearance of males (2 responses), progress in treating cancer (1 response), a biological war (1 response), causing harm to nature (1

response), an increase in the productivity of breeding animals (1 response), animal transgenesis (3 responses).

Many students qualify results without specifying what they are. Results are unacceptable, useless, expensive, mediocre, dangerous, negative, minimal, still poor, successful, conclusive, satisfactory, perfect, encouraging, very good, efficient, positive, unknown. Five students provided a percentage (0%, 1%, 0.0001%).

Students' responses bear witness to the influence of media coverage around Dolly's birth. The result of cloning is a ewe, Dolly, or Dolly the ewe, whereas in 1993 bovines were the species most often mentioned. Frogs were cited because many articles on the event mentioned that the first clone of an adult individual had been obtained with amphibians. For example, the title of an article in *Le Monde* on March 3rd 1997 indicated that the Dolly event had been predictable as far back as 1950. The article included a separate box describing the successful cloning of an adult frog, under the title *Il y a 30 ans, les amphibiens* (Amphibians - 30 years back). Contrary to general belief, no researcher had succeeded at the time in obtaining a second identical frog from an *adult* frog (Blanc, 1986). Similarly, regarding those who mentioned the cloning of monkeys, it should be remembered that the media described an American experiment with monkeys shortly after the birth of Dolly was announced.

What applications might there be for animal cloning ?

Forty students admitted they did not know. The others mentioned one or more applications.

The applications given were associated with animal selection, improved yields, animal reproduction, improvements in the quality of animals and animal products, research, saving threatened species, extending a meat-based diet worldwide, and trade. The aim would also be to *photocopy* valuable animals. Five students thought that the idea was to *photocopy* the best animal in all breeding stations.

Animal transgenesis applications were considered : production of milk containing proteins for pharmaceutical use, xenotransplantation and the production of humanised milk. Plant applications were mentioned, and also human applications such as treatments for sterility, human cloning (mentioned 6 times), improvements in human medicine, paternity testing, drug testing and the duplication of human organs for transplant purpose (mentioned twice).

The comment "*males won't be needed any more*" appears again, and also risks associated with eugenics: "*it's what Hitler wanted to do*" ; "*the applications could threaten the future of humankind*" ; "*it's a disgrace*".

Categorising attitudes and opinions on animal cloning

Students' attitudes

25 students expressed positive attitudes, 82 expressed negative attitudes and 20 were unsure. Some of the ambivalent attitudes were expressed as follows : *“the technique may bring improvements, but cause an animal's genetic make-up to deteriorate”* ; *“a considerable advance in genetics research, but we don't know its consequences or limits”* ; *“cloning is of value to improve breeds, but if it happens all the time will there still be any natural breeds ?”* ; *“it's a good thing because you can develop really high-performance animals, but it means nature isn't allowed to take its course any more”* ; *“it's a major advance for genetics research which will help to control disease, and save time for breeders. But there may be repercussions later for animals : new diseases for instance”*. The 20 ambivalent responses were all given in two points linked by a restrictive connector, which typically produced formulations structured as "positive view but negative view" or "negative view except positive view".

In addition, 7 students stressed the need for controls, either over "crazy" researchers or over producers : *“an advanced technique which has to be kept under control”* ; *“if they are used in an intelligent way, these discoveries could be very useful, especially in poor countries. But even if researchers press for such uses, financial interests and producers' interests are bound to come first. I think that regulations in the law have to very strict because these discoveries might degenerate”*. Seven other students were concerned about the risks of applying cloning techniques to humans, although they approved of cloning as long as it is restricted to animals: *“animal cloning could be of great value for the future. If food becomes too scarce, they could always be eaten (what else would be the point of cloning animals??). But human cloning would be a bad thing because people could use it to create armies”* : in this case, animals are seen as objects and people as instruments. One student expressing an ambivalent view emphasises the danger of seeing animals purely as instruments : *“it's fine if it's used to add qualities to certain breeds (better milk production etc.). But it shouldn't be used indiscriminately, to make pigs with 18 legs to produce more ham, for instance. Cloning means that animals will become machines and will all be identical. Nothing can come of all minds being the same”*.

Advances in animal breeding after the Second World War led to the development of a scientific model equating animals with machines, which blatantly contradicted the traditional livestock farmer's view of animals as individuals. The increasingly technical structure of the profession, together with its economic logic equating farms with industrial businesses encouraged farmers to use technologies developed from scientific research results. But as livestock farming became increasingly artificial, objections began to emerge. The scientific model was no longer accepted as a matter of course. The reluctance of some farmers to adopt *modern* techniques did not stem so much from what was seen as incompetence as from their professional ethics: good livestock farmers were

those who knew how to look after their animals and made sure they always had individual attention (Larrère & Larrère, 1997).

Students expressing positive attitudes expected to see *perfection* in products, improvements in selection procedures, quality and productivity, higher incomes, possibilities for “*recreating individuals that are becoming extinct*”, the creation of new species, relief for populations experiencing hardship, progress in treating AIDS, and even possibilities for creating the perfect human being : “*it's wonderful, we'll be able to mix people with different qualities to create a perfect human being*”. (These students actually made frequent use of the words *perfect* and *perfection* as lexical items.) Cloning, moreover is “*100% reliable compared to normal methods of reproduction which go wrong more often*”. There is a certain similarity here with the comment made by the ethics specialist, Dr Fletcher, in the New York Times (1993) on the "human cloning" experiment undertaken by Stillman and Hall : “*A human being is a creator, and the more a creation stems from human will and human reason, the more human it will be. This is why (...) laboratory reproduction is infinitely more human than conventional heterosexual conception.*”

Negative attitudes are both clear-cut and terse : “*it shouldn't be allowed*” ; “*I think it's terrible*” ; “*playing with fire*” ; “*there's absolutely no point*” ; “*it's stupid*” ; “*it's awful*” ; “*it's a complete con*” ; “*it's a crazy thing to do*”. These attitudes clearly express rejection, even fear. The reasons for these attitudes, when they are given, are based on the risks involved in going against nature : “*nature will end up getting its own back : the method produces mutants*” ; “*nature will end up going haywire*”. It's wrong to “*meddle with nature*” ; nature should be “*left to take its course*”. Cloning means the end of biodiversity : “*we're risking disaster with all this manipulating*”. The *perfection* of cloned individuals is inherently unacceptable and will also have negative economic repercussions : “*I think it's terrible because there won't be any more competition between livestock farmers. Everything identical, nothing but perfection*” ; “*animal cloning is a challenge to nature. But they can't possibly apply it to farming or we wouldn't need farmers any more because there won't be any more diversity and we'll only ever produce the same animals. The world economy would suffer because there would only ever be quality products and no more competition on the market. So I'm against cloning. It's a threat to humanity*”. With overproduction a problem, what is the point of cloning ? “*we're overproducing already, so how can cloning solve anything ? It can only make things worse. It's like increasing quantities of milk per cow - that brought in milk quotas*”. A pattern emerges in which science is opposed to nature : “*it's a good thing for science, but I'm against it because I think you have to let nature take its course and not disrupt the way things work*”. Besides, scientists are a menace : “*it's been dreamed up by scientists to kills off farming*”. Cloning could “*introduce diseases*”. Cloning is expensive, so it can only benefit rich countries and anyway “*it's just money down the drain, there are more important things to see to. Instead of fooling about with clones they ought to be curing diseases like Aids or cancer*”. This type of *manipulation* could *destroy the environment, the ecosystem*. Males might disappear because they won't be needed any more.

And most of all, cloning might be applied to humans: “*soon they'll be cloning humans. What chance do we have of escaping from the technological omnipotence symbolised by Frankenstein's monster ?*”.

Scientific imagination has already been the subject of an investigation by Albertini and Bélisle (1988). According to Holton (1981), the patterns of scientific imagination determine the directions taken by scientific communities. These patterns of scientific imagination, or *thêmata*, relate to the age-old archetypes which appear in the symbolic endeavours of human beings. These archetypes are the universal structures making up the psyche, which Jung called the collective subconscious. “*These thèmeata are not usually apparent as such ;*

they may be uncovered in an analysis of concepts, in studies of methodological choices, or in basic premises or hypotheses."

According to Albertini et Bélisle, scientific popularisation practices are developed from the substance of these thémata. *"The role played by thémata in social cohesion is to some extent similar to the role of the paradigm in promoting consistency in science. Where for the majority of society acceptance cannot take place on the real level of scientific formalisation, these thémata make acceptance possible on the symbolic level."* Unless they become too effective in counteracting powerful ideological checks ...

The CCSTI exhibition entitled *"Créatures artificielles"* held at Villeneuve d'Ascq in 1992 provided material for comment to illustrate the importance of symbolic thought in technical and scientific popularisation. Amidst various cultural references (literary texts, robots, literary creations such as Pinocchio and Frankenstein, statues), the exhibition featured different representations of contemporary technology (industrial robots, computer-generated imagery, genetic engineering etc.). The exhibition aimed to illustrate the mythical theme of the artificial creature. According to Maitte, CCSTI director and the designer of the exhibition, in an interview with Habert (1992), *"any information on new technologies has to be set within some cultural and historical context, because you need historical references to be able to think into the present, and cultural continuity has to be demonstrated"*. Maitte supports the idea of a link connecting myth and modern technology. On the subject of medically assisted procreation in particular, he tells Habert that : *"Man has always sought to remedy his imperfections by creating a better human being "*. The question is whether the link between modern technology and myth should be highlighted to help the public to view topical issues with greater detachment, or on the contrary to encourage the public to legitimise technology without a critical analysis.

According to Albertini et Bélisle, popularisation involves putting forward analogies and evocative imagery which are rooted in scientific imagination. Science and technology, as conveyed by popularisers, play a part in the constant renewal of society's collective imagination.

Students' opinions

The students were asked to give their opinions on the various potential applications of animal cloning. Some, however, focused on consequences rather than applications. Nine students expressed positive opinions, 46 negative opinions, and 12 had ambivalent opinions. Those expressing positive or negative opinions were able to cite one or more applications. Positive opinions were based on applications in livestock farming, medicine, food production (especially in developing countries) and the conservation of threatened species. Negative opinions were also based on livestock applications, but more especially on human cloning : *"better animals, armies of strong men, elite members of the nation"* ; *"the different potential applications may be harmful to mankind and lead to the end of humanity. Everyone will be wanting their own clone, which is likely to cause problems. Also, cloning is done without the need for male reproductive organs, so ultimately there won't be any men, only women"*.

Animal cloning questionnaire

Eight statements expressing positive repercussions of cloning were put to the students :

Animal cloning will increase incomes among livestock farmers

Animal cloning will have no negative effects on the environment

Animal cloning will improve the selection of breeding animals

Animal cloning will help preserve biodiversity

Animal cloning does not raise any ethical problems involving humans

Animal cloning does not raise any ethical problems involving animals

Animal cloning will help to alleviate famine in the Third World

Animal cloning will increase revenues for selection firms

The students were asked to say whether they agreed or disagreed with these statements, or whether they did not know.

The majority of students agreed that animal cloning would increase selection of breeding animals (66.5%). Opinions varied with regard to an increase in income for livestock farmers (38% agreed, 42% disagreed) and selection firms (41% agreed, 33.5% disagreed). The majority disagreed with all the other positive statements : 58.5% on environmental issues, 66.5% on biodiversity, 69.5% on ethics involving humans, 58% on ethics involving animals, 56% on famine alleviation in the Third World. 12.5% of the students were enthusiastic about animal cloning, while over 71% expressed anxiety.

Students' opinions were divided as to whether they would eat meat from cloned animals, and even more so on the question of joining a protest movement if high quality cloned calves were to be bred in France.

Those expressing anxiety about animal cloning were mainly concerned about the environmental repercussions, consequences for biodiversity and ethical consequences involving both human and animals.

Opinions on animal transgenesis

To identify students' opinions on animal transgenesis, the context of each question was specified. The object was to determine how far a given context might shape students' statements of opinion, by checking whether they were influenced by the different applications (medical, industrial, veterinary, etc.) and candidate species (domestic mammals, mice, fish). (see questionnaire in Appendix).

Patterns of opinion on animal transgenesis

Students' opinions on animal transgenesis differed markedly according to the context and potential applications. Medical applications were those most widely accepted, followed by veterinary applications. 64.7 % of the students approved of the production of oncomice to study cancer development and improve cancer treatment, and 53.7 % approved of the production of transgenic ewes as

synthesisers of human proteins for pharmaceutical use. Industrial applications (i.e. in the food industry) were rejected, with 82.6 % of students disagreeing with the production of giant transgenic sumosalmon fish, and 71.1% disagreeing with the production of transgenic cows to obtain higher quality milk for dairy processing. 80% of students thought that animal transgenesis applications of this type would mostly be of interest to the research community, followed by the dairy industry (56.6%).

Regarding veterinary applications, opinions formed a curve determined by the candidate species. 56.6 % of students approved of the production of transgenic cattle for their resistance to certain diseases, 54.9 % approved of the same for pigs and 47.9 % for fish.

However, 61.8 % of students disagreed with the production of transgenic cows to obtain humanised milk. 70.5 % would not give milk of this type to babies. But while only 21.9 % thought that producing humanised milk would be of benefit in industrialised countries, 56.6 % felt that it would benefit developing countries where malnutrition and high infant mortality rates are prevalent. But 76.3 % thought that in any case, developing countries would not have the means to apply animal transgenesis techniques.

The logic behind the wholesale rejection (by 82.6 % of students) of giant transgenic fish is identical. 91.1 % would refuse to eat such fish, and 75.7 % think that African countries would not have the means to breed them.

Why do students agree or disagree with current research aiming to obtain giant transgenic fish for fish farms ?

Whether they agreed or disagreed, students gave several arguments to support their view. The 143 students who disagreed with the production of giant transgenic argued that such fish are of no use, that nobody knows what the consequences may be, that local fishermen will lose their jobs, that tampering with nature always carries risks, that new diseases such as BSE may appear, that it would disrupt the balance of the environment, that it would be illegal. They also mention the weight of consumer opinion, secondary effects, public health, biodiversity decline, overproduction and the disruption of ecosystems. Arguments call on ethical, health, economic, political and especially ecological considerations. One student clearly has "Jaws" in mind : *"They would be too big to control and might attack people"*. The 25 students who were in favour of producing giant transgenic fish argued that there would be no risk to the environment *"as long as the fish are farmed in an enclosed space, no harm would be done to the trophic chain"*, that it would benefit countries with food security problems, increase yields, *"reduce the spread of disease"*, and that we could *"create new breeds"*. The handful of students with ambivalent opinions were specific in their view that it would be acceptable for poor countries, *but not*

rich countries, or acceptable for poor countries *but may* cause new diseases to appear, or that it would be of economic value *but* would fly in the face of nature.

Significant dependence

There were many instances of significant dependence between the different variables. Students' attitudes and opinions on animal cloning and animal transgenesis are highly correlated. Of particular note is the highly significant dependence between students' anxieties with regard to animal cloning, their willingness to join a protest movement if cloned calves were to be bred in France and their opinion on various applications of animal transgenesis. The more anxiety they feel about animal cloning and the more likely they are to protest, the more strongly they reject animal transgenesis.

Conclusion

The intensive media coverage of the birth of Dolly has stimulated the appropriation of knowledge on animal cloning among students, though without improving their understanding of the basics of biology, and without altering their opinions and attitudes. Our study had already confirmed in 1993 and 1995 that attitudes and opinions precede knowledge (Simonneaux, 95, Simonneaux & Bourdon, 97). Assessments of a design for a scientific exhibition on biotechnology in bovine reproduction showed that respondents tend to appropriate and memorise knowledge without changing their opinions (Simonneaux & Jacobi, 1997). Attitudes, as the keystone of social representations, are not easily swayed. How far can scientific popularisation and/or education influence pre-existing attitudes and opinions ? Does the former play a role in constructing the latter ? Are the hopes for public acceptance entertained by the champions of biotechnology merely utopian ? Are we simply witnessing the classic resistance of individuals to any technological innovation ?

From the standpoint of formal education, the point at issue is how to develop students' questioning ability, how to help them grasp the complexities involved in making decisions on issues which are likely to produce social repercussions (economic, ethical, ecological, etc.). Analysing students' conceptions helps to highlight obstacles to acculturation. The "obstacle" notion brings a dynamic aspect to educational practice in the sense that it presupposes action of some kind, and raises the question as to how to deal with such obstacles.

For those interested in the "obstacle" notion in educational terms, it will be apparent that approaches may be developed at two different levels : scientific and technical knowledge, and opinions. Regarding the former, our observations are substantially similar to those put forward by science educationalists concerning concepts in biology, physics or chemistry, the only difference being that there should perhaps be more emphasis on the incompleteness of biotechnical knowledge and on the stakes involved in scientific and technical research. Opinions, however, raise quite different questions in terms of education, since the obstacle in this case is emotional. This does not under any circumstances mean that

emotions should be suppressed, but rather that students should be helped to identify their own emotional standpoint, the arguments used by scientists, popularisers, teachers, other students and by themselves, the validity of these arguments, the different stages in decision-making, and so on.

The aim is to help students to identify the criteria and information which support a point of view, theirs as well as those held by others, so that they can problematise the issue. The most effective means to meet this objective is discussion (in the generic sense), which seems to represent an appropriate form of devolution. The rules of the game are established and explained, and the objective of the discussion is made clear : this may be to define an issue, to reach a decision on well-argued grounds, to identify areas of uncertainty or to define the condition or conditions under which a change of view may be considered. This sort of situation, in which knowledge is problematised, brings out various facets of problem-solving situations : as well as enacting the different stages in problem finding and problem solving, students 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. The aftermath of a discussion, whatever the form it takes (debate, role play, game, etc.) is essential to the process : this is the stage which, as the different steps in an argument are highlighted *a posteriori*, helps students to achieve greater distance in relation to the topic - or, in other words, to adopt a metacognitive and "meta-emotional" approach.

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TEACHING AND LEARNING

THE TEACHING AND LEARNING OF EVOLUTION AT THE PRIMARY LEVEL

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Abstract

This paper presents a study of the teaching and learning of evolution as a part of the subject Nature/Technology. Both qualitative and quantitative methods were used. Results from two classes at the primary level (age 11-12 years) are presented and discussed. Before the topic work many children had formed ideas about the origin of life and about evolution. These ideas were identified and categorized, and the teachers used them to inform their teaching. Consequently it was possible to enhance individual students' understanding of evolution. Working with the key concepts of evolution led to a conceptual change. This focus was important for the development of student understanding to a level, at which they could transfer their ideas from one learning situation in school to another. However, it was necessary to use a template to guide student's thinking to ensure that they understood the connection between three key concepts of the theory of evolution.

Introduction

Curriculum demands: According to the curriculum statements (1994) the main features of evolution should be taught in the Danish primary school as part of a new integrated science subject, Nature/Technology, in grades 1 to 6 (age 7-12 years) with a special emphasis in grades 5 and 6. By tradition, evolution was not taught until the secondary level in Denmark (as it was also not taught in many other countries). Consequently, the teachers may lack experience in dealing with the processes of evolution at primary level.

Review of research: Studies of student's ideas about evolution were reviewed by Wood-Robinson (1994). Many students are aware of evolution as a phenomenon, but they have difficulties in understanding the concept of 'adaptation'. This should not be a surprise, since the same word is used in biology to describe changes at both the individual and population levels (Wood-Robinson 1994). Some students explain the process of evolution in Lamarckian terms or they use 'teleological' reasoning. Swedish students in Grade 7 used teleological explanations of evolution, and they still used the same kind of explanations in Grade 9 (Pedersen 1994).

A Danish interview study of 38 students aged 11-15 years (Olesen 1988) was of special interest to our project. Olesen grouped the student interviews into 'no theories', 'weak theories' and 'firm theories about evolution' and looked at their distribution related to age. He found an interesting pattern. The number of children with 'firm theories' showed a peak at the age of 12, a minimum at 14 and another peak at the age of 15. Olesen interpreted the first peak as 'personal theories', theories with strong personal explanatory power, but quite different from accepted scientific theories. The firm theories held at the age of 15 years were similar to the scientific theories but not necessarily of high value or explanatory power to the owner. From this Olesen assumed, that students need to have scientific theories presented in a way they find useful.

The number of classroom studies on teaching and learning of evolution is few. A study (involving students aged 14 years) focusing on the confusion of the Darwinian and the Lamarckian view, was reported (Jiménez-Aleixandre 1992). The results indicate that both discussion of students' ideas and explicit comparison with school science are needed to assist students in accepting new ideas. Hedegaard (1988) reported that students aged 10-11 years can get an overview of important concepts from evolutionary biology. A concept model was used as a tool to develop this overview, a so called 'germ cell model'.

In summary, studies have indicated that many students have formed their own ideas about evolution and, that they especially have difficulties in understanding inheritance and adaptation. Contrarily, the students at the primary level may be able to understand the basic Darwinian ideas, if they have relevant learning experiences.

Design of the study

Working hypotheses: The study reported here addressed three hypotheses:

- I. Many children have formed ideas of the origin and evolution of life at a rather young age. These ideas can be identified and categorized by teachers and can then inform their teaching in such a way, that it will be possible to enhance learning for the individual student and to determine whether working with the key concepts of evolution can lead to conceptual change.
- II. Focusing on key concepts is of importance for understanding and for transfer from one learning situation in school to another, as well as for transfer from school to everyday life.
- III. Differentiated teaching is essential to enhance learning for all pupils in a class, and a variety of learning activities may be needed to promote conceptual change.

Methodology: In the selection of a methodology we wanted to pay due regard to the democratic intentions of the Danish Act of Education (1993) which requires that: At each form level and in each subject, the teacher and the pupil shall cooperate continuously in determining the objectives. The work of the pupil shall be organised with due consideration of these objectives. The establishment of

working methods and the selection of subject-matter shall as far as possible take place in co-operation between teachers and pupils (§ 18.4). Accordingly, this study was designed as a case study combined with the elements of democratic action research (Henriksen et al. 1990). This means that during the project the researchers had three main functions as: dialogue partners, consultants and analysts.

Participants in the project: The authors of this paper co-operated with five teachers that taught four classes, two 5th grade and two 6th grade classes. The researchers invited experienced teachers to participate on the following conditions: They taught Nature/Technology in Grade 5 or Grade 6; they saw the teaching of evolution at primary level as a great challenge; they were interested in collaborating with researchers and other teachers and, their participation was permitted by their head of school.

Pilot study and planning: During half of a school year the participants met once a month to discuss the possibilities and obstacles of working with evolution in the primary school, and to share theory, results from former research, learning theories, ideas and experiences. These discussions included how to probe the children's ideas and learning. The group decided to try out different methods in classes, which were not involved in the study itself. Since the teachers did not use a textbook, they were inspired by the discussions to form their own topic work and to build their own frames of reference as to theory, resources, media and activities. Individually they made preliminary plans for their teaching. The answers from the pilot study were used to identify possible conceptual obstacles in the teaching and learning process and to inform the planning of the topic work. At the meetings the researchers had all three functions mentioned above. Since it was impossible for the researchers to observe the topic work in all four classes, a joint decision was made to have the teachers and students keep diaries during the topic work to document their activities and ideas.

The teaching period: Each teacher was responsible for the teaching of evolution as part of her/his ordinary teaching during the school year. The teachers adjusted their teaching in response to the pupils' ideas and work. Consequently, the selected learning activities varied. They studied a variety of examples, Danish as well as distant. They went on excursions in their neighbourhood, to the Aquarium etc. The duration of the teaching period also varied from 25 to 55 lessons spread over two to four months. This does not imply that they dealt with evolution in every lesson. The teachers integrated other learning areas into the topic work, e.g. relevant geographical and physical aspects, fables and information searches of the Internet. All classes used the video: 'The theory of evolution illustrated by animals on the Galapagos islands' (Hesselholdt 1998).

During the teaching period, all participants met to discuss ideas as well as problems. The two researchers visited all four classes to get a personal impression of their activities. Although for only a couple of days, these visits were important

as a basis for discussions with the teachers as well as for the later interpretation of the data collected.

Data collection: Materials produced by teachers and students during the topic work were collected by the researchers for analyses. The collected materials included: An identical writing and drawing assignment that all students did at the beginning (pre test) and at the end of the topic work (post test I); a guiding template as 'post test II' (see Figure 7); the diaries that all teachers and all students kept during the topic work. Both qualitative and quantitative methods were used in the analyses.

Follow up: All participants met to compare and discuss their experiences. Report writing by the researchers included categorizing ideas and learning activities, theoretical analysis and reflection. It was a joint decision by the participants, that the reports should not include detailed descriptions of the topic work. Only descriptions of activities of general interest should be included in the reports. This decision follow the democratic intentions mentioned above. The final report in Danish is intended to be an inspiration to other teachers as well as teacher educators in their planning of teaching evolution. The report writing is in progress.

The topic work on evolution

Possible teaching content: Modern evolutionary theory is so complex that teaching and learning it at the primary level must focus on a few concepts with good explanatory power. In designing the project we based our ambition on previous research, especially the Danish study (Olesen 1988). Our ambition was to help students change their understanding from one level to another more scientifically accepted one. Related to working Hypothesis I, we focused on four possible levels for explaining change and adaptation (Figure 1).

- Level 0:** The student has no idea that organisms have changed over time nor about adaptation.
- Level 1:** The student explains change and adaptation as a result of a purposeful change or as a response to environmental needs (teleological or Lamarckian explanations).
- Level 2:** The student explains adaptation as a result of natural selection (Darwinian explanation).
- Level 3:** The student explains adaptation as a result of natural selection and mutation etc. (Neo-Darwinian explanation).

Figure 1. Initial hypothesis about students' levels of understanding.

Our expectation was that the students would be able to use a Level 2 explanation. However, to us two questions were not sufficiently answered by earlier research:

Would it be possible for students to use explanations at Level 2 in an acceptable way without an understanding of inheritance and genetics?

Darwin did not use modern genetics when he constructed his theory. So, it may be more important for pupils learning to merely be aware that Level 2 implies an understanding of the conditions for life, the interaction between organisms in their ecosystems, and the interaction between organisms and their environment.

Would it be possible to demonstrate 'natural selection' in a short time span?

Recent studies of Galapagos finches by the Grants (Weiner 1995) and other studies, have elucidated processes of adaptation and evolution over a short span of time. That inspired us to look for different ways in which to demonstrate the meaning of natural selection.

Results from the pilot study: The trial test questions in the pilot study provided a great variety of ideas, which made it clear to the teachers, that they should prepare responses to individual answers in their own class. Many students showed an interest in the history of the earth and important events, e.g. the extinction of dinosaurs and, they had difficulties in conceptualising the span of time from the beginning of life until today. Thus the pilot study led the teachers to extend their frame of reference, when they planned their topic work.

Content reflections and student responses caused a discussion of relevant concepts, e.g. vital necessities, habitat, mode of life, species, population. The difficulties with the use of the word 'adaptation' (in it's Danish equivalent) were also discussed. The group decided to focus on animals, although we were aware that plants should be included in the teaching of evolution.

Based on the pilot study we selected one of the methods useful in studying pupils' ideas: The students should all answer the same question by writing and drawing at the beginning and, in a slightly modified form, at the end of the topic work. The question was: *Why is it that there are so many different kinds of animals on the earth?*

Categorization of students' responses and results

Up to now we have analysed the data collected in two of the participating classes, one 5th grade (14 students) and one 6th grade(23 students).

When we started to analyse students' responses to the question: *Why is it that there are so many different kinds of animals on earth?* and their responses to the template, designed to guide the students in explaining *how a new species might come into existence* (see Figure 7), we discovered, that our hypothetical levels of understanding (Figure 1) could not explain the full variety and complexity of the students' ideas. It became necessary to discriminate between six main categories (Figure 2), two main types of descriptions and four main types of explanations, each including a number of sub-categories. The complete list of sub-categories is shown in Appendix 1.

1. Descriptions, non-chronological and without developmental ideas
2. Descriptions - chronological and with developmental ideas
3. Explanations for the start of 'life' or a special creator
4. Explanations through usefulness or activity
5. Explanations of evolution by one or more isolated aspects
6. Explanations by combining multiple aspects of evolution

Figure 2. The six main categories of students' thinking.

The distribution of students' ideas are illustrated by the concept map in Figure 3. The numbers of responses belonging to each category are shown for the two classes. The answers to the question: *Why is it that there are so many different kinds of animals on earth?* are shown as 'PRE' and 'POST I'. The answers to the template guide are shown as 'POST II'.

The response of one student to each test may be composed of a descriptive and an explanatory part and belong in one or more sub-categories. The numbers of responses belonging to each category (in the boxes in Figure 3), give a sum of registered ideas in the category. This means that the numbers are not equivalent to the number of students. Some answers were consistent, while others were composed of meanings, that were not consistent from a logical or theoretical point of view.

Our results confirm Hypothesis I. Most of the answers reflected an idea about changes, more or less evolutionary. Only few students' responses in the PRE-test belonged to category 1. The students either described changes and events (cat. 2) or they explained by 'a start' or 'a creator' (cat. 3). Answers in category 3 reflect personal theories about the origin of life. Very few students used teleological or Lamarckian ideas (cat. 4) in their essays .

The students' responses to the same question after the topic work (POST I) indicate a conceptual change. Fewer answers belong to category 1 and 3, and more answers belong to category 2 and 5. Answers in category 5 indicate an understanding of the key concepts of evolution, but the students used only isolated aspects in their explanations.

The results from POST II, in which the guiding template (Figure 7) was used, show a quite different pattern. All answers belong to category 5 or 6. Most of the students were able to combine multiple aspects of evolution in a scientifically acceptable way (cat. 6). This test was not administered previous to the topic work, therefore we don't know, how the students would have responded at that time. (However, we asked another 5th grade to do the same test. It proved too difficult for the students to give an answer without extended instruction.)

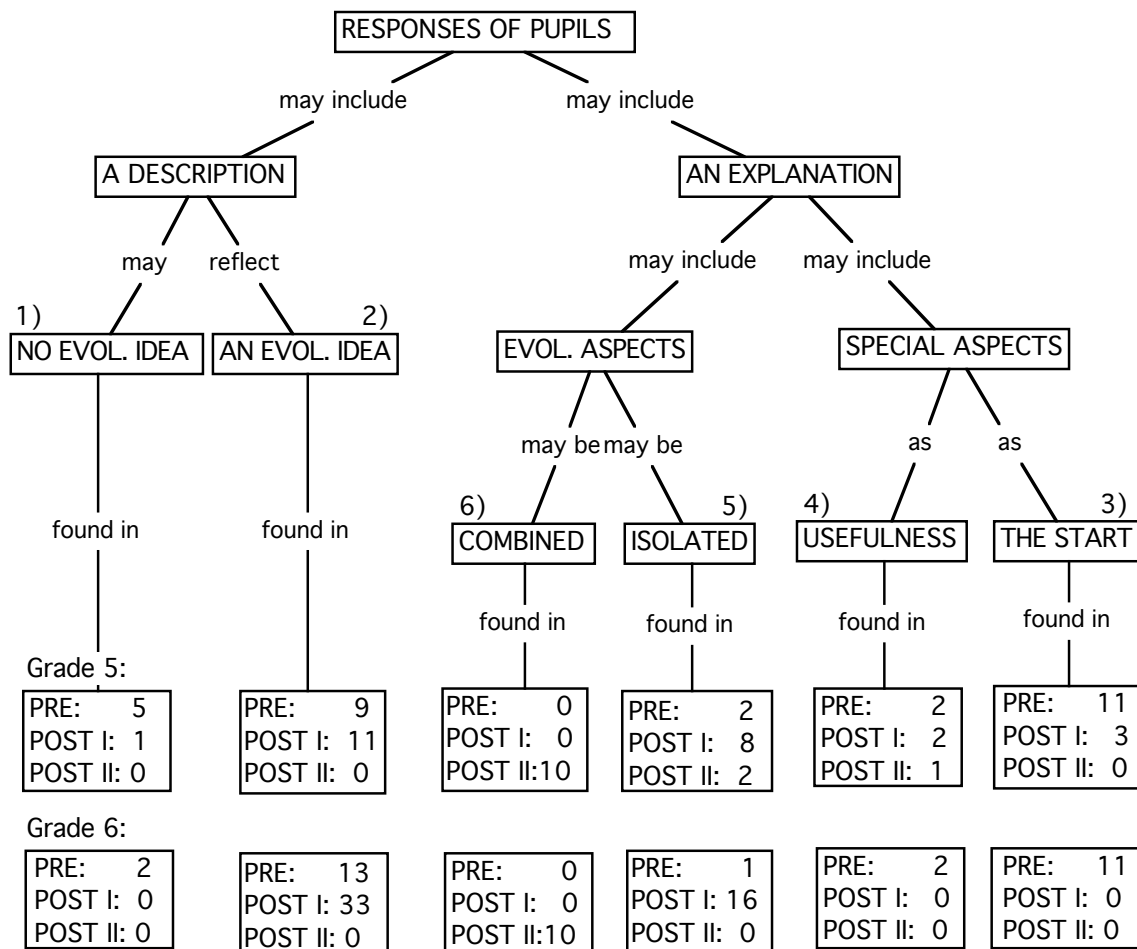


Figure 3. Students' responses shown in a concept map with the number of answers in each category 1-6. Grade 5 in the upper row of boxes, grade six below.

Discussion

Patterns of children's learning

Further analysis of the student answers shows that the children are thinking about three different aspects relevant to their understanding of evolution: the origin of life, sequential appearance of organisms and, processes leading to new organisms. Accordingly, the *patterns of learning* evolution are that individual students change their ideas:

- from category 3 to sub-category 2.1.
- from category 1 to category 2,
- from category 3 or 4 to category 5 or 6 (see Figure 3 and Appendix 1).

In this paper we are presenting the results at a class level. Our analysis tells us that, in both classes, very few students did not change their ideas. However, individual differences in changes are not dealt with in this paper.

The first pattern was:

Personal, scientifically not accepted, ideas (from religion, science fiction and fables) about the origin of life (cat. 3) migrate to the development of an inanimate nature seen as establishing vital living conditions (sub-cat. 2.1).

	Grade 5		Grade 6	
	Category 3	Category 2.1	Category3	Category 2.1
PRE	11	1	11	3
POSTI	3	1	0	14
POST II	0	0	0	0

Figure 4. Results indicating the first pattern of learning evolution.

At the start of the project the children in Grades 5 and 6 expressed many different ideas of a non-scientific nature (Figure 4, cat. 3). At the end of the project these ideas had almost disappeared. In Grade 6 the children instead expressed many scientifically acceptable ideas (cat. 2.1), which reflect that the physical development of the earth led to the establishment of vital conditions for the origin of life.

Ann Zetterquist (1998) studied teachers' views on their teaching of evolution in Sweden and suggested that we 'give evolution its deserved place - to be the connecting thought in the biology courses'. But she does not tell how this is done. We suggest that it is essential to discuss: What are the fundamental conditions of a 'good' life for various organisms? A Danish research group presented a list of biological generalisations, some about conditions for life, and suggested that they should be a focus in biology teaching in the first five grades at the primary level (Andersen, etal. 1984). We think that by focusing on conditions for life, the morphology and behaviour of animals could be understood as the 'tools' to fulfil their needs. Then adaptation and natural selection could be presented as a logical extension of what students have previously studied. A comparison of the pre and post answers shows, that many of the students, at the end of the project, could see the importance of, for example, water for the beginning of life. We did not test that knowledge explicitly before the start of the project. So we don't know if the students had this important foundation before the topic work or if this understanding was learned during the project.

The second pattern that was found in the answers of the students was:

Descriptions of a number of animals without an idea of evolution (cat. 1) migrate to series of animals with less (cat.2.2) or more articulated phylogenetic links (cat. 2.3).

	Grade 5			Grade 6		
	Cat. 1	Cat. 2.2	Cat. 2.3	Cat. 1	Cat. 2.2	Cat. 2.3
PRE	5	6	2	2	6	4
POST I	1	4	6	0	6	13
POSTII	0	0	0	0	0	0

Figure 5. Results indicating the second pattern of learning evolution.

In the pre test only a few students expressed the idea, that no change had taken place (Figure 5, cat. 1). In the post test only one response in this category was found. Instead, the children described *a developmental series/* named the first organisms/ mentioned that some kinds of animals (e.g. dinosaurs) do not exist anymore (cat. 2.3). Some of the children mentioned the similarities and differences between chimpanzees and human beings. Our analysis shows, that many of the children were able to articulate their knowledge of details in the development from 'primitive' organisms to mammals. The students' difficulties in imagining the enormous span of time from when life first began to their time had not disappeared, although the teachers tried out many analogies to illustrate the span of time on a smaller scale.

The third pattern that could be seen in the answers of the children was:

Less accepted non-scientific explanations of how evolution works (cat. 3 or 4) migrate to either simple (cat. 5) or detailed scientifically acceptable explanations (cat. 6).

	Grade 5				Grade 6			
	Cat. 3	Cat. 4	Cat. 5	Cat.6	Cat. 3	Cat.4	Cat. 5	Cat.6
PRE	11	2	2	0	11	2	1	0
POST I	3	2	8	0	0	0	16	0
POST II	0	1	2	10	0	0	0	10

Figure 6. Results indicating the third pattern of learning evolution.

This pattern was what the researchers focused on from the start of the project. The results, shown in Figure 6, indicate that only 2 and 1 responses (cat. 5) expressed isolated aspects of evolution in the pre test. In contrast 8 and 16 responses expressed this kind of understanding in POST I. Category 6 responses were only found in POST II - in the answers to the guiding template discussed below.

Aspects of working with key concepts

We saw the problem of understanding the theory of evolution as an example of conceptual learning. The second working hypothesis states that focusing on key concepts is important. Why is conceptual thinking so important? The abstract nature of a concept makes it possible to combine diverse examples, including examples in new situations, i.e. concepts make transfer possible!

The theory of evolution can be seen as a complex network of concepts that form a coherent structure. The widespread use of Darwin's theory in biology attests the theory's inherent possibilities of transfer, but the abstract nature of its concepts also makes it difficult to learn and to understand them. To make it easier to learn the concepts, they may be illustrated by a variety of examples.

Although an example is more concrete than the concept, each example that is used to illustrate a concept, can be represented at different levels of abstraction as suggested by Bruner et al. (1966). The concept 'variation' could be introduced at a *symbolic level* (e.g. words telling about how only the ground finches with the strongest beaks survived on the Island of Daphne), at an *iconic level* (e.g. a film showing the finch trying to eat a seed with a thick shell) and at an *enactive level* (e.g. the children are trying to crack something).

Each learning activity has to present examples, which help the students to understand one or more of the key concepts, i.e. part of the theory. The understanding of the whole theory demands an understanding of the connection between the key concepts. Therefore each activity in some way or another has to be related to the structure of the whole theory. Each activity often takes more than one lesson. The risk is, that the students have difficulty understanding the connections between the concepts of the theory. How can the teachers help the students to connect the different concepts into a theory? In the project we discussed three methods:

One way to keep the elements related to the whole was attempted in our project by showing the students a film: 'The theory of evolution illustrated by animals on the Galapagos islands' (Hesselholdt 1998). In this film, animals from the islands give examples of the three fundamental concepts: adaptation and natural selection (marine iguana and the flightless cormorant) variation in characters (the shield of the giant tortoise and the beaks of Darwin's finches) and the preservation of the selected characters (the ritualised behaviour of the frigate bird, the blue footed booby and the albatross).

A new species of..... comes into existence.
Where it lives:
The animals which survive:
The animals which die or move to another place to live:
The new characteristics does not disappear as long as:

Figure 7. The text from the guiding template used to help a student to structure what she/he understands of the relations between the concepts of evolutionary theory. (The original template had extended space for drawing and writing.)

Another way to help the student to keep the connection is to present the key concepts of the theory of evolution on one piece of paper. Such an overview may be both concrete and abstract. A concept map is often a structure of concept words, but it could also be iconic, e. g. drawings of animals. This leads us to another aspect of learning. Following a constructivistic view the teacher could be misled to think, that the children themselves should create a concept map showing relations between the concepts of the theory. After our experience it is too difficult for many children at the primary level. These students must be offered a guiding template mirroring the theory, so they can fill in different drawings and comments at the correct place in a sequence.

The assessment at the end of the project (POST II) used such a guiding template (Figure 7). It was amazing to see that the children, who showed only a fragmented understanding of evolution in their essays, could fill in the template using an animal of their own choice and, demonstrate a coherent understanding of the basics of the theory of evolution.

A third way to keep the elements related to the whole is by using questions to guide the learning process. This is closely related to the motivation for learning. If the teacher can engage the children in asking and answering questions, their learning is then led by curiosity. Our analysis of the teaching process as documented in the diary of the teachers, will possibly elucidate how this intention functioned in practice.

Concluding remarks

Our results document, that students at the primary level may obtain a basic understanding of the dynamics of evolution and use that understanding on new examples - that is, if different levels of representation are used in both the learning activities and the assessment forms.

The two classes included in this analysis were different and, they were taught differently according to the students' prior learning experiences and understanding. What they had in common was, that the teachers involved the students in most stages of the topic work as demanded in the Danish Act of Education. The students had opportunities to choose individual areas to study. The teachers tried to interact with the individual child and used a variety of learning activities at different levels of abstraction to promote thinking. Our future analysis of teachers' and students' diaries may illustrate the practice of differentiated teaching.

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APPENDIX 1

Categorization of students' thinking of evolution based on the question: *Why is it that there are so many different kinds of animals on earth?* and on the guiding template.

0 The response could not be categorised.

1. DESCRIPTIONS, NON-CHRONOLOGICAL/ WITHOUT DEVELOPMENTAL IDEAS

- 1.1. States that the many different organisms e.g. animals which are living now, have always been there.
- 1.2. Names some organisms arranged in anon-chronological way/no developmental idea.
- 1.3. Describes some characters of an animal perhaps using the word 'adaptation'/ The characteristics of animals are fitting their environment.
- 1.4. Describes the distributions of animals in nature perhaps using the word 'adaptation'/ If the habitat changes new animals move in.

2. DESCRIPTIONS - CHRONOLOGICAL, WITH DEVELOPMENTAL IDEAS.

- 2.1. Describes the start of inanimate nature (e.g. the big bang)/ changes (e.g. continental drift) - as conditions for the start of life, e.g. water, sun and oxygen.
- 2.2. Names some animals arranged in a chronological way/with developmental idea/names the first organisms, i.e. the start of life.
- 2.3. Describes a developmental series/ names the first organisms, i.e. the start of life/ mentions that some kinds of animals (e.g. dinosaurs) do not exist anymore.

3. EXPLANATIONS FOR THE START OF 'LIFE'/ A SPECIAL CREATOR.

- 3.1. Hocus-pocus/ It just happened (naturalistic)/ The water created the animals.
- 3.2. They came from the sky.
- 3.3. God's creation/ Adam and Eve.
- 3.4. Fairy tale/ Fable/ A poetical explanation of the characters of animals.
- 3.5. Aliens have brought the animals to the earth/Strange creatures came from space (science fiction).
- 3.6. Eggs in a nest are hatched/plants became animals. Reproduction or multiplication.

4. EXPLANATIONS THROUGH USEFULNESS/ACTIVITY (teleological)

- 4.1. The variety of animals arose because they were useful for human beings/ and vice versa.
- 4.2. The variety of animals arose because they were useful for the needs of other animals.
- 4.3. Animals change/develop their characteristics, when they need them.
- 4.4. The activity of an animal leads to the development of new characteristics (e.g. animals living in the water got legs, when they moved from water to the dry land. If animals eat plants they become plant eaters).

5. EXPLAIN EVOLUTION THROUGH ONE OR MORE ISOLATED ASPECTS OF EVOLUTION

- 5.1. Reproduction: The animals are reproducing, consequently there will be different kinds of animals.
- 5.2. 'Mixing': Mating between different kinds of animals leads to a new kind of animal.
- 5.3. Adaptation: The characters of animals changes if the habitat/conditions makes it necessary.
- 5.4. Selection: Some animals are coping better than other animals under specified conditions / in a certain habitat / Use the concept of natural selection of the fittest.
- 5.5. Mating between animals with 'the right' (beneficial)characters within the same species (hints at variation in a population).

6. EXPLANATIONS BY COMBINING MULTIPLE ASPECTS OF EVOLUTION

- 6.1 The living conditions of animals lead to a selection of animals with beneficial, relevant characters in a population, the fitting characters are preserved through mating with animals with the same characters i.e. animals can attain a better adaptation if the living condition are rather constant.
- 6.2 The living conditions of animals lead to a selection of animals with beneficial, relevant characters in a population, the fitting characters are preserved through mating with animals with the same characters i.e. animals can attain a better adaptation if the living conditions are rather constant.) Because the offspring of the animals are different, the process of adaptation will take a long time.

***MEANINGFUL LEARNING OF THE THEORY OF
EVOLUTION IN HIGH SCHOOL IN ISRAEL USING
A 'COLLECTION' OF READING MATERIALS***

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Abstract

The development and implementation of a curriculum for the study of evolution was investigated in Israeli high schools. The curriculum was designated to influence conceptual change in high school students. Teachers were invited to teach evolution, using a unique resource – 'Asufa' (in Hebrew collection), a collection of works from books and journals. The teachers were offered guidelines aimed at helping students learn the principles of evolution, meaningfully. The achievements of the experimental group were higher than those of the comparison groups.

Introduction

'Nothing in biology makes sense except in the light of Evolution' stated Dobzansky in 1973. Many scientists agree that the theory of evolution provides a framework, which can adequately represent the uniqueness and coherence of the life science (Nickels et al. 1996, AAAS 1989, Keown 1988, Rutherford & Ahlgren 1990). What is the place of this unifying theory in the Israeli biology curriculum?

Previous to the study we examined the situation from some perspectives: student's concepts and beliefs, achievements in the 'Bagrut' (matriculation examination), existing conventional learning books, and teachers' attitude and perception of the subject.

In Israel, all academic students study biology in grade 10, since up to this grade level all students follow the same school subjects. In grades 11 and 12 only certain subjects are compulsory, while others, such as science are elected subjects. Elective subject courses are designed in two levels. Although a common syllabus guides the biology curriculum and instruction of evolution regardless of grade level and course taken, teachers are expected to adjust their particular course to the prior knowledge and general nature of their students.

According to our findings, since 1991, the Israeli elective curriculum (teachers have to choose 6 out of 9 basic subjects) in biology makes it possible for teachers

who find the evolution subject difficult not to choose it – only 25% of the students choose to refer to the subject in the matriculation examinations designated as the Bagrut. Teachers who 'dare' to teach evolution find that students' achievements in the matriculation examination in evolution during the last 7 years were poor compared to achievements in other subjects! It seems that the topic of evolution, which is usually taught as the last subject in Israel high school, is considered to be interesting by the students but difficult to teach and learn by their teachers. Keown (1988) summarized this situation by writing 'Evolution is the unifying concept, the commonality that ties all of earth's life together. This beautiful umbrella concept *is too often not carried* from the biology class by secondary students. It is important for them to see evolution as the process linking past life to contemporary life and most important, to see how evolution explains our own condition'.

What are the possible explanations to the fact that teachers (and students) in Israel do not tend to choose this elective subject?

The teaching of Evolution poses two dilemmas: one concerning pedagogy (Tamir 1993, Bishop & Anderson 1990) and the other concerning teachers' and/or students' personal beliefs which may create a conflict with the scientific concepts (Eglin 1983, NAS 1984, Lawson & Worsnop 1992). It is well documented that misconceptions and personal beliefs might interfere with subsequent learning and are difficult to change (Deadman & Kelly 1978, Good 1992, Ausubel et al 1978, Demastes et al 1995a).

In our pre-evaluation in Israel we found that:

- Students have problem with the semantic meaning and translation in the Hebrew language of some concepts' such as variation, fitness, species.
- Students have difficulties in understanding basic concepts such as adaptation, analogy, homology, and species (Brumby 1979, Brumby 1984, Clough & Wood-Robinson 1984, 1985 Hallden 1988, Jungwirth 1975, Lucas 1971, Settlage 1994).
- Students use teleological explanations in order to interpret evolutionary phenomena and biology facts (Jungwirth 1977, Bartov 1978, Tamir & Zohar 1991).
- Students use anthropomorphic explanation by relating to various organisms, criteria and processes characterizing human behaviour (Jungwirth 1977, Zohar & Ginossar 1998).
- Students offer Lamarckian views and conceive adaptation as an active process – organs develop according to necessity by being used, or not used (Lord & Mario 1993, Bizzo 1994, Sinclair & Pendaruis 1997).
- Students have difficulty in identifying the phylogenetic connection between species- lack of appropriate learning opportunity can be implicated as one of the sources of it (Cummins et al. 1994)
- Teachers are not aware of students' alternative concepts (Jungwirth 1975a, Zuzovsky 1994, Anderson 1984, Tatina 1989).

- Textbooks use teleological and anthropomorphic explanations (Jungwirth 1975).
- Textbooks and teachers do not encourage the linking of studied concept to prior knowledge (Aleixandre, M. J. 1994, Gunstone et al., 1998).

The conclusions of our findings concerning the curriculum and the existing learning materials in evolution created a need for new learning materials and opportunities.

The development process of the reading materials

A survey of the main existing articles about evolution published in Hebrew in the years 1980 – 1995 was carried out by researchers in the Hebrew University. It was found that there are various materials available to choose from, suitable for the developing of instructional materials for teaching and learning evolution in high school. The materials were sorted out and organized in 7 proper chapters according to their content and level of difficulty. The new book got the name 'Evolution – Asufa' (Asufa means to assemble in Hebrew). Questions and activities were designed to enhance meaningful learning and reading.

We find that the 'Asufa' is characterized by its potential to:

- Demonstrate to the students the dynamic nature of scientific knowledge
- Demonstrate the importance of articles as a source of scientific knowledge
- Offers activities aimed to help students learn the principles of evolution, meaningfully.
- Demonstrates different methods of presenting and summarizing scientific materials.
- Offer a variety of articles and activities, which present numerous possibilities to match materials to learner's level (for the lower and the higher levels), and to personal interest.

Being aware of the dynamic nature of scientific knowledge an Internet site was developed (<http://www6.snunit.k112.il/science/biology>). This site gives us the opportunity to update publications in the scientific literature, new materials and useful suggestion are being offered on a regular basis in this site. The site enables teachers and students to read new works in evolution and other biology subjects.

In this article we report the implementation, and classroom evaluation of the evolution program based on the reading materials and the activities in the 'Asufa'. The program was aimed at conceptual change, for high school students in Israel. It represents a special attitude toward teaching the subject. The activities developed for it are based on recommendations intended to enhance meaningful learning and reading e.g.: concept mapping, V mapping based on Novak & Gowin (1984) recommendations. To try and overcome the difficulties, teachers were invited to teach evolution, using the 'Asufa' accompanied with the investigators' personal guidance.

The focus of treatment offered by us was the cognitive structure of the students, its content and organization and the many ways it is influenced by learning. It was

based on the theories of learning and reading such as Ausubel (1968) and Gowin (1981), and on constructivist view of science such as Glasersfeld, E. von (1989, 1995) and Driver & Bell (1986). In this study we invited the teachers to implement instructional approach based on the CCM (conceptual change model offered by Posner, et al. 1982), class and group discussion (Schwab 1963, Sharan & Sharan 1992, Scharmann, 1994), in order to enhance students' involvement in the learning process. Teachers were also offered strategies emphasizing the unique contribution of evolution as a high-level advance organizer to the study of biology.

Research objectives

This study belongs to the line of studies that are aimed to investigate high school students' conceptions about evolution (Demastes et al 1996, Jensen & Finley 1995, 1996). It offers a new, different pedagogical approach to its place in the curriculum sequence and adds new dimensions by investigating the cognitive change high school students (specializing and not specializing in biology) undergo while learning Evolution.

The objectives of the research were:

To examine and compare the influence of the new program combined with teachers' guidance, on the achievement of the students, to the influence of other treatments on:

- Acquiring the Darwinian concept of evolution
- Replacing misconceptions to scientific explanations
- The ability to distinguish between scientific to anthropomorphic explanations (Bartov, H. 1978).
- The ability to extract new knowledge from an unfamiliar text
- Identifying the major 7 themes in biology as identified by Schwab (1963).
-

Methods

Evaluation of the materials and their implementation was carried out on a larger scale. The sample included 225 students in 11 classrooms all over Israel, 11 high school biology teachers participated in the study.

The effectiveness of the treatment was studied by measuring the progress of the experimental group as well as comparing pretest - posttest result to 3 other groups. The experimental group was combined of three 10th classes. The students in these classes studied the new program accompanied by the investigator guidance.

The achievements of the students in the experimental groups were compared with the achievements of three comparison groups (Seven 11th grade classes and one 12th grade class):

- Students that studied evolution using the 'Asufa'- without the interference of the researcher.
- Students that studied evolution using a conventional book.

- Students who did not study evolution as a separate subject but had it integrated within various other topics – integrated study.

We used a variety of assessment instruments to obtain comprehensive diagnosis of students' difficulties and misconceptions and to follow the changes in them due to the treatment. Evaluation of the materials and their implementation was carried out employing a pretest-posttest design. Data collection included students' results based on: multiple-choice questions, justifications to some of these questions, open ended question, analyzing an unfamiliar text, and an attitude questionnaire. The posttests questionnaire included some of the questions of the pretest plus additional questions.

Data analysis was carried out with conventional statistical methods with the use of a SPSS software package, in particular frequent distribution, means, standard deviation, t – tests, and analysis of covariance was used. Effect size (Cohen, 1969) and Gain of Possible Gain Theile, (1938) were calculated.

Results and discussion

The knowledge questionnaire was composed of 25 multiple questions (15 were identical in the pre and the post) and 4 justifications.

Table 1. Mean gains in the knowledge questionnaire and effect size (E.S)

Group	Pretest knowledge		Posttest knowledge		ES to the Asufa + guidance
	X	SD	X	SD	
Asufa + guidance (N= 90)	27.8	14.2	77.7	12.0	
Asufa alone (N= 60)	53.6	22.1	74.7	16.5	0.18
Conventional text-book (N= 36)	30.4	13.9	58.9	18.3	1.07
Integrated study (N= 39)	40.0	20.4	35.3	22.6	1.97

0.2 – very small difference; 0.2 – 0.3 small difference; 0.4 – 0.6 medium difference; 0.6 - 0.7 – large difference; 0.8 - and above very large difference

The results in table 1 indicate that the knowledge and understanding of evolution before instruction was intuitive and superficial. Most of the misconceptions found in the analysis of the Bagrut answers were also found in the answers to pretest questions. These learning problems were treated in the program of the experimental group.

Posttest result showed that students who studied the new program based on the materials in the 'Asufa' accompanied by the researcher guidance, achieved better on the evolution topic than the students in the other groups. The use of the new materials brought about significant changes in students' conceptions and improved understandings in most of the topics that were dealt in it. Students in the experimental group and in the comparison classes, except the students of the integrating group (two 11th classes that study evolution as an integrative subject) have improved the knowledge and understanding following instruction. However the frequency of misconceptions in the comparison groups was higher than in the experimental group, and most of the justifications to multiple questions in the posttest of the main study, given by students who studied the new program were correct.

Open ended questions

Open ended question include: explanation of two evolutionary phenomena (development of speed in the cheetah and the disappearance of the snake's legs), analyzing unfamiliar text describing evolutionary phenomena, composing a sentence which explains the relationship and meaning of two concepts (evolution – variation, adaptation – natural selection), and identifying the major themes in biology as identified by Schwab (1963). Comparing the achievements in the open ended questions (table 2) reveals that the achievements of the experimental group were significantly and meaningfully better than the comparison groups in acquiring scientific concepts and implementing them in answering the open ended question.

Table 2. Results of open ended test questions. Effect Size (E.S) comparing the experimental group with the other groups.

Open Ended Questions	Asufa alone (N= 60)	Conventional book (N= 36)	The integrated study (N= 39)
Analyzing Unfamiliar text	0.12	0.90	1.05
Evolutionary Phenomena - cheetah	0.44	0.77	1.31
Evolutionary Phenomena - snake	0.57	0.66	0.60
Identify major themes in biology	0.80	0.66	1.25
Evolution - Variation	0.35	0.82	-
Natural selection – adaptation	0.40	0.16	1.63

0.2 - very small difference; 0.2 – 0.3 small difference; 0.4 – 0.6 medium difference, 0.6 - 0.7 large difference; 0.8 – and above very large difference.

The results in table 2 indicates that fewer of the students in the comparison groups were able to provide complete answers to the open ended problems in the posttest.

Students of the experimental group gained higher scores in all the aspects examined..

Students of the Asufa group (N= 60) and Asufa + guidance group (N= 90) responded to an attitude questionnaire at the end of the evolution course. Their responses to the questions reveals that students' attitudes toward the new learning materials were generally favourable.

Students find learning evolution as interesting and they had the feeling that they understood the subject. To their opinion, the materials in the Asufa are represented in a clear way and they recommend to prepare other biology books similar to the 'Asufa'.

Recommendations

In this research we demonstrated the unique contribution of a new kind of resource book for students, an 'Asufa', for the learning and studying of Evolution. We find that learning and teaching with the 'Asufa' can be effective in helping high school students, both biology and non biology majors, to acquire the Darwinian concept of evolution meaningfully.

We believe our findings will be beneficial to:

- Assist teachers who consider Evolution too difficult to teach and learn, to elect and teach it
- Convince teachers to use evolution as a high-level advance organizer to the study of biology
- Prove that Evolution can be successfully integrated as the first subject of the biological curriculum studied in the 10th grade.

The curriculum on Evolution which integrates biological content represented through articles with didactical mode of teaching/learning according to the CCM (implemented in small discussion groups) is a promising as a way of instruction which could encourage more teachers and students to choose this elective subject. The new materials and the didactical mode of teaching/learning were found to be effective in bringing about conceptual change. Teachers and students favourably accepted the Asufa and students who used it improved their knowledge and understanding. The Asufa can serve as a model to other books, organized similar to it, in different biology subjects.

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*FOSTERING ARGUMENTATION SKILLS
THROUGH BIO-ETHICAL DILEMMAS IN
GENETICS*

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Abstract

The unit 'The Genetic Revolution- Discussions of Moral Dilemmas' teaches argumentation skills through dilemmas in modern human genetics. The research presented here centers on assessing the effect of the instructional unit on 9th grade students. Argumentation skills were assessed by analyzing students' written work-sheets and audio-taped discussions. The results show that students in the experimental group (but not in the control group) have significantly improved their post-test scores compared to their scores in the pre-test and were able to transfer their newly acquired argumentation skills to a new context. Students in the experimental group also scored significantly higher than students in the control group in a knowledge test in genetics. A comparison of transcripts from early and late discussions show that in the late discussions, students were more careful in making claims, and took more care to make their claims explicit and to justify them compared to the early discussions. In the late discussions students also tended to talk for longer periods of time and their discourse was more complex than in the earlier ones.

Introduction

An argument is an assertion and its accompanying justification (Toulmin, 1958). Several researchers (e.g. Baron, 1991, Johnson and Blair, 1991; Kuhn, 1991, 1993; Perkins, Farady and Bushey, 1991; Means and Voss, 1996; Voss and Means, 1991) regard argumentation skills as part of informal reasoning and report studies that document difficulties in people's ability to use those skills in a sound way. Exploration of variables that affect argumentation skills showed that no significant difference in performance was found with respect to gender, and that only limited effects were found with respect to prior knowledge and intelligence. A developmental trend was found between age 8 and early adolescence with no additional improvement later on, indicating that at present schooling may be doing very little to foster children's argumentation skills. Nevertheless, arguments have a central role in science education (Kuhn, 1993). The practical implications of this view were formulated by Driver and Newton (1997) in the following way: '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' (pp. 11).

The unit 'The Genetic Revolution- Discussions of Moral Dilemmas' (GreDMoD) is part of the 'Thinking in Science Classroom' project in which learning activities designed to foster higher order thinking skills and scientific argumentation are integrated into the regular junior high school science curriculum (Zohar, Weinberger & Tamir, 1994; Zohar, 1996). In this particular unit, issues involving Science, Technology and Society (STS) are discussed by addressing moral dilemmas (i.e., a social issue) that originate in modern Genetics along with some of its recent technological innovations. The 10-12 hours unit was written for 9th grade students. The research presented here focuses on assessing the effect of the instructional unit.

Purpose

The purpose of this study is to answer the following questions:

1. What are students' initial (i.e., pre-instructional) argumentation skills in the context of bio-ethical dilemmas in genetics?
2. To what extent can instruction affect students' argumentation skills?
3. Can students who have acquired argumentation skills in one context (bio-ethical dilemmas in genetics) transfer these skills to a new context (moral dilemmas taken from everyday life)?
4. Does instruction in argumentation skills that is integrated into the teaching of biological topics affect the conceptual understanding of those topics compared to the level of understanding achieved through traditional instruction?

Methodology

A. Curriculum Design

The learning materials address moral dilemmas regarding recent developments in Genetics. The GreDMoD unit is structured around three topics:

(1) *Biological knowledge*: Some of the dilemmas were written about concepts that are taught in the regular genetics curricula (e.g., recessive and dominant traits, X-linked traits and nature versus nurture). Other dilemmas refer to concepts that are not part of the regular curricula (e.g. additional information about genetic traits and counselling, gene therapy and genetic cloning). The introductory section of such dilemmas includes a short teaching unit concerning those concepts. Each dilemma includes questions that require knowledge of genetic concepts. Therefore, students must make use of their biological knowledge when they think about the dilemmas. In addition, the value of grounding decisions upon reliable knowledge is explicitly emphasized.

(2) *Principles of bio-ethics*: A distinction is made between knowledge and values and it is emphasized that values are not determined by knowledge: although all

students share the same knowledge base, each one may make their own independent value decisions. The following issues are discussed: moral dilemmas, ethics, bio-ethics and common principles in bio-ethics.

(3) *Argumentation skills*: The program addressed the following argumentation skills: (a) the ability to offer a theory; (b) the ability to provide supporting justifications; (c) the ability to offer an alternative theory; and, (d) the ability to rebut the alternative theory. Between confronting the first and second dilemmas, one lesson was devoted to explicit instruction of argument structure, focusing on the differences between good and bad arguments (e.g., good arguments include true, reliable and multiple justifications; they also refer to alternative theories and rebut them). Then, these skills were practiced throughout the program by several means: discussions among pairs of students, group discussions, whole class discussions and individual written assignments.

B. Subjects

Subjects in this study were 9th grade students in two middle- class heterogeneous schools in Israel. Students had learned basic concepts in genetics as part of their science curricula prior to the beginning of this study.

C. Experimental Design

Subjects were divided into two groups: experimental (N=99) and control (N=87). However, the number of subjects who have answered each item may be smaller because subjects that did not answer both pre- and post- test items in a specific test were deleted from the sample. All subjects have learned some advanced concepts in genetics during this study. Students in the experimental group learned these concepts through the unit 'bio-ethical dilemmas in Genetics'. Students in the control group learned these concepts by conventional methods. Both groups studied these concepts for the same amount of time (approximately 10 lessons). Students were assessed before and after instruction by several means.

D. Instrumentation

Argumentation skills were assessed in the experimental group using a performance assessment approach, i.e. work- sheets that students completed and discussions that took place during instruction were used for assessment purposes. The same written tasks were given to the students in the control group and were presented as questionnaires.

Several instruments were used:

1. *Written work-sheets*: Students in the experimental and control groups addressed the following tasks:

A pre-test that revolved around a dilemma related to genetics.

A post- test that revolved around another, different dilemma related to genetics (post test 1)

A second post-test that was identical to the pre-test (post-test 2).

In addition, two logically-equivalent questionnaires about moral dilemmas taken from everyday life (e.g. should students report a class mate who had cheated in a

test) were assigned to students in the experimental group at the beginning and at the end of the program in order to assess transfer.

2. *Audio-taped discussions:* Two collaborative groups of students who were engaged in discussing bio-ethical dilemmas were audio-taped. The transcripts of these discussions were analyzed in order to compare (in each group) the quality of the arguments in the first discussion with their quality in the second discussion.

Genetic Knowledge was assessed by two means:

a. *One item in the pre-test* (and post test 2) addressed the extent to which students consider biological knowledge while thinking about the dilemma.

b. *A knowledge test in Genetics* The knowledge test included 20 multiple choice items. Part of the items were taken from previous years' matriculation exams (from a non accelerated, basic level biology course). Topics that are not normally covered by the matriculation exam were covered by items that were written especially for this test. Content validity of these items was checked by an expert. The knowledge test was administered to students in the experimental and control group at the end of the program as the term exam in biology.

Results

A. Results from written tests – reasoning

A1. *Students' initial reasoning abilities*

Analysis of the pre-tests show that at the initial stage of the study approximately 90% of the students were able to formulate an argument which included a conclusion and at least one justification. A similar proportion of the students were also able to formulate an alternative theory and a rebuttal and to justify them. However, students tended to back their conclusions with few justifications (see lines pertaining to number of justifications in pre-test columns of tables 1 and 2). In addition, the structure of students' arguments at that stage tended to be simple (see lines pertaining to argument structure in pre-test column of tables 1 and 2).

A2. *Assessing the effects of the GREMoD unit on reasoning abilities*

A comparison of pre- and post-tests show that while both experimental and control groups had similar scores in the pre-test, students from the experimental group scored in the post-tests significantly higher than students in the control group. Students in the experimental group (but not in the control group) improved their scores in the two post-tests (1 & 2) compared to their scores in the pre-test. Their gains were found to be statistically significant for all the categories that were explored: formulating arguments, counter arguments and rebuttals, number of justifications and argumentative structures. Gains were also found for the two categories that addressed moral reasoning: formulation of a moral dilemma and quality of moral reasoning. Mean scores and standard deviations for these tests were not calculated because the various categories differ in the number of criteria

for their analysis (i.e., their scales range between 3 and 6. This variability would have distorted the standard deviation calculated for a mean score, because the variation on a scale of 3 is smaller than the variation on a scale of 6). A detailed description of the comparison between the pre-test and post-test 1 is found in table 1. Similar differences (not shown here) were found in a comparison between the pre-test and post-test 2. It may therefore be concluded that the GREMoD unit had a positive effect on students' abilities to reason in the context of moral dilemmas presented in a biological context.

Table 1. Comparison between pre-test and post-test # 1 in the experimental group

skill	pre-test		post-test		n	t
	mean	S.D	mean	S.D		
formulating an argument	2.9	0.3	3.0	0.0	75	-2.97**
number of justifications	1.2	0.6	1.9	0.8	75	-6.42***
argument structure	1.1	0.6	1.5	0.5	75	-5.11***
formulating a counter argument	2.8	0.6	3.0	0.0	72	-3.35***
number of justifications	1.2	0.7	1.8	0.8	72	-5.31***
counter argument structure	1.0	0.6	1.3	0.5	72	-4.76***
formulating a rebuttal	2.7	0.7	2.9	0.3	67	-2.11*
number of justifications	1.2	0.6	1.7	0.8	67	
rebuttal structure	1.1	0.5	1.3	0.5	67	-2.89**
formulating a moral dilemma	2.2	0.9	2.9	1.2	74	-5.19***
level of moral reasoning	2.6	0.9	3.6	0.7	75	-9.44***

* $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$

A3. Assessment of transfer

In order to assess transfer, students in the experimental group answered two logically-equivalent questionnaires about moral dilemmas taken from everyday life. In order to confirm that the two questionnaires are of the same difficulty level, a pilot test was conducted (with a group of 30 students who did not participate in this study). The two questionnaires were randomly assigned to students in this group. No significant differences were found between the scores on the two questionnaires. Table 2 shows a comparison between scores of the experimental group students in the pre- and post- tests. The results show that students improved their scores regarding the moral dilemmas taken from everyday life in all the categories that were analyzed. It may therefore be concluded that

instruction related to moral dilemmas in biology enabled students to transfer their newly- acquired skills to a new context.

Table 2 Comparison between pre-test and post-test consisting of dilemmas taken from every day life in the experimental group

skill	pre-test		post-test		n	t
	mean	S.D	mean	S.D		
formulating an argument	2.7	0.6	2.9	0.3	73	-2.4*
number of justifications	0.9	0.5	1.4	0.8	73	-5.0***
argument structure	0.9	0.6	1.1	0.6	73	-2.8**
formulating a counter argument	2.6	0.9	3.0	0.1	73	-4.1***
number of justifications	0.9	0.6	1.7	0.8	73	-8.5***
counter argument structure	0.9	0.7	1.5	0.5	73	-5.8***
formulating a rebuttal	2.4	1.0	2.9	0.4	67	-4.2***
number of justifications	0.8	0.6	1.4	0.7	67	-7.2***
rebuttal structure	0.8	0.7	1.5	0.6	67	-7.6***
formulating a moral dilemma	1.4	0.9	2.3	1.2	73	-6.7***
level of moral reasoning	1.6	1.1	2.6	1.1	73	-6.6***

* $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$

B. Results from written tests-biological knowledge

Students in the experimental group also scored significantly higher than students in the control group in the knowledge test in genetics ($X = 72.9$, $S.D = 6.0$ and $X = 59.4$, $S.D = 4.1$ respectively, $t = 3.94$, $p < 0.001$).

C. Results from transcripts of group discussions

C1. Analysis of argumentative elements

For two groups, two discussions were audio-taped and later transcribed and analyzed. These two particular discussions were chosen for the present analysis because they addressed the only two dilemmas that students discussed in whole groups, uninterrupted by either teachers' intervention or by a written assignment. Formal instruction about principles of bio-ethics and about structure of arguments took place between dilemma #1 and dilemma # 2.

Transcripts were divided into idea units- the smallest units of speech that could be analyzed, consisting of a single idea (Pontecorvo and Girardet, 1993). Idea units were analyzed by using predominantly the classification system conceived by Pontecorvo and Girardet (i.e., claims, justifications, concessions, oppositions, counter-oppositions and qualifiers). Claims (or conclusions) and justifications

were the most frequent idea-units (ranging between 64.2% and 75.8% of all idea units in the various recorded discussions). The late discussion in group 2 was very short, lasting only 3 minutes. Nevertheless, the following differences pertaining to claims and justifications were found in both group 1 and group 2:

1. A decrease in the frequency of claims (out of the total number of idea units) in the second discussions compared to the first ones (see table 3).

2. Claims were further classified into explicit and implicit claims (i.e., claims that were implicit in the argument rather than stated explicitly). In the second discussion, an increase in the frequency of explicit claims (out of the total number of claims) was found, compared to the first discussion.

A Z test for testing significance of differences between two frequencies in dependent populations showed that these two differences were statistically significant ($p < 0.05$, see table 3).

3. The mean number of justifications per claim was calculated. The results show an increase in the mean number of justifications per claim in the second discussion compared to the first one. This difference was statistically significant ($p < 0.01$ in group 1 and $p < 0.05$ in group 2)

Taken together, these findings indicate that in the second discussion, students were more careful in expressing claims, in taking more care to make their claims explicit and in justifying them compared to the first discussion.

Table 3. Frequency of claims (out of the total number of idea units) and explicit claims (out of the total number of claims) in first and second discussions in two collaborative groups of students ***

	first discussion		second discussion		Z
	n	%	n	%	
% of claims- group 1	207	36.7	153	30.0	-1.75 *
% of claims- group 2	189	38.1	56	17.8	-3.30 **
% of explicit claims- group 1	76	35.5	46	80.4	6.43 **
% of explicit claims- group 2	72	40.3	10	70.0	1.67 *

* $p < 0.05$; ** $p < 0.01$ *** Six students participated in the first discussion group 1 and seven students in group 2. In the second discussion there were six and five students respectively.

C2. Conversational turns as the unit of analysis

Following Resnick et al. (1993) transcripts were divided into sections that lasted 1 minute each. Then, the number of conversational turns per minute (i.e., the number of times speakers alternated in each minute) was counted. The results

show that the number of conversational turns per minute was almost always higher in the first discussion as compared with the second, indicating that in the first discussion students tended to talk briefly while in the second discussion they tended to talk for longer periods of time, allowing more complex discourse than in the first discussion .

In order to support the previous finding, the mean number of idea units per conversational turn was calculated. The results show that the mean number of idea units per conversational turn increased from 1.4 in the first discussion to 2.4 in the second discussion in group 1 ($t=3.75$, $p<0.001$) and from 1.5 to 1.9 in group 2 (this difference was not statistically significant). These results indicate that students' discourse in the second discussion was indeed richer in ideas than in the first discussion.

Conclusions and Discussion

Our findings show that before instruction, most students can formulate simple (but not more sophisticated) arguments. In this study, students were explicitly taught the principles of a good argument, followed by intensive opportunities to exercise these principles in the context of a specific science content. Results from both written tests and transcripts of group discussions support the conclusion that such instruction enhances both conceptual understanding and argumentation skills. Students were able to transfer reasoning abilities taught in the context of bio-ethical dilemmas to the context of moral dilemmas taken from everyday life.

Since argumentation skills are usually ignored in school so that students' potential abilities may not be fully expressed, it is not surprising that even a short exposure to the principles of a good argument followed by intensive opportunities to exercise those principles may induce substantial change. The finding regarding the gain in biological knowledge compared to a group of students who have studied by traditional means is supported by a previous evaluation study of another unit from the 'Thinking in Science Classrooms' project. In that unit, students who have learned about the role of water in living organisms by solving problems that required scientific and critical thinking skills scored significantly higher on a knowledge test than a comparison group who have learned the same topic by conventional instruction (Zohar, Weinberger & Tamir, 1994). There are several possible explanations (which are not mutually exclusive) to that gain in knowledge: (a) Addressing the genetic concepts from the perspective of the social issues of moral dilemmas, creates 'ed instruction' (see Bruer, 1993 for review) in the sense that the social issues create an 'anchor' for learning that generates interest and connects to students' out of school life experiences; (b) In the GreDMoD unit students are not passive recipients of facts but active problem solvers that must integrate the biological concepts with higher order reasoning in order to solve the problems presented in the program; and, (c) Diverse means were used for instruction of the GreDMoD unit. Most lessons were not teacher-centered in the sense that for substantial amount of the time students worked in pairs and/or in small groups that were rich in social construction of knowledge.

In addition to gains in knowledge and reasoning, our findings also show some improvement in students' moral reasoning (see last two rows of tables 1 and 2). It should be noted that this last finding should be taken with caution because the present study did not attempt to address the full complexity of the issue of moral reasoning. The only two aspects of moral reasoning that were addressed here are the ability to formulate a moral dilemma and Kohlberg's measure (Kohlberg, 1976) for the level of moral reasoning (which is in itself a controversial measure, e.g. Gilligan, 1982). Of the multiple aspects of moral reasoning, the GREMoD unit addressed mainly the need to justify one's judgements by referring to abstract rules and presented students with a list of appropriate rules. The ability to justify one's judgements by referring to abstract rules is the main element of moral reasoning that is addressed by Kohlberg's measure. Therefore, the only claim that can be made from this study about gains in moral reasoning is limited to showing that students were able to apply in specific contexts the general rules of bio-ethics that they had been taught.

Nevertheless, our findings imply a suggestion for educators whose primary goal is moral education (and who believe that moral education requires the development students' skills for moral decision-making). The deficiencies in students' initial argumentation abilities in the context of moral dilemmas and the progress in the level of argumentation that was observed following explicit instruction, suggest that including a short unit of instruction about argument structure (focusing on the differences between good and bad arguments) may enhance students' ability to discuss moral issues in a sound way.

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*TEACHING BIOLOGY - FACILITIES, CURRICULUM
TIME AND APPROACHES TO TEACHING AND
LEARNING FOR 16-18 YEAR OLDS*

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Abstract

Two surveys of Centres entering students (academically able 16-18 year olds) for A-level Biology examinations have been conducted. One survey sampled all the remaining Centres studying Nuffield A-level Biology while the other was directed to those Centres entering candidates for other A-level examinations in the geographical area of 9 local education authorities (LEAs) in central England. The survey covered Maintained schools, Independent and Grant Maintained schools as well as Sixth Form and other Colleges. The survey questionnaire included 20 questions which explored facilities, curriculum time, fieldwork and approaches to teaching and learning. This paper reports on the findings arising from these studies.

Introduction

Currently there appear to be few problems with A-level biology. Recruitment to courses is good and the percentage of the cohort studying the Life Sciences Post-16 is continuing to grow after a small blip in 1995 (Lock, 1997). Many successful students go on to courses in further and higher education where the biological/life sciences continue to recruit well and to fill their places. Furthermore, the subject is seen as attractive and useful. At A-level there is a modern feel about courses with biotechnology, ecology and genetic engineering featuring strongly. Compared to the position of, say, A-level Physics the position for Biology is good (Reiss, 1998). Not for Biology teachers the problems of student recruitment, or of attracting a relatively balanced number of male and female students. Unlike Physics, Biology appears to have a modern and attractive image; many Biology teachers are well satisfied with the way things are.

However, there is growing anecdotal evidence of concerns amongst teachers of A-level biology about the direction that the subject is taking; see, for example, Lock, 1998. Such anecdotal evidence was expressing concern about the teaching and learning styles that students of A-level biology experience. To some degree, there was suspicion that the limited range of assessment strategies, that modularisation

of courses had brought about, was leading to approaches to teaching and learning that were more concerned with increasing the grades obtained in the modular tests than in developing a good broad education in A-level biology. This suggested that the teaching styles become more heavily teacher-centred, didactic in nature and reducing the opportunity for student discussions and even practical work. Pressures on lesson time, usually from senior management teams, meant that opportunities for extended practical work were curtailed. Financial constraints inevitably led to larger working groups, fewer opportunities to maintain and replace expensive items of equipment. There were even suggestions that changes in initial teacher education meant that teacher skills in using apparatus such as spirometers and kymographs were reducing. To some this appears to conflict with the current push for wider development of ICT skills as equipment, such as that mentioned in the previous sentence, provides excellent opportunities for data-logging and computer control.

In summary, the nature of the teacher concerns included five areas: a) the restricted, and mainly teacher-centred, range of approaches to teaching and learning, b) the limited opportunity for practical work, and the recipe-following nature of much of it, c) the influence that module assessment had had in restricting the variety and nature of examinations, d) the over-prescriptive content in syllabuses leaving little room for teacher or student choice and, e) the limited time available in initial teacher training and in-service work for upgrading biology knowledge and content.

There has also been a national series of meetings that have explored the future of the science curriculum and made a wide number of recommendations with respect to developments for the next millennium (Reiss, Millar and Osborne, 1999). Prominent amongst them is the suggestion that the biology curriculum would benefit from being presented as a number of explanatory stories rather than the current mass of often seemingly unconnected detail. The adoption of such suggestions would, however, address only one of the five issues raised in the preceding paragraph.

Inevitably, there comes a time when anecdotal evidence alone is inadequate. No matter how many times meetings of teachers appear to endorse the general view, no matter how broad the spectrum of contributors to those views, for example, OfSTED Inspectors (inspectors of national standards), science advisors, teachers, teacher trainers, A-level students themselves, there is always a suspicion that the presenters of such evidence have been selective in the information offered. Qualitative and sporadically collected and presented evidence maybe enough to convince some that there is an issue here to be addressed, but in order to convince some of the sceptical, a more hard-faced, rigorously collected, quantitative approach is more convincing.

It was against such a background that two pilot studies were undertaken; data from these is reported here. A short 20 question questionnaire was piloted and trialled locally and then sent to 150 Centres in the centre of England who prepared

candidates for A-level Biology examinations. This included all such schools and colleges in 9 Midland LEAs and the Grant-Maintained and Independent schools in the same geographical area. The questionnaires were sent out in January 1998 and by half-term of the Spring term 81 Centres had made returns.

The questionnaire asked about teaching arrangement and facilities, teaching methods, practical work and its assessment and teacher views on successful Biology teaching. A range of open and closed questions were used as well as a Lickert Scale which attempted to assess the frequency with which a wide range of teaching and learning styles were used.

By way of contrast, the same questionnaire was sent nationally to all the Centres who were entering candidates for the Nuffield A-level Biology examination. Such Centres falling in the geographical region of the first study were only included in the Nuffield Biology sample. The total of Centres responding in this study were 41, representing an 80% response rate. The Nuffield data was collected using an identical questionnaire in the Autumn term 1997.

Results and Discussion

The information presented here is drawn mainly from the 81 Centre returns from schools in the larger survey. In the latter part of this paper I will draw on data from the Nuffield Centre survey.

Figures 1 and 2 illustrate the number of students that responding Centres had in the Year 12 (Figure 1), and Year 13 (Figure 2) cohorts. These figures show that while there are still several small cohorts of students (less than 15 students per year) there are also a pleasing number of institutions where much larger cohorts of A-level Biology students are to be found and where, in some, up to 10 different teaching groups of A-level Biology students are found in one year cohort.

The differences between Figures 1 and 2 with regard to the number of Centres with up to 15 students in the cohort may suggest that the number of small, and potentially non-viable A-level groups is reducing, although an alternative explanation could be sought in terms of changes in demographic trends. What is beyond question is that there were more students studying A-level Biology in the Centres responding in the Year 12 cohort than in the Year 13; clear evidence of continuing growth in the popularity of A-level biology.

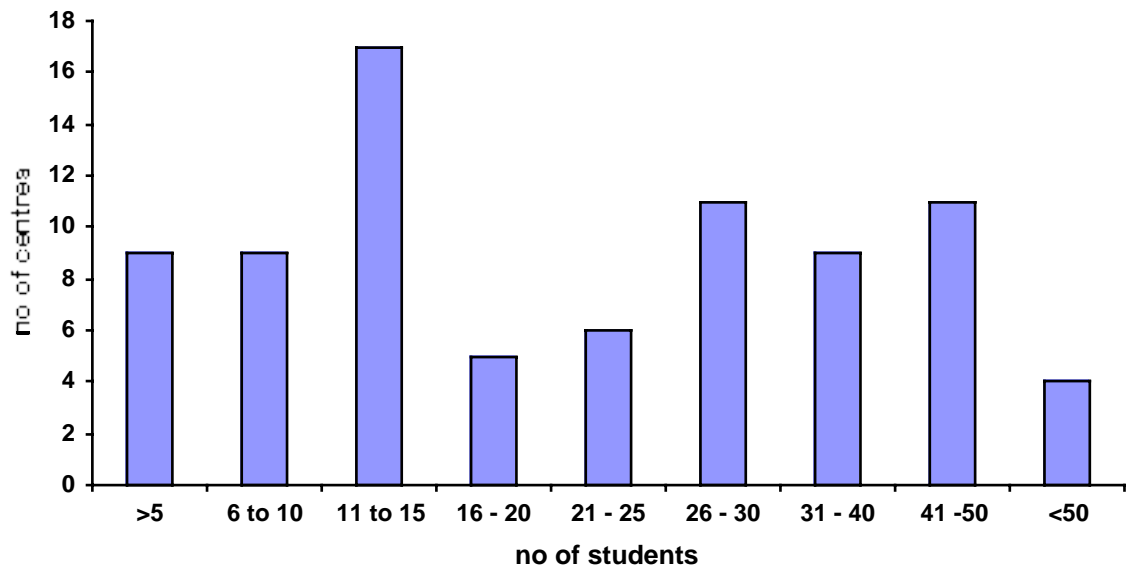


Figure 1. Number of Students in Year 12 cohort (n=81)

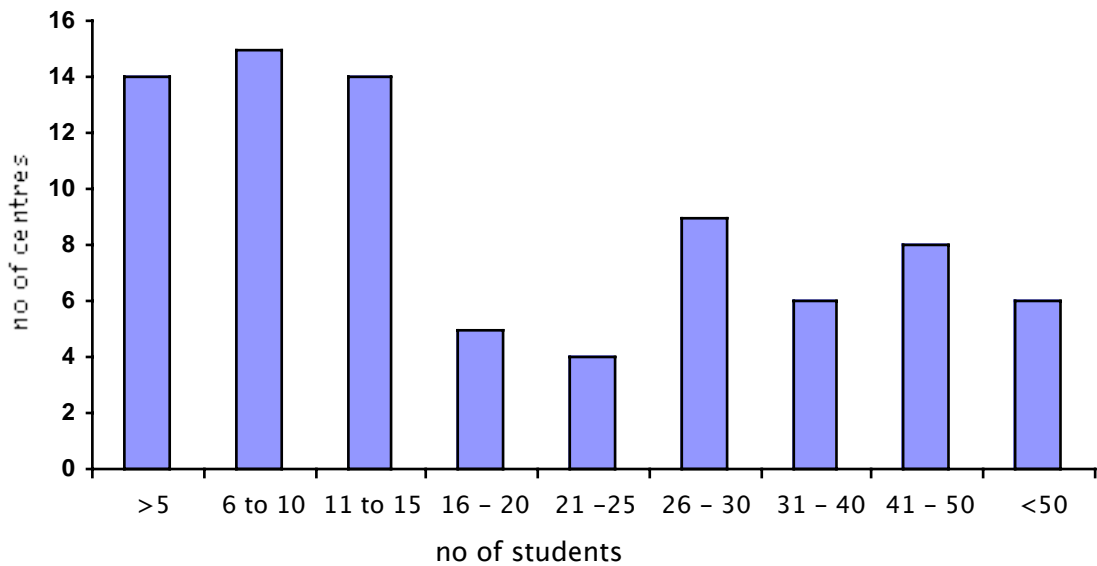


Figure 2. Number of Students in Year 13 cohort (n=81)

In anecdotal evidence I had collected before the survey (Lock, 1998), I had found schools in which Years 12 and 13 were taught together by a single teacher. This mainly happened in schools that were trying to establish an A-level course and where very small, non-viable numbers of students were attracted to the course. This posed particular problems where courses were modular as the two cohorts were often working on different modules which made excessive demands on teacher time, not just within the lesson but in preparation for them too. In this survey only 4 out of the 81 Centres who responded taught first and second year A-

level students together in the same group. None of the Nuffield Biology Centres used this practice. I would suggest that such an approach to A-level Biology teaching is not appropriate for students and places unreasonable demands upon teachers.

What is a reasonable amount of teaching time for the study of A-level Biology? I come from an era when the pattern of 8 x 40 minute periods per week appeared to be the norm. This would give 320 minutes teaching time per week. Figure 3 shows that such a value would now be considered generous by most teachers of A-level Biology. A wide variety of teaching times were reported from 225 through to 405 minutes per week. In all except 3 Centres the teaching time available was the same in the first and second year of study. In the 3 Centres that proved the exception to the rule there was less teaching time for the second year. The data in Figure 3 does not provide evidence that the time available for teaching A-level biology is reducing but several teachers did make comments that shorter teaching time did reduce opportunities for practical work and particularly for continuing the sort of whole investigations used at GCSE into study at post-16 level. This seems to suggest that continuity and progression of the skills developed at Key Stage 4 is not as prevalent as it might be. In some Centres, the longest continuous period available for teaching is 50 minutes which must place severe limitations on the nature and content of practical activities that can be completed in such a time period.

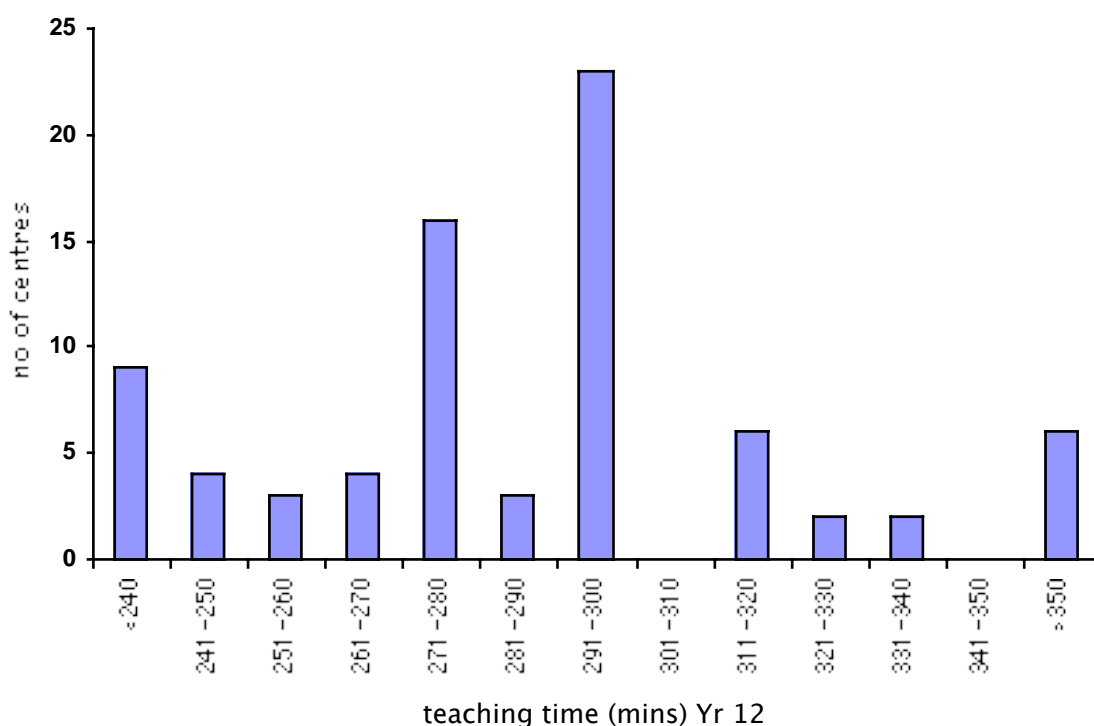


Figure 3. Teaching Time (minutes) for Year 12 (n=79)

Data in Table 1 illustrate some elements of the facilities available to A-level teachers. Under 50% have a dedicated laboratory for the exclusive use of A-level candidates and under 10% an animal room. Others have indicated that this didn't mean that animals were not used in their teaching as they pointed out that stocks were maintained in prep rooms and on the side benches in labs. The percentage of Centres with access to a greenhouse was encouraging although the questionnaire did not explore the extent to which they were used or the specimens that were grown in them and the purposes to which they were put. Garden plots and ponds were available to about 20% of Centres although again the ways in which these were used were not explored by the questionnaire.

Table 1. Facilities at A-level Biology Centres (n = 80)

Do you have	Yes %
<i>a dedicated A-level lab?</i>	44
<i>an animal room?</i>	8
<i>a greenhouse?</i>	50
<i>a garden plot?</i>	19
<i>a pond?</i>	20

One of the further anecdotal pieces of evidence collected from teachers was that opportunities available for field work were reducing. Some put this down to Local Education Authorities closing down field centres which they had formally owned and managed, while others suggested that these, particularly residential ones, were not popular with students who had regular paid employment in the evenings. Figure 4 shows that 13% of the responding Centres undertook no days of field work, while a further 23% did just one or two days. However, with just under 50% of the sample retaining 5 or more days of field work the position is far from discouraging.

The questionnaire also explored the type of habitats that were being used by the Centres and this data is presented in Table 2. Clearly, large numbers of Centres are still using coastal habitats with 41% of Centres using marine environments and a further 40% using sand dunes or salt marshes. Moorland and bogs continue to be well used. It is interesting to note that woodland and fresh water are the most popular habitats used as these should be in relatively easy access to all Centres. Together with grassland, these latter two habitats should be accessible to all schools and open to easy investigations without the necessity of expensive residential field study. For many schools studies in habitats such as these should be possible within normal lesson times. I suspect that school fields, where they still remain, are a widely under used resource for ecological work in A-level Biology or, indeed, at Key Stage 3 or 4 (with 11-16 year old students).

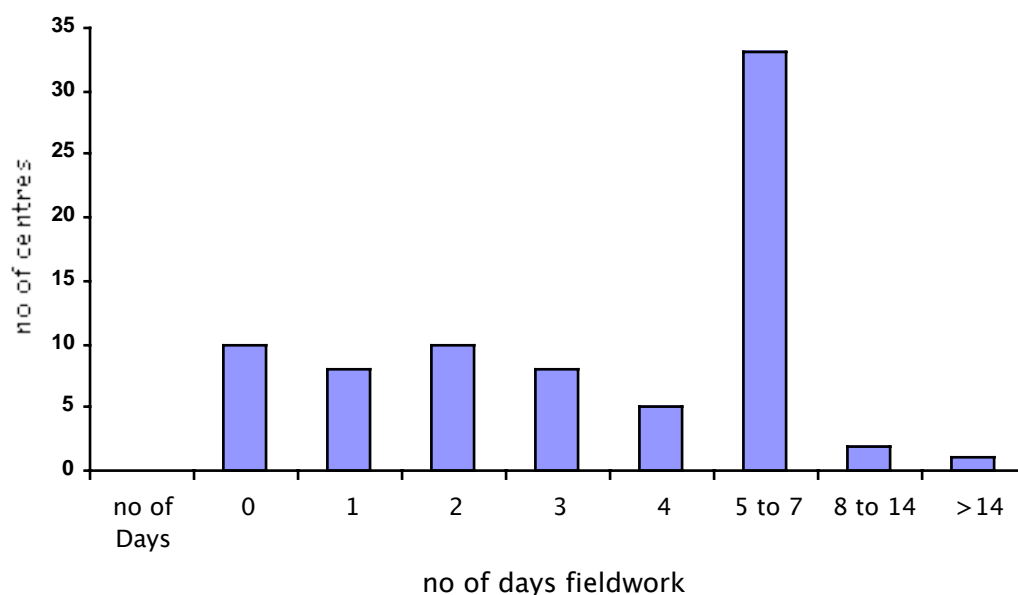


Figure 4. Number of days spent on fieldwork (n=77) (Please note that the version of this figure in the paper handed out at the conference was inaccurate)

Table 2. Habitats Used by Centres in Field Work (n = 80)

Habitat	% of Centres
<i>Freshwater</i>	64%
<i>Marine/rocky shore</i>	41%
<i>Moorland/bog</i>	19%
<i>Woodland</i>	46%
<i>Grassland</i>	25%
<i>Sand Dunes</i>	31%
<i>Salt marsh/mud flats</i>	9%
<i>Sandy shore</i>	4%

Teachers were asked to estimate the percentage of time spent teaching theory and practical in the first year of an A-level course. The data provided by 71 Centres is shown in Figure 5. The reason for the lower sample number in this figure is that 10 Centres provided data in a form which did not make it possible to calculate percentages. The anonymity of the questionnaires meant that there was no opportunity to clarify this data. Figure 5 shows a clear bi-modal distribution with around 25% of teaching time devoted to practical work in the 'typical' Centre. It is very evident from Figure 5 that there is a wide variety of practices within Centres. At one extreme more than 95% of teaching time is devoted to theoretical work. In contrast, in a small number of Centres, time is distributed equally between theory and practical work with, in one Centre, the majority of time spent

on practicals. It is impossible to stop wondering about the quality of the experience that students get in situations where less than 15% of the teaching time is devoted to a practical activity. Such a point is highlighted even further when the data in Figure 6 are considered. Here the data gathered from Centres teaching Nuffield A-level Biology is presented and it shows a marked contrast.

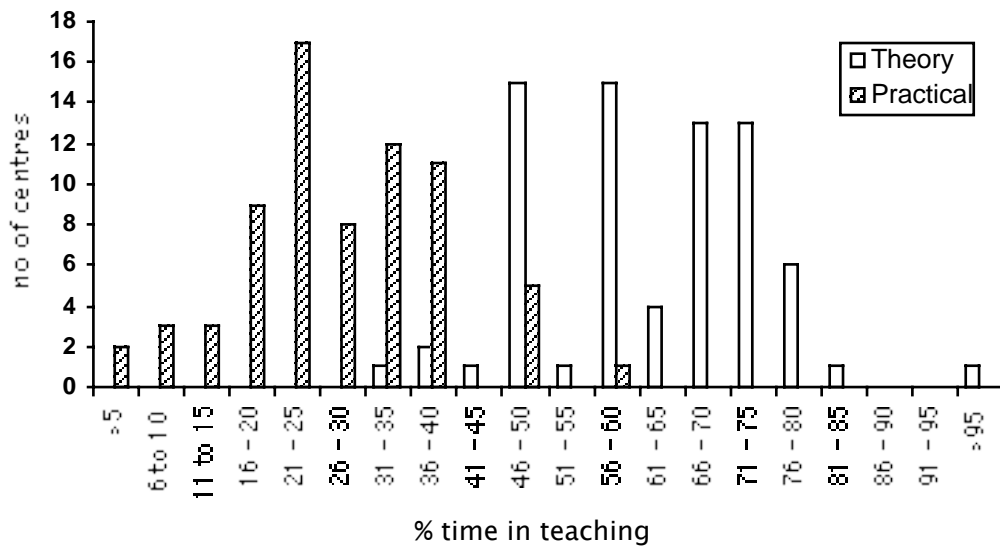


Figure 5. % time spent in teaching Theory/Practical Year 12 (n=71)

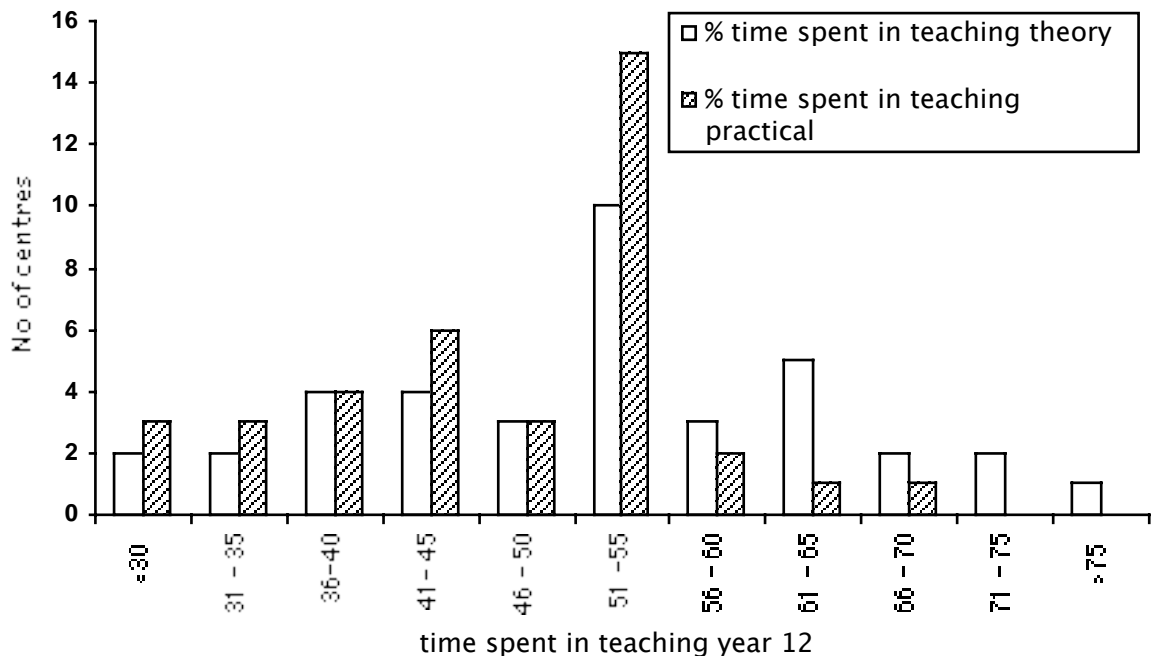


Figure 6. Time spent on teaching Theory/Practical to Year 12 Nuffield Biology Centres (n=38)

The data for the Nuffield teachers is not bi-modal with the distribution of practical work and theory clearly overlapping and both with the modal value at 50%. It is clear from comparisons of Figures 5 and 6 that students following Nuffield A-level Biology courses have a very different balance of theory and practical work than many of their contemporaries who are being prepared for entry to other examinations. Such an observation begs questions about the variation in the quality of experiences that different students experience and the potential impact this has upon their views of Biology or, indeed, their interest in and commitment to further study of the subject.

It is difficult from a questionnaire to gain insights into the quality of experience that students get; such measures are not amenable to measurement by questionnaire. However, further insights can be gained from investigating the methods of teaching and learning used by the teachers responding in the two separate investigations. It is here that the data collected has only been partially analysed so that the results presented in Table 3 report on only 6 of the 26 teaching methods that were a part of the Lickert scale exercise. Some of the data collected from this question is presented in Table 3. In the questionnaire 'rarely' was defined less than once per term, 'occasionally' as at least every term and 'frequently' as every week.

Table 3. Frequency of Use of Teaching Methods (other n = 81; Nuffield (Nf) n = 40)

TEACHING METHOD	% of Centres using							
	Never		Rarely		Occasionally		Frequently	
	Other	Nf	Other	Nf	Other	Nf	Other	Nf
<i>Dictation</i>	45	95	23	2	10	2	22	2
<i>Lecturing</i>	25	9	9	6	16	48	51	36
<i>Board/OHP copying</i>	7	11	9	21	32	27	52	41
<i>Student discussion</i>	1	2	22	4	33	36	43	57
<i>Computer simulation</i>	37	25	33	43	30	32	0	0
<i>Data-logging</i>	28	25	46	48	26	27	0	0

The most marked difference is between the use of dictation by Nuffield teachers as compared with those entering other examinations. 95% of Nuffield teachers never dictate with only one teacher of Nuffield A-level Biology reporting dictation as being used rarely, occasionally or frequently. Whilst it is still pleasing to see that over 45% of teachers directing candidates to other boards never use dictation, it is disturbing to find 22% regularly using this method of teaching.

In my view, dictation is an unacceptable teaching method at any level and especially so at A-level. There can be no justification for using this approach at

this level as it is a direct waste of student time. I can see that there may be times when notes composed by the teacher are appropriate for students to have. It is, however, a real challenge for the teacher to write in such a way that the notes are well understood by students; once through the pen, once through the head does not mean that student understanding is enhanced. If students must have teacher-composed notes then there are a range of other ways in which a sheet produced by the teacher can be used in a student-centred way to enhance learning, for example, the notes that would have been dictated could be handed to a student on a worksheet and then student time could be directed towards reading the passage and asking some questions about it. Alternatively, the passage could be presented with words and/or phrases deleted. The task for the student could then be to read the passage, read a textbook and attempt to complete the passage. Lesson time could then be usefully used in students comparing how they've completed the piece in small groups and/or a small group discussion to ensure that the work had been undertaken to the satisfaction of the teacher.

A similar line of argument could be applied to board or overhead projector copying although this sort of activity can be much more student-centred if, for example, the student is copying a diagram and then using a textbook to label the diagram or alternatively where the copying leads directly to some other, more student-centred, activity. Copying *per se* is only marginally more educationally justified than dictation unless it is made student-centred in some way. With copying, students themselves are able to 'chunk' the information and hence attempt to make some sense of it. In contrast, in dictation it is the teacher who is making decisions about how the information is 'chunked'. The data in Table 3 show only small differences between teachers of Nuffield A-level Biology and others with respect to copying but there is a slight indication that such strategies are used less frequently by Nuffield teachers.

Student discussion as a teaching method is more likely to be used by teachers of Nuffield Biology although the differences are small. Perhaps the most disconcerting feature of data on discussion is the 22% of other teachers who rarely give students an opportunity to discuss i.e. less than once per term do these teachers permit such a teaching approach.

Computer simulation is a teaching opportunity that has been around for 10 years or more. Whilst it would be unusual to expect any of the teachers to respond saying that they used this method frequently, it might be something that could be expected to be used at least every term. The data in Table 3 show very little difference between teachers with regard to use of this method. The relatively high percentage of teachers who never use this method does, however, give cause for concern. It is clear that, although long established, opportunities for using this technology are not widely being taken advantage of. The similarity between the data-logging use and that of the computer simulation is surprising, for whilst computer simulations have been around for some time, opportunities for data-logging are more recent. The data in Table 3 suggest that there is little difference in use of these methods between teachers of Nuffield Biology and those entering

other Board examinations. Equally the data shows that data-logging opportunities are presented to A-level candidates as infrequently as are computer simulations. With current pressures on developing the profile of information and computer technology (ICT) within the curriculum such findings do give some cause for concern. Cautious interpretation should be made of the data in Table 3 and further analysis of teaching methods by examination board and linear or modular examination mode are necessary before any more firm conclusions can be drawn.

Summary

The purpose of this paper has been to draw attention to the wide variety of experience of A-level teaching to which students are exposed. Undoubtedly the data here show that the majority of teachers offer a broad range of experience and opportunity to A-level candidates.

There are, however, some indications of concern relating to the small size of some A-level teaching sets, the teaching time available and the proportion of this that is devoted to practical work, the facilities available to teachers within Centres and the opportunities available for field work. There are also some early indications arising from this data which suggest that some students experience teaching and learning styles which are overly teacher-centred and only minimally involve ICT.

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*THE PROBLEMS, PROCESSES & OUTCOMES
OF INDIVIDUAL RESEARCH PROJECTS IN
BIOLOGY CONDUCTED BY STUDENTS IN
ACADEMIC HIGH SCHOOLS IN ISRAEL*

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Introduction

This study examines, and details, how research projects in biology are carried out in Israeli academic high schools. Based on the problems and difficulties we identified, we suggested certain improvements we hope will help students attain the status of independent learners.

For the past 200 years, teachers and educators - among them Rousseau (1944, 1976), Dewey (1916, 1960), Piaget (1970), and others - have endorsed the idea of students undertaking *independent work* in a subject of their own choosing. These scholars highlight the importance of this experience for the students' development throughout their studies and indeed throughout their lives. This is even truer today in our modern technological society. The vast volume of information available and the rapidity with which this information changes require us to become lifelong independent learners, as mentioned by - Smith, 1990; Areglado, Bradley, and Lane, 1996. Students at the elementary school, junior high, high school, and college level are required to undertake projects in different disciplines, and especially in science.

The research project, in its Israeli guise differs from every other form of work at the high school level discussed in the general literature. Often it provides a special experience that students remember as one of the highlights of their high school years (Levtzion, 1987; Sevar and Brin, 1993). Thanks to the research project, and particularly that in biology, high school student master the arts of independent study, experimental learning and inquiry skills (Fig 1)

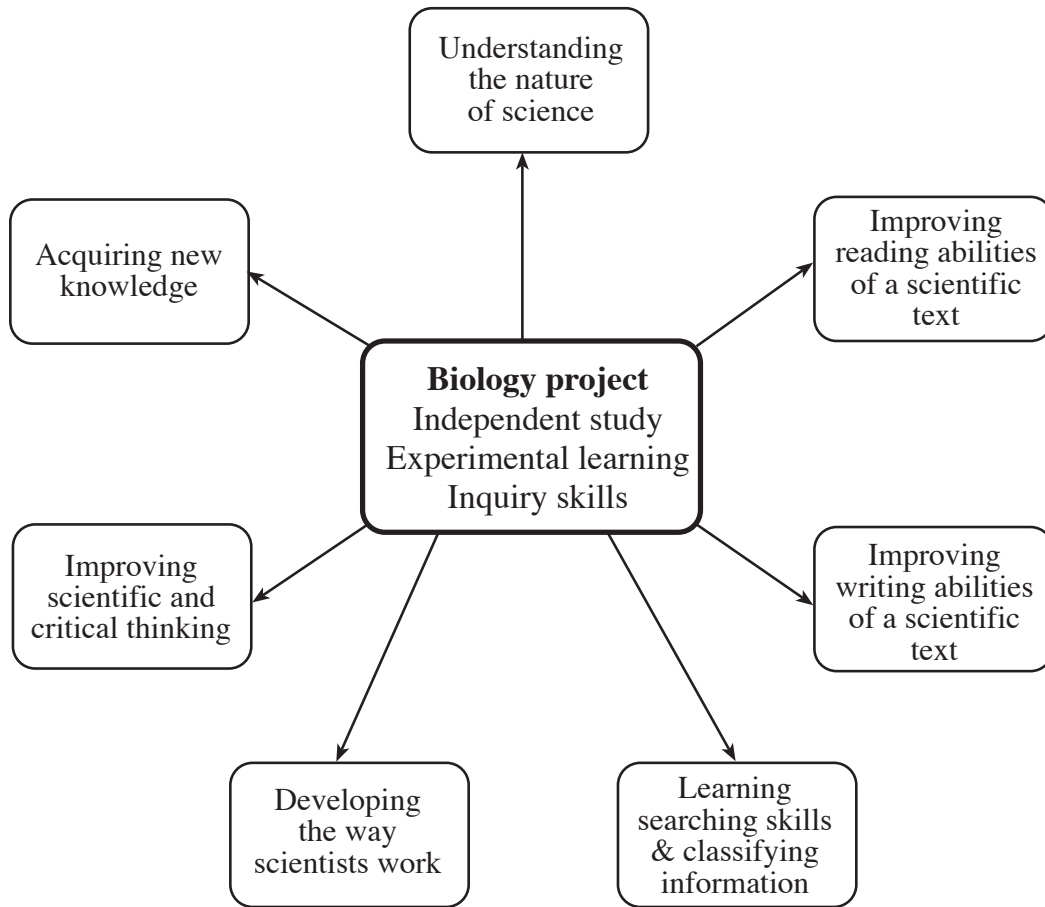


Fig. 1. Research project - its importance

The research project was inaugurated in Israel in the 1950s (Shapira, 1974). It is defined by the Ministry of Education as: “*independent, academic, or academic-application oriented work, which involves an attempt to summarize and clarify a certain topic.*” (Ministry of Education and Culture, 1984). Projects in biology must include laboratory and/or field research and take a full year to complete (eleventh grade and the first trimester of the twelfth). Students are given credit for their projects on their matriculation certificates.

Similar programs discussed in the literature aim at:

1. Independent learning
2. Independent research
3. Critical reading

In recent years, the evaluation of Israeli high school students has expanded beyond tests to include projects and portfolios (Ministry of Education and Culture, 1994, 1995 a & b). Since research projects dovetail with this policy, it is important to examine them closely.

Our view of the system and the relationships among all the relevant parties is presented in fig. 2. Every student has a personal instructor, in addition to the

director and co-ordinator. The student's project proposal must be approved by the supervisors in the Ministry of Education.

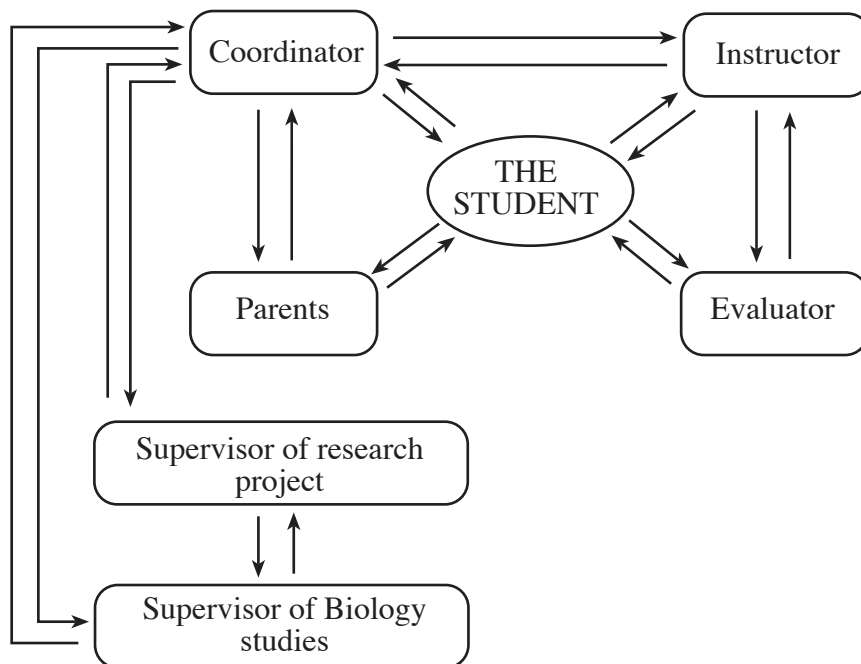


Fig. 2. The participants of the projects and the relationships among them

Objectives

This study was intended to present a detailed picture of the process of doing a research project, with emphasis on the field of biology. What is unique about this study is the attempt to consider the entire process from many viewpoints and at the different levels, including: the national level (the educational system), the school level, and the individual-student level, with the aim of exploring and specifying the problems and difficulties encountered at each level, and with the goal of suggesting improvements that can help students who do research projects to attain the status of independent learner. Hence, the questions posed by the study were aimed at clarifying the problems and difficulties that characterize projects at each of the three levels mentioned above.

The main *objectives* of this study are the following:

- A. To describe the overall picture of schools involved in student's research projects in Israeli academic high schools.
- B. To examine the biology-projects proposals and evaluations
- C. To compare the national results of biology matriculation exams with those of students who did projects.
- D. To closely observe the work of a group of students in a multidisciplinary project workshop in order to examine the changes in their study skills and attitudes. Identify problems encountered by those who take part in process of the research projects.

Methodology

This study integrates quantitative and the qualitative approaches. The two approaches are used in social science research, particularly in the field of education. Various scholars have recommended integrating the two approaches (Scriven, 1972; Goetz & Le Compte, 1984). Integration of the approaches enables one to overcome some of the limitations of each of them. According to Guba (1978), integration of the approaches for the purpose of data gathering increases the reliability and validity of the data that are gathered. What is unique to this study is the consideration of the process of preparation of research projects from various viewpoints.

The *positivist-normative* approach (the quantitative part of the study) employed a national survey to analyze research projects at the national level. Here objective research tools were applied to a broad population, as will be discussed in detail.

The *ethnographic-naturalistic* approach (the qualitative part of this study) involved monitoring the activities of a small number of students in the framework of the workshop class. Investigative tools included open and closed questionnaires and follow-up reports. Our methodology was based on the case study. Since the investigator was also the leader of the workshop this study also bears resemblance to action research.

The study had three phases; The first two phases of the study were part of the survey.

The first phase: a national survey

In this phase we described the overall picture of schools involved in student's projects. A questionnaire was sent to all principals of academic high schools in Israel, and the findings were based on responses from 127. This phase will not be described, but the second and third phases will be presented in detail.

The second phase: basic aspects of the research-projects

This phase dealt with proposals for biology projects, project evaluation, and students' achievements. Students who wish to undertake a project must send a proposal to the Ministry of Education for approval. Proposals include: (a) title; (b) questions or purposes of the study; (c) short theoretical introduction; (d) methods and tools, including samples and replications; (e) preliminary bibliography and (f) information about the instructor. Some students are asked to submit a revised proposal, on occasion more than once. We examined all of the approximately 600 proposals that the supervisor of biology received in 1990 and 1991 and made a content analysis of the proposals as well as the corrections and correspondence, using criteria validated by experts.

When students finish their projects they send them to the Ministry of Education for evaluation. The evaluator - usually a scientist or a biology teacher (with at least a master's degree) - is appointed by the national supervisor of biology. The

evaluator submits his or her evaluation with a letter of explanation. We also did a content analysis of all the letters that the evaluators wrote in 1992 and 1993.

Third Phase: a multidisciplinary workshop for doing research projects, a case study

We planned and implemented a multidisciplinary school workshop in order to characterize the process and identify problems encountered by all the participants who took part in preparing a project.

I directed this model of a multidisciplinary workshop for about a decade in one Jerusalem high school in, in this research a case study was performed, following a project workshop for about two years (1991-1993). The group included 17 students - 9 girls and 8 boys - 13 from higher level classes and 4 from a lower level. The subjects included were Biology and Sociology - 4 students each, Film making - 2 students and all other projects one student each: Geology, History, Music, Literature, Arabic, Physics, and Theatre. The meetings were held weekly for two periods beside personal meetings. The curriculum prepared was aimed to suit the various subjects. The curriculum included study materials, exercises, and assignments that were utilized in the framework of the workshop. Part of the assignments were designed for all the students, others were tailored individually. The curriculum was structured to provide the students with tools that would help them in writing scientific papers - involving development of skills related to definition of the subject, search for relevant material in the form of a literature survey, use of the library - including catalogues and databases, critical reading, scientific composition, etc. As every student had an instructor, the scientific apparatus was his responsibility.

All sessions of the workshop were held in the library, which served both as a study room and a "laboratory" - for study and for operation of the process of scientific composition, and for learning to use all of the materials that the library provided- involving not just familiarity with catalogues, methods of classification, and the listing and citing of bibliographical sources, but also familiarity with types of books and scientific texts and sometimes also clarification and review of information, definition of concepts, etc.

The tools that were used in this part of the study were: a report on the class sessions by the director of the study and an observing teacher; observations, and open and closed questionnaires that were given to the students during the workshop.

Findings

Main findings of the second phase were

1. Research projects in biology included a wide range of fields. The most popular fields were medicine, agriculture, zoology, cell biology and tissue studies.
2. Of those whose proposals were approved, over 40% did not complete their projects.

3. Forty percent of the proposals required revisions. Often the reason given was that the topic was inappropriate because it did not include experimental/research work, as is required (Agrest, Statter and Lezrovitch,1997).
4. Seventy-five percent of completed research projects received grades of 86-100.
5. Comments on evaluations generally focused on three aspects: (1) the form of the paper and quality of the writing; (2) the use of scientific tools; and (3) the overall quality of the project. Poor writing was mentioned in 34% of the evaluations. Criticism regarding scientific tools involved the use of statistics (15%), methods and materials (10%), presentation of results (15%), and conclusions (13%). In 22% of the cases, after the evaluator met with the student, he or she expressed concern that the student did not fully understand theoretical background of the project (Table 1).
6. During the two-year period under study, the gender breakdown among those who did research projects in biology was in synch with that of the entire population of advanced biology (girls, 60%; boys, 40%).
7. As we had hypothesized the students who did a research project in biology did better on the advanced matriculation examinations in that field than did those students who did not do a biology research project. We compared their final grades for the year, the grades they received on the written theoretical examination (particularly the section where the student must analyze a scientific research text and on their laboratory examination. In each case, the students who did research projects, received grades 4-12 points higher than those of their peers (Table 2).

Table 3. Aspects of evaluation comments to 330 biology research projects.

Aspect	Comments (%) n=330	
	Negative	Positive
1. External face & writing expression		
a. style	34	5
b. editing	3	29
c. content	6	28
2. Scientific tools		
a. method & materials	10	27
b. results	15	28
c. statistics	15	5
d. conclusions	13	24
3. Oral examination		
a. mastering the theory	22	59
b. ability to explain findings	12	63
c. general evaluation of the research	3	19

Table 4. Grades of projects and matriculations in Biology

	1992				1993			
	writing projects in Biology n=47		matriculation in Biology n=7695		writing projects in Biology n=52		matriculation in Biology n=8262	
	average grade	s.d.	average grade	s.d.	average grade	s.d.	average grade	s.d.
theoretical written exam.	76	13	67	15	75	14	66	16
annual grades	85	7	78	11	86	11	78	11
analyzing a scientific research ¹	75	18	63	21	68	15	61	25
laboratory exam.	79	13	76 ²	14	82 ²	12	76	-
projects	91	7	-	-	90	6	-	-

1. Part 3 of the theoretical written exam
2. 1992: n=7872 1993: n=8456

Main findings of the third phase:

From the information that was received by means of the different questionnaires that were given to the students of the workshop, their parents, the instructors, and the teachers, we learned that all of the students in the workshop choose to do a research project and showed great motivation for doing one. The motivation stemmed from a desire to widen and deepen knowledge in the chosen subject area, from enthusiasm for learning for its own sake, as well as from the intention to exploit the opportunity to earn additional points toward the matriculation degree. The students' expectations about the research project as well as the workshop were fulfilled, in regard to both research skills and information skills (search for materials, use of library resources, writing skills).

The students regarded the research project as a personal challenge, as a means for acquiring knowledge and broadening horizons, and as an opportunity to acquire tools for study in the future, and intended to recommend doing research projects to siblings and friends. Most of the students felt that the work was enjoyable, interesting, provided an opportunity for high achievement, and contributed to their ability to think and work independently.

The students indicated that the workshop mainly contributed to: preparation of the proposal for the research project, finding an instructor, receiving encouragement and support. In the process of doing the research project, the workshop also made important contributions to: increasing familiarity with the library, search for sources, preparation of section titles for the paper, and summarization of material from sources.

The work done in the workshop was meaningful to the students (according to the testimony of the students, the parents, and the teachers) in terms of providing encouragement and support and aiding most of the students while they carried out their research project.

Among the 17 students who began projects, 14 completed them (82%), a relatively high proportion. The three students who abandoned their projects prepared work of a more limited scope instead, and like the rest of the students received credit in their matriculation certificate for participating in the workshop and doing a research project.

The achievements of the students, as assessed by the Ministry of Education's evaluators, were very good, the average grade for the whole group was 89.6. the research project, according to the testimony of the parents, instructors and teachers, affected the development of both personal and interpersonal skills, and strengthened self-confidence, initiative, responsibility, and independence.

Recommendations based on the findings

Recommendations on the pedagogical plane

1. A recommendation that all students will carry out a project, as part of matriculation demands. In order to fulfill this, the schools must change its concepts and assume the central role in development of skills for doing research projects as part of the basic educational process.
2. Teachers must be trained and allocate hours of instruction to the subject. To operate a multidisciplinary school workshop, which will be conducted by a staff of teachers (two teachers from different areas of knowledge and a librarian), and for which the recommended room for study is the library. It is recommended to use a study program for the workshop that is based on the present study (including a time schedule and exercises).

Recommendations on the organizational plane:

1. To create a position of a coordinator for projects in the schools and to provide more training to teachers in this area.
2. To help in finding instructors (and to publish lists of instructors according to areas of knowledge).
3. To simplify and shorten the process of approval of proposals for projects.
4. To have projects evaluated by two evaluators (instead of one, as today),

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ENVIRONMENTAL EDUCATION

***PROMOTING REASONING AND ARGUMENT
ABOUT ENVIRONMENTAL ISSUES***

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Abstract

In this paper some features of argumentation about environmental management are discussed. Participants are High School students in 11th Grade, working during one month, in Spring 1998, in a real problem about water drainage in a wetland. The students were videotaped and audiotaped while working in small teams, both in the field and in the classroom, assessing the impact of a project which involves building a pipe across the wetland. Data collection includes field notes and analysis of the transcriptions as well as of the students' productions in portfolio format. Toulmin's argument layout (Toulmin 1958), is used as a tool for the data analysis. The paper discusses some features of the design of the unit which, in our opinion, are effective in promoting argument in the classroom. The different positions of individuals and small groups are analysed. The argument patterns about an environmental issue have distinctive features compared with other related to more conventional science topics. For instance, in environmental issues there is not an unique argument of reference which represents the experts view and also the values (beside models and theories) act as backing. The results show a development of the ability to evaluate the quality of a landscape and to assess the environmental impact of an intervention. This ability involves an understanding of the complexity of such decisions and the acknowledgement of benefits and disadvantages in almost any alternative solution.

**Reasoning and argument:
theoretical framework and objectives of the study**

In this paper some features of argumentation about environmental management are discussed. It reports a study which is part of a project about reasoning and argumentation patterns in Secondary School. Students' argument patterns while learning science are studied by means of discourse analysis in the classroom. Our interest focuses on 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 processes of reasoning related to learning science, as a different dimension of the study of products or learning outcomes.

What we mean by argument is related to the ability to reason. Particularly argument could be defined as the ability to relate data to claim, and claims to

theoretical background and, as several authors have proposed (Kuhn 1993, Driver & Newton 1997) should be part of the goals of science education. We believe that, in order to be able to build models which explain the natural world and to operate with them, the students need, besides learning meaningfully the concepts involved in them, the capacity to choose among different options and to reason which criteria lead to the option chosen. To include argumentation among the goals of science education means, among other:

- To recognise the contribution from the discursive processes and practices in the building of scientific knowledge (Latour & Woolgar 1986, Driver & Newton 1997). To do science is not only to “perform experiments” but also to propose and to discuss ideas, to evaluate different alternatives, to choose among different explanations.
- To extend the understanding of science learning, that is not only exploration, but also justification of theoretical explanations in connection to data and evidence (Kuhn 1993), in other words analysing hypothesis and conclusions in relation with empirical tests.
- To have as an objective the participation of students in the discourse of science, discourse here meaning (Lemke 1990) the language in use in the scientific community, that is not only the words but also the semantics, the resource system for creating meanings.

To promote the capacity of argumentation is an objective of epistemic nature, having to do more with the ways of building scientific knowledge than with the content, but we should keep in mind that in order to be able to participate –to a certain extent– in the building of science, one must handle concepts and theories. The arguments which are our focus are those substantives (Toulmin 1958), in which the knowledge of content is a requisite.

Taking decisions about data, discussing patterns in them, justifying decisions, formulating an explanation, all this is to participate in the discourse of science at different levels, in a research laboratory or in a science classroom. Lemke (1990) distinguishes among two classroom situations: either the students “talk science”, participate in the science discourse, or they do not when they perform stereotyped tasks.

We are interested in exploring “what counts as” evidence, claims or justifications for the students. The objectives of the whole study are to identify argument patterns used by Secondary School students and to document instances of reasoning and argumentation in classroom settings. In this particular paper we address these research questions:

- To identify different arguments about environmental management in a wetland.
- To analyse the dependence of the context, in terms of the particular features of the arguments about an environmental issue, compared to arguments on standard science topics.
- To analyse the development of the ability to evaluate the quality of landscapes and to assess the impact of human actions on it.

This work has, as one of its goals, to incorporate two lines which sometimes seem to be apart: environmental education practices and mainstream science education research. We are using an environmental problem, drawn from the real world and close to pupils, to develop different contents from the Science curriculum (in the Biology and Geology subject). In particular we offer an instance about how environmental contents related to procedures and attitudes can be developed.

In the course of the project we have found that there is not much argument or discussion in traditional science classrooms. We see argumentation related to a classroom environment in which students are engaged in inquiry, working with authentic problems, and therefore related to instructional design.

In the second section the methodology and some features of the instructional design of the unit intended to promote inquiry and argument are discussed. In the third, some case studies of the students' arguments are presented and the last section discusses the educational and research implications.

Methodology and features of the unit

Participants

Data were drawn from a public High School in the city of Vigo, in the south of Galicia (Spain). Participants are enrolled in the night shift, which means that either they work during the day or that they have dropped the full day courses and are enrolled in just two or three subjects each year. In other words, they are a bit older than the typical 11th Grade students (17 years), their ages ranging from 17 to 21 years.

The participants are two groups of High School students in 11th Grade enrolled in a Biology and Geology course which belongs to the Science strand. The unit about environmental management makes part of their coursework, because the teacher-researcher (the second author) is designing her own materials intended to include an environmental education dimension. The arguments discussed in this paper are drawn from one of the intact groups, 38 students distributed in 6 teams.

Data collection

Students were videotaped and audiotaped while working in teams, both in the field and in the classroom. Data collection includes field notes by an external observer (third author) and analysis of the transcriptions as well as of the students' productions in portfolio format: responses to particular subtasks, notebooks and final reports, drawings, maps etc.

Several tools are used in the data analysis, some drawn from the literature, as Toulmin's argument layout (Toulmin 1958) for the study of the argument components, other developed in the course of the project (Jiménez, Díaz & Duschl 1998), as a frame for the analysis of epistemic and procedural operations

belonging to scientific culture. The students' arguments discussed here are analyzed in terms of the argument components following Toulmin: a) data: which can be administered or obtained, and of empirical or hypothetical nature; b) claim: which could be more (hypothesis) or less (conclusion) tentative; c) warrants, reasons which justify the connection between data and conclusion; d) backing (background knowledge) of a theoretical or general character to which the warrants are related. Sometimes there are also e) modal qualifiers, which specify conditions for the claim, and f) rebuttal, which specify conditions for discarding the claim.

The unit about the “Budiño's Pipe”

The students were working during one month, in February and March 1998, in a real problem about water drainage in a wetland, assessing the impact of a project which involves building a pipe across the wetland; this work being part of their coursework, and being directed by their regular teacher (second author).

The unit and the study make part of project RODA (ReasOning, Discussion, Argumentation) carried on in the University of Santiago and supported by the DGICYT. All the tasks designed in the project are intended to be authentic problems, which means (Duschl and Gitomer 1996) on the one hand problems which have some relevance to the life of the students, and on the other hand, problems which are discussed using similar criteria about evidence and justification to the criteria the scientists would use. The notion of authentic problems draws from the situated cognition perspective (Brown, Collins & Duguid 1989) the idea of designing classroom tasks according to scientific culture, that is the culture of the science practitioners, and not to stereotyped school culture. Although authentic problems do not need to be “true”, the issue chosen for this study is a real problem: the assessment of the environmental impact of a drainpipe in a wetland near Vigo: the marshes of Budiño.

The marshes of Budiño is a wetland, which has the status of area of natural interest, belonging to the basin of the river Louro (“golden” in Galician) and includes a pond. Presently it is surrounded by an industrial area and a granite quarry which drain their sewages into the wetland and the river. All the area is heavily polluted, some of the small ponds are dry and plants (for instance the only representative of carnivorous plants in Galicia, a small *Drosera*) and animals –particularly amphibian and migratory birds– are suffering the consequences of the destruction of their habitats. In 1993 several government offices cooperated in the elaboration of a “Plan for the integrated (environmental) reorganization of the Basin of River Louro”. One of the actions projected in this plan is a network of drainpipes crossing the middle of the wetland, with the objective of collecting all industrial and domestic sewages. The importance of the drainpipes is evidenced by their cost: 10.000 million pesetas out of a total of 13.000 millions (about 77 and a half million euros). In the first draft of the project the main drainpipe was projected surrounding the wetland and the pond, but in the final project the layout of the drainpipe was changed, and it crossed the wetland, dividing it in two. As it turned out, the only reason for the change was to reduce the cost of the drainpipe.

The students were presented with the situation and, after a field trip to the actual site, asked to analyze a dimension of it working in teams and to produce a report about the convenience (or not) of the pipe and, if this was the case, to produce alternative solutions. Six teams (four composed by six students, two by seven students, although, due to the nature of the night shift, not all of them attended the courses every day) worked on six different dimensions of the issue and then shared their reports using the jigsaw technique. This technique (Chambliss et al 1996) involves the distribution of different tasks among teams in a first step, and then breaking the original teams and building new ones composed by one member of each original team, in this case one person from each group A-B-C-D-E-F. Each of these students is responsible for summarizing to the others the report from her or his original group, which promotes the participation of all. The six dimensions were:

- A) Plant communities: species, identification, distribution.
- B) The planned drainpipe: its function, impact, benefits.
- C) The landscape: visual traits, limits, colours; production of a sketch.
- D) Animal communities: status of endangered and protected species; alimentary networks.
- E) Environmental situation of the area: pollution, how the pipe will influence it.
- F) Biotope: geological history of the area, origins of the landscape.

In the reports all the teams had to address four issues:

- Features of the area and its value.
- Their own statement of the problem (about building the drainpipe)
- Their arguments for or against the drainpipe.
- Their final decision about building it or not.

As goals for the unit we intended:

- On the one hand, to apply the disciplinary contents developed during the first half of the term to the solution of this problem, for instance: action of atmospheric agents, relief formation, landscape etc.
- On the other hand, to integrate the environmental education dimension, paying attention to procedural and attitudinal contents such as: interpreting and producing maps and sketches; perceiving the landscapes through the different senses; evaluating the quality of a landscape and its aesthetic values; assessing environmental impacts; developing tolerance towards contradictory opinions; appreciating the importance of biodiversity.

The question of the drainpipe was chosen, among other possible environmental issues, because of its complex nature: building the pipe would involve *benefits* for the wetland, mainly by avoiding the pollution from the sewages. But at the same time, it would involve *damages* to the wetland, destroying some fragile habitats. This double nature, we believed, would promote a variety of opinions, argumentation and debate among different positions, better than another issue (wood fires, for instance) where almost everybody would agree.

The development of the unit had four phases: 1) Starting up with whole group activities, including the field trip to the marshes and statement of the problem. 2) Team work, production of the six reports and maps. 3) Sharing of information in the new teams and debate in the whole group. 4) Debate with the presence of outside experts: the engineer who wrote the drainpipe project and the president of Erva (“grass”) an ecologist group with a long involvement in the defence of the Budiño's marshes.

Results: should the drainpipe be built?

In order to analyse different arguments about the drainpipe we will draw in this paper from data coming from the transcription of the videotape of the whole class debate on March 3rd 1998, before the debate with the outside experts. There were some changes in the students' positions after this debate which are discussed in another paper (Jiménez, Pereiro & Aznar 1999). This data are complemented by the groups written reports and the field notes from the observer.

Argument of reference

We will begin by discussing the argument of reference, which represent the experts' view. It has to be noted that we are interested in substantive arguments that, following Toulmin (1958), are these in which the knowledge of the content is a requirement for understanding. That means that we focused our attention, not on any kind of arguments and opinions, but only on these dealing with the question: should the drainpipe be built?

The reflections of the three researchers during its elaboration, which led to a restatement of the problem, illustrate the complexity of the problem. When producing the argument of reference, we realized that the answer to this question was not straightforward, but rather could be broken in two parts:

- Should **a** drainpipe be built? to this question the experts' answer, in our opinion, should be yes, because of the critical situation of the marshes currently.
- Should **this** drainpipe with **this layout** be built? in our opinion, the answer here should be not, because a) its negative impact (decreasing of waterflow, dividing the wetland, alteration of ecological balance) is greater than its positive effect, and b) because there is an alternative layout (the first draft) which avoid these negative consequences. This opinion is represented in form of the Toulmins' scheme in figure 1.

As seen in this argument of reference, the justifications for the claim (warrants, in Toulmins' terms) are of two kinds, being the first warrant another argument, in the form of what Kelly, Druker & Chen (1996) call subsequent argument, which in turn has two different (even contradictory) warrants.

This complexity means that there is not an unique argument of reference, as occurs in other domains, for instance Genetics (Jiménez, Bugallo & Duschl 1997), but rather the argument in figure 1 can be viewed as one of the possible arguments of reference.

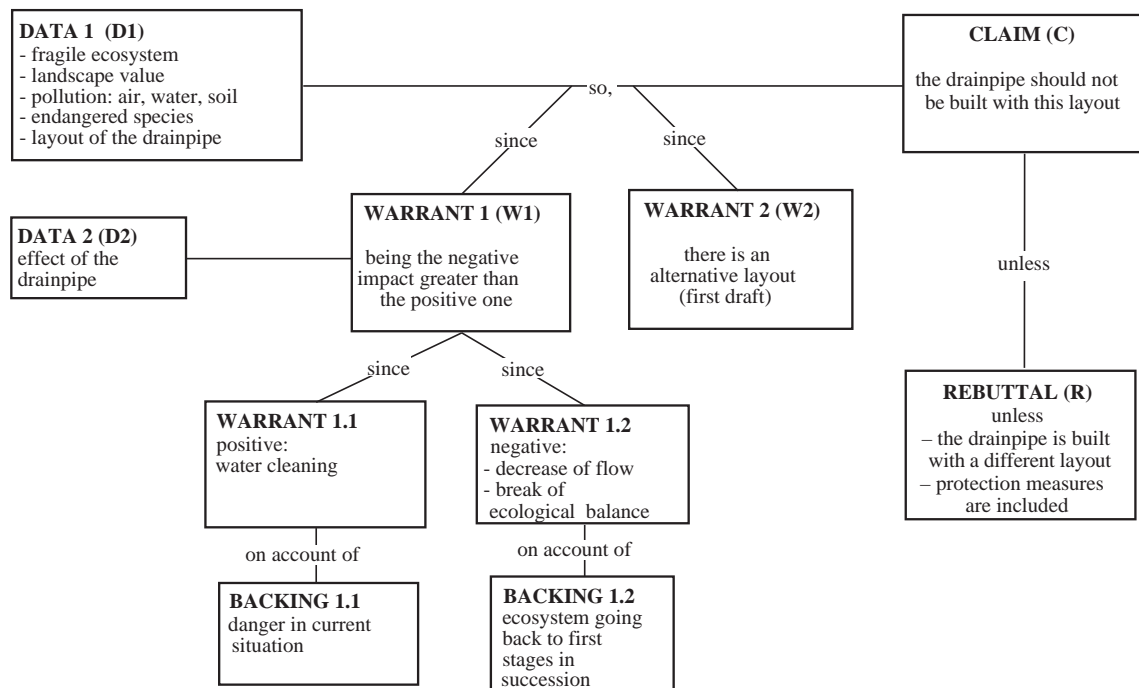


Figure 1. Reference argument for the drainpipe

Arguments in the whole class debate

The analysis of some fragments of the transcription is presented in three columns: in the first the actors, students and teacher are identified (with pseudonyms respecting their gender) and the number of the group indicated, in the second are represented the argument components in Toulmin's terms, and in the third some comments, like a summary of the main ideas or concerning other dimensions in the dialogue, as the status of experts or the values.

In some moments –usually speaking in plural as "we"– the students are talking as speakers for the group, while other times they are expressing her or his own opinion.

line	actor	Transcription	Argument	Comments
1.1	Ismael G6	In order to decide the convenience of building the drainpipe, we took into account mainly the importance of the valuable features of the area, aesthetics, social and all this	data	
1.2		And also the for and against, above all taking into account the pollution	backing	
1.3		but we conclude that, as well if it is built as if it isn't, pollution is going to affect it and the Nature will be damaged in both cases.	Warrant	

line	actor	Transcription	Argument	Comments
6.1	Orencio G6	If, in order to save the river Louro from pollution, we need to kill the marshes' ecosystem, it would be of no use.	Warrant	a different layout
6.2		Then, if we are looking for a solution for cleaning the river Louro but without damaging the marshes	Qualifier	
6.3		an alternative is to divert the drainpipe or part of it.	Claim	
10.2	Beatriz G5	it is one of the few areas declared of natural interest in Galicia	warrant 1	a different layout
10.3		If we build the drainpipe is going to influence the biodiversity, because they are not reforesting it.	warrant 2	
10.4		We would look for a third... a third...	claim	
15.1	Isaura G5	Because... the question is that we don't know more systems for cleaning rivers.	background knowledge	expertise
15.2		Then, not knowing them, we cannot criticize it accurately.		
16	Luz G5	But we won't build the drainpipe.	claim	not this layout
23.1	Isaías G 3	We think that, even if in the short term it would be negative... the building of the drainpipe	qualifier	drainpipe, yes
23.2		in the middle and long term it would be productive (...)	claim	
23.4		We must view things in the long run (...)	backing	
23.5		because the pollution problem would disappear and it would be possible a recovery of this area (...)	Warrant	
29.1	Leila G 2	We propose a different alternative that could be building the drainpipe in a different place	Claim	not this layout
29.2		in order not to destroy the ecosystem	Warrant	
29.3		as it would take a long time to recover. (...)	Backing	

line	actor	Transcription	Argument	Comments	
37.2	Daniel G 1	We believe that the drainpipe should not be built	Claim	not this layout	
37.3		because it would be a great disaster for the environment	Warrant 1		
37.4		and the area would be damaged and as a consequence it wouldn't be a mature ecosystem (...)	Warrant 2		
39.1	Mar G 4	We believe that building the drainpipe would destroy a great deal of the ecosystem, because it crosses the pond in the middle	Warrant 1		
39.2		and some plant species would also be destroyed	Warrant 2		
39.3		and then animals which depend on these plants will also die.	warrant 3		
39.4		Then, the conclusion we reached is to do it with a different trajectory	claim		not this layout
39.5		which means more money (...)	data		
42	Teacher	The fact of this solution of yours being more expensive: do you see it as very serious?		Question	
43	Mar G 4	Very serious? We see as more serious crossing the middle of the pond.		Values	

All the teams (although group 4 did it the last) reported and, as seen in the transcriptions, five of them took positions against building the drainpipe –although they propose different alternatives– and only one (group 3) in favour of building it. Then the teacher proposed to discuss the reasons in favour and against it and assigning the first turn to group 3, because they represented the minority position.

line	Actor	Transcription	Argument	Comments
49.1	Isafas G 3	I, because we must be practical,	warrant 1	Values
49.2		the drainpipe, either it is built as it is projected, or it won't be built,	Claim	no other options
49.3		Because the Government and all them they are not doing it again.	warrant 2	
49.4		Money is very important and they are not going to spend more money of what they want in the project	warrant 3	
49.5		and we have to view things in the long run (...)	warrant 4	
49.8		Then it must be built (...)	Claim	

line	Actor	Transcription	Argument	Comments
52.1	Beatriz G 5	Of course, if they were going to reforest it	Qualifier	
52.2		then it should be done (...)	Claim	
56.1	Isaías	The building of the drainpipe, we clarify, that we are in favour of it	claim	
56.2		if then they reconstruct the ecosystem	qualifier	
56.3		because it has a great potential and it would be silly not to reconstruct it.	warrant	
57	Teacher	You would ask that they take some steps in order...		
58	Isaías G 3	No. First the pipe must be built as it is and then they have to repopulate animals and plants (...)	claim	Drainpipe, yes
60.4	Julio G 1	If they drive the sewages (from industries) to a place where it wouldn't damage the pond and they place a purifying plant	warrant	Alternative: purifying plant
60.5		then the pipe won't be needed (...)	claim	no need of it
62	Isaías	If the engineers, who know more than we do, made a project, it would be a reason for it...		Expertise
63	Fran	They don't know a word!		Expertise
64.1	Isaías	I don't agree with this		
64.2		I think that if they did it this way there should be some reason.	warrant 1	expertise
64.3		The economy is very important	warrant 2	
64.4		We must be practical	warrant 3	values
64.5		and if they did it that way it is because there is no more money. (...)	warrant 2	
65	Teacher	You speak as someone directly affected: do you feel like one?		
66	Isaías	I don't know, people are not aware of the problems, people are not conscious of anything. You don't feel that people in the area see it as a problem		lack of awareness of "others"

It is interesting to analyze the reasons (warrants, in Toulmins' terms) that Isaías offers when justifying the position of his group in favour of the drainpipe. The reasons are not in terms of environment, pollution or otherwise but in terms of what we interpret as “common sense” values: practical vs idealistic views, “we must be practical”; importance of money and economy; and the knowledge attributed to the experts, in this case the engineers who wrote the project. It is worth noting that he comes from the town near the marshes and the teacher prompts him to speak as someone directly involved in the problem. Then he

diverts the argument towards the lack of awareness of the population. All in all he is implying that he does not like the project but that you have to accept it. The arguments of Isaías in lines 49, 62, 64 and 66 are represented in Toulmins' layout in figure 2

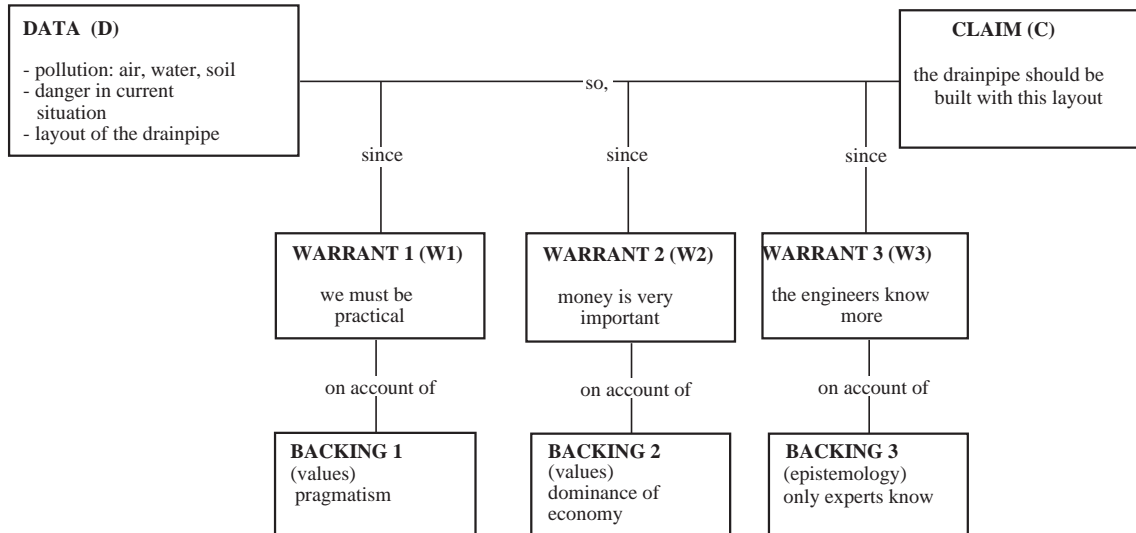


Figure 2. Isaías argument lines 49, 62, 64, 66

The variety of different solutions offered by the other four teams could be noted: a different trajectory for the pipe or for a section of it, a purifying plant placed in the industrial area. None of the groups gave a simple negative to the drainpipe, they offered alternatives. It was this variety, the reasons offered and the careful reports which convinced the engineer responsible for the project to participate in a debate with the president of the environmentalist group in front of the class. As an instance of the positions against the projected drainpipe, the argument of Ismael and Orencio from group 6 is represented in Toulmins' layout in figure 3

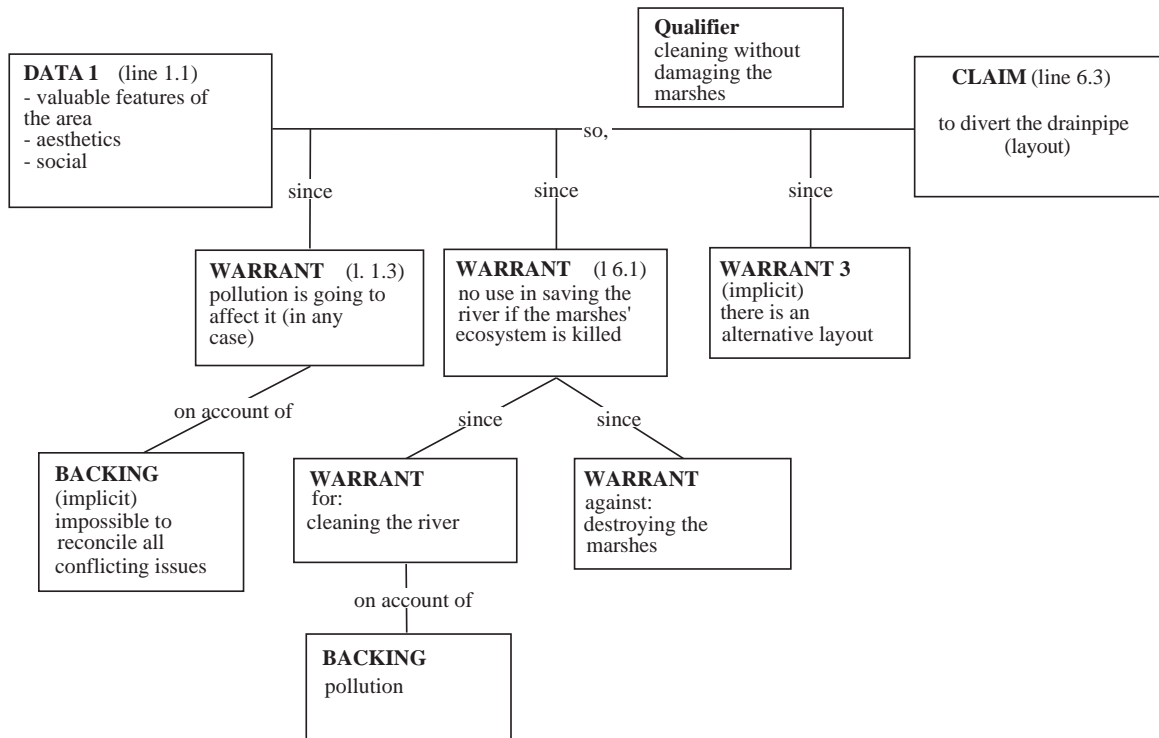


Figure 3. Group 6 argument, lines 1 and 6

Common features in the arguments

The arguments from the five groups opposing the new layout of the drainpipe share, in our opinion, a number of features summarized below. Not all the aspects mentioned appear in the excerpts given above, but in the full transcription.

- Awareness of the importance of taking steps for cleaning the river (all groups). It is not an opposition to a drainpipe, but to this particular layout.
- Awareness of the importance of mature ecosystems, and the dangers involved in going back to the first steps of ecological successions (mentioned by groups 1 and 5).
- Acknowledgement of the category of experts to different persons and instances, not only to technicians (engineers) but also to environmentalists (groups 1 and 5).
- Acknowledgement of the existence and importance of different values: ecological, aesthetic and not only economical: groups 1 (ecological), 2 (historical), 4 (economy is not the most important), 5 (area of natural interest), 6 (aesthetic, social).
- Ability to assess different dimensions of environmental impact of human actions in the ecosystem (all groups).

There are other questions, such as the high involvement in the task, which caused some students –who in the first part of the term had failed in almost all subjects– to take a new interest in science and even in the school. Another issue is the

difficulties and benefits that they find about the groupwork, that cannot be discussed here in detail.

Discussion and educational implications

In summary it can be said that the students were involved in the tasks and activities in the unit to a high degree. It seems that the design, using a real problem, and the way the teacher managed the classroom, giving them responsibilities in the reports, attending to their suggestions, proposing new activities –such as the debate with the two experts– was adequate for motivation and developing an interest. Our interpretation is that this speaks for the importance of dealing in the classroom with issues which can be appreciated by students as having relevance to their lives outside school.

There are, beside this, some features of the design of the unit which, in our opinion, are effective in promoting argument in the classroom. For instance the complex nature of the problem which couldn't be dealt with simple "drainpipe yes" or "drainpipe no" arguments. The problem is, we believe, representative of many environmental issues which involve conflicts between different positions and interests or groups of people. The jigsaw technique, which required all students to take the responsibility for sharing their knowledge with others, was also helpful. Asking the students to elaborate a material "product" as Duschl and Gitomer (1996) propose, reports, maps, sketches, helps them to refine their arguments in order to be clear and convince others. And the portfolio system, the recollection of all the materials and answers of each student, promoted metacognition, being a guide in the reflection that students were asked to write about the changes in their opinions.

The argument patterns about an environmental issue have distinctive features compared with other related to more conventional science topics, such as Genetics (Jiménez, Bugallo & Duschl 1997), or buoyancy (Álvarez 1998). For instance, in environmental issues there is not an unique argument of reference which represents the experts view, and at the end of the unit we could write arguments from students with different warrants from the one in figure 1. Another issue which emerged from the analysis of the students' arguments is the importance of values (pragmatism vs utopian, economic vs ecological etc) which act as implicit or explicit backings in them. This again is different from other science topics where models and theories are used as backings. The goals in an environmental issue are related, not only to the application of scientific concepts and patterns, such as ecosystem or succession, but also to the development of criteria which could guide decision among different options.

There were some difficulties encountered during the development of the unit which should be taken into account by people undertaking similar paths. It took a long time, which caused reduction of other topics from the curriculum. The students are not used to work in teams and they spend too much time in reaching a consensus about strategies for the tasks. They find difficulties also in the selection

and handling of information, and part of the information given to them (for instance about the way the quarry is damaging the landscape) was never used in the reports. Perhaps, as we discuss in another paper (Brañas & Jiménez 1996), this could be attributed to the scarce attention given to environmental problems related to geology as compared to other issues which affect plants and animals. The exploration of the relationship among the arguments and the biological and environmental knowledge could be an interesting line for further research.

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*THE ROLE OF BIOLOGY TEACHERS IN
INTERDISCIPLINARY ENVIRONMENTAL
TEACHING AND LEARNING CONTEXTS*

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**Interdisciplinary teaching and learning through environmental
education: problems and research questions**

Environmental studies are part of the core curriculum in senior high schools. However, there is evidence that merely science teachers and above all biology teachers feel responsible for teaching and learning settings concerning environmental issues. And there is evidence too that those issues are treated mainly as environmental science studies rather than as complex interdisciplinary problems including social aspects as well. Recent environmental social studies put forward that environmental problems are mainly questions of collective and individual life styles, acting patterns and conditions (Fuhrer 1995, Kaufmann & di Giulio 1996, de Haan & Kuckartz 1996). Following those findings environmental issues have to be seen in a wider sense as cultural and subjective interpretation phenomena, not only as objectively measured scientific facts (de Haan 1995). Individuals and social groups are constructing their own view and interpretation of observations and facts according to their values, social contexts and life goals.

Concerning EE it can be concluded from recent research outcomes that teaching and learning has to focus on analyzing social systems and on the question under what conditions those systems will develop towards sustainability. By exploring social systems students analyze individual and collective acting and critically reflect causes of human impacts on the environment, individual and collective values and conditions of human acting. We described that kind of approach as a critical socio-ecological EE (Kyburz-Graber et al 1997a, b; Kyburz-Graber 1998).

In order to study and analyze how teachers develop curricula of interdisciplinary problem-based learning in the light of a critical socio-ecological EE a research project was launched some years ago. Former research outcomes indicate that boundaries in professional development and disciplinary thinking are probably much more influencing the way of teaching and learning than external boundaries

like infrastructure in schools and timetable (OECD-CERI 1991, 1995, Kyburz-Graber et al 1995).

Our research interests concerned the following questions:

- How do teachers and students develop local curriculum in the light of critical environmental education based on exploring local social issues?
- What kind of teaching-learning culture arises from that environmental education approach?
- What are the conditions of a critical socio-ecological approach to EE in senior high schools in terms of internal personal prerequisites and external school structure?

Research design: case studies on interdisciplinary environmental education in senior high schools

We invited teachers to collaborate in the theoretical development of critical socio-ecological approach to EE and to initiate school projects. Seven school-based in-service seminars were offered to each teacher team. Conditions for the collaborating teachers were: building up an interdisciplinary teacher team (at least four teachers of different disciplines) and attending the seminars and realizing school projects.

Methodology of case study research

The overall aim of our research study was to explore the reality of critical socio-ecological EE with respect to conditions, prerequisites and EE concepts of teachers as well as with respect to school framework and its influence on teachers in the specific context of schools. Case study analysis is an appropriate methodology used to analyze complex social situations with a large number of variables (Yin 1994). It seeks to provide answers to questions of Why and How in a specific social situation rather than What and How many. The scientific background of case study research is the hermeneutic approach to understanding a special context. In a first step a case study research is descriptive. In a second step it is explorative by questioning causes and backgrounds of the described phenomena. And in a third step a case study can also be explanatory if theoretical interpretations are developed out of data analysis. Yin argues that the better the theory basis for data analysis is the more a case study research can be performed as an explanatory research instead of only descriptive. In reality generating the theoretical basis of a case study is an iterative process between theoretical reflection and analyzing data. Case studies build on multiple sources of evidence and on data analysis by triangulation.

We used multiple-case design to explore different school contexts and to work out similarities and differences in main questions of teaching and learning EE. To use multiple cases design means to follow a logic of replication which is based on theoretical reflection rather than on large numbers of samples. It is asked if each

case reveals the same syndromes in spite of different contexts or, if this is not the case, the theoretical background has to be questioned.

Data basis of our case studies was built on in-service seminar protocols, reflections and outcomes, questionnaires, group discussions with teacher teams and students, project documents and reports of talks, telephone calls and letters. Data were transcribed, codified, summarized in clusters and used for descriptive and interpretative steps of content analysis (Mayring 1993, Miles & Hubermann 1994)

Primary analysis on interdisciplinary teaching and learning incl. main outcomes

While working with the teachers a new aspect emerged which we had not expected as strongly influencing the teachers' collaboration and school projects: The role of biology teachers. We started therefore a secondary analysis of the collected data exploring features of the biology teachers' roles and their effects on local interdisciplinary curriculum development and professional development.

Secondary analysis on the role of biology teachers

The theorybasis was taken from the outcomes of the primary analysis that is the concept of critical socio-ecological EE including questions of participatory teaching and learning. The research questions are:

- How did biology teachers use the theoretical concept of critical socio-ecological approach to EE? What was changed compared with their previous concept of EE and in their teaching style in the light of professional development?
- What role did the biology teachers play during the process?
- How was the effect of biology teachers on their colleagues and on students?

The secondary analysis was based on the same data material as the primary analysis. All data were selected from the material which concerned biology teachers. Data were condensed in several steps to brief descriptions of the situation of the biology teachers in the four schools.

Research outcomes on the role of biology teachers

Brief portraits of four schools

Eight biology teachers participated in four school projects. A fifth school is not included in this secondary analysis because in that teacher team no biology teacher participated. The projects of the four schools were:

- School A: School cafeteria
- School B: River recreation places
- School C: Lakeside recreation places
- School D: Shopping center

An overview on the four school projects is given in table 1.

Table 1. Overview of the four school projects

project title	Interdisciplinary teacher team	classes; age of students	content aspects dealt with in the project	methods used in the project
school cafeteria: How can the school cafeteria contribute to sustainable food production	5 teachers disciplines: biology, geography, history	2 classes 17 year old students	origin, production and variety of food offered in the cafeteria; waste of the cafeteria: inside and outside of school; waste discipline, action week	Collecting information, diet diary, interviews, excursions, discussion with experts, presentation of outcomes, organizing action weeks in the cafeteria
River recreation places: How much and which kind of recreation the natural and social environment is capable of carrying?	11 teachers disciplines: biology, chemistry, economy, English, French, geography, history, mathematics physics	2 classes 16 and 18 year old students	Analysis of use modes in the system, use conflicts, solutions communication between young and old people, recreation activities, impacts, fauna	observation, personal experience, interviews with people concerned and experts, collecting information, designing maps, chemistry analysis, photo-documentation, exposition, planning and realization of a beach-volley field
Lakeside recreation places: How much and which kind of recreation the natural and social environment is capable of carrying?	7 teachers disciplines: biology, German, geography, psychology, design	3 classes 17 and 18 year old students	Inquiry in a nature protection area: plants and animals, recreation activities and behavior; market strategies concerning the area; history of the lake; values and thinking in complex situations; origin and effects of UV radiation	Field observation, vegetational maps, photo-documentation, designing maps, collecting historical and recent information, interviews with people concerned (tourists, inhabitants, professionals), survey by questionnaire, simulation game, analysis of PR actions
Shopping center: What kind of consumption can our society afford?	4 teachers disciplines: biology, English, German, geography/history	1 class 17 year old students	History of the shopping center (s.c.), landscape planning, "sound landscape" of the s.c., open and hidden PR, images of the s.c., views of people concerned (customers, staff, direction)	Introduction into ecology by the example of the s.c., document-analysis, individual work experience in the s.c.; survey by questionnaire, interviews, photo-documentation, production of learning material for young students

The situation of the biology teachers in each of the four schools is shown in the following brief case descriptions.

School A: School cafeteria, 2 biology teachers (AR, AS), 2 classes

The subject of the school project is early defined by all 5 teachers. Changing something visible in the school cafeteria is especially the idea of the two biology teachers. In the course of the in-service seminars they are demonstrating that scientists are practitioners and like to work on concrete and handy problems, 'taking the shovel'. They expect from the research team recognition and acceptance. Both of them want to work with the critical socio-ecological concept for EE but are afraid that the subject could be too complex for their students. They want the students to make experiences by themselves, on the other hand they repeatedly ask the question: 'And what about, if nothing comes out of the project?' Uncertainty and not knowing the outcome of the process they feel as something threatening. Biology teachers discuss about the demand of scientific work of students: Does inquiry need to satisfy scientific standards?

In the first part of the project they determine the teaching-learning process, in the second part they leave it to the students to do their group work. Several times they talk about uncertainty. Teacher AR initiates a discussion with students what he has never done before. AS asks students for written feedback which is given by 6 of 20 students. In the end both biology teachers recognize that they should have included the students right from the beginning: 'It was the aim that it would be their (the students') project and not ours. But that was a failure right from the beginning' (AS). And another self-critical statement: 'We thought that we could sit down in the in-service seminars and consume. We did not expect that we had to do curriculum development work. We did not use the suggestions from you researchers.' (AS) The biology teachers agree that they have expected more support from the research team.

School B: River recreation places, 2 biology teachers (BR, BS), 2 classes

In one class the school project is predefined to be part of a study week. The teachers of the other class are open for an new approach. Both biology teachers see environmental action of the students as the main goal. BR is interested to 'jump in something unforeseen'. He expresses repeatedly that he does not feel comfortable with an open, not pre-defined situation. He prefers to give defined tasks to the students they can use for observing their environment. He hopes to evoke curiosity within the students. Biology teacher BS wants to introduce students to ecology by system theory. Despite of suggestions to bring ecology closer to students everyday life the teacher holds to her pre-existing idea. BR confesses that he would not dare to initiate an open teaching-learning process if the research team had not 'thrown him into the water'. In the final discussion both biology teachers state once more that practical change was their main goal for EE and that they were disappointed that nothing real happened. BR claims that a skiing camp would have led to the same result as concerned improving social relations. Finally he admits that interdisciplinary work was useful for him - earlier he had confessed that he was afraid of cooperation especially with teachers of the same discipline. He feels that his colleague (history teacher) is better qualified for helping students in group dynamic problems. He as a biology teacher does not feel competent except in problems concerning biology. Regarding the project as a whole he concludes that students did not ask him as a biology teacher. He thinks that he would have needed more 'tips' in order to maintain his initial strong motivation. In the end both biology teachers feel somehow disappointed. BS admits that she did not really join the project.

School C: Lakeside recreation places, 2 biology teachers (CR, CS), 2 classes

The biology teachers feel responsible for the project because they were asked first by the school leader to participate in the research project. CR is interested because he is highly engaged in local nature protection activities, CR is interested to learn more about EE. CR has decided ahead that he wants to introduce his students into a significant lakeside area and show them protected plants and birds. He looks upon human beings as being outside of nature. During several in-service seminars CR talks of his ideas about teaching nature protection. His colleagues have no chance to talk him out of his ideas. CR is convinced that biology is much more important than anything else and therefore he wants to give priority to thorough nature observation. He cannot imagine that social science methods to analyze social systems could be used in the same high standard as nature science methods. Biology teacher CS first starts with guided instruction but then opens up the project for the students so that they finally find their own questions. He does the project in team-teaching with his geography colleague. The students had taken the initiative to talk with the research team about the philosophy of critical socio-ecological EE and consequently demanded a self-responsible learning process. Several times during in-service seminars the question emerges how good and useful it is to initiate discussions in classroom. CR argues that he has no time for discussions because 'birds outside in the nature are not waiting with their breeding' and he wants to show it to his students. The situation turns when the students of CR want to discuss with the research team like their colleagues in the parallel class. Later on, in agreement with their teachers students join the in-service seminars. Students are interested in real project work where they can bring in their interests. 'It is a hard mirror', CR says after a feedback discussion in a seminar where students strongly criticize him. From that time CR is rather quiet and listens to his colleagues and his students much more than before. He recognizes the need for negotiating common goals with the students. CS who was open to the needs of the students confesses that he would not have been able to stand an open process if he had not cooperated with his geography colleague. For CS it is difficult not to be accepted as expert in an open teaching-learning process and to 'stand the situation that disciplinary knowledge is not asked by the students'. He is uncertain what his new role is in an interdisciplinary process.

School D: Shopping center, 1 biology teacher (DR), 1 class

The subject of the school project is chosen in the first in-service seminar by all four teachers. Biology teacher DR wants to give an introduction into ecology as he usually does for classes according to the curriculum. Nature circles, nature without the shopping center, biotops of animals are questions he wants to work on. His planning does not include the social system approach. His colleagues and the research team suggest a more adequate approach, they develop together the idea of exploring ecological terms and issues in the shopping center itself. DR feels uncertain how students would get active by themselves and find their own questions. He does not dare to try new ways of ecology teaching. By his colleagues he is finally forced to coach a student' group preparing a questionnaire for staff, customers and direction of the shopping center. DR does not feel comfortable with his task, withdraws himself more and more and at last does not even join the final discussion of the researchers with the teacher team.

In the following section we are regarding the outcomes under three aspects: the roles of the biology teachers in the process of the in-service seminars, in the process of the curriculum development and in the teaching-learning process.

Roles of biology teachers in the process of in-service seminars

In the beginning of the in-service seminars the biology teachers were looked upon and accepted as experts for EE. School leaders partly unconsciously underpinned that role asking first biology teachers to participate in the research project. In schools A and C biology teachers strongly influenced the discussion in the seminars and used quite a range of time for presenting their arguments for what they had decided to do in the school projects. In all four schools the biology teachers brought into discussion ideas they had developed ahead, alone or in discussion with their colleagues (school B). We did not find one case where biology teachers first listened to their colleagues what they thought of an appropriate curriculum for critical socio-ecological EE. Biology teachers were interested to get inputs from the researchers but did not really use them for developing new approaches to EE.

Roles of biology teachers in curriculum development

In almost all of the curriculum development situations the biology teachers followed mainly their own and previously developed ideas of how to contribute to the interdisciplinary school projects. If some of them picked up suggestions of the research team or their colleagues it concerned special aspects of the curriculum development as for example the menu-journal and working with subjective concepts of students in school A. In school C biology teacher CS started a completely new approach forced by his students who had expressed their anger about the process they qualified as normal and directive. By the support of the research team teacher CS was encouraged to experience an open process together with his students and to let them find their own questions. In school B the teacher team chose a similar start for the school project. In that case it was not the biology teacher who influenced the decision but the teacher team as a whole wanted to experience a new approach.

In all schools neither the teacher colleagues were able to influence the biology teachers' contribution to the curriculum project nor did the biology teachers bring into discussion their disciplinary view. The primary analysis had revealed that the teacher teams had important interdisciplinary discussions about social and ecological relations, historical aspects, interdependence between nature and human beings and about values. But those aspects were mainly mentioned by others than biology teachers and none of the teachers further developed those aspects within the school projects (Kyburz-Graber et al 1997b).

It can be concluded that biology teachers played an important role as far as concerned maintaining the traditional role within EE. With respect to the development of aspects of a critical socio-ecological EE the biology teachers' role was marginal and in some cases rather blocking.

Roles of biology teachers in teaching-learning processes

It can be said that probably in all schools the biology teachers made some progress in reflecting their teaching routines in classroom. Even in school D where the biology teacher was more and more withdrawing himself from the

common process, some irritation could be recognized concerning his role in an open interdisciplinary teaching-learning process. Compared with the teachers of other disciplines it was striking to see that biology teachers were strongly concerned with the question what an adequate teaching-learning style might be in a project where students themselves developed their questions. What is the role of a science teacher in a situation where students want to feel self-responsible for their group work and outcomes? Biology teachers were fundamentally touched in their self concept of a science teacher who they thought to be responsible for scientific knowledge transmission and for the learning processes of their students. That irritation was ongoing during the whole project and when we finished with the last seminar some of the biology teachers felt that they were ready for really changing curriculum and teaching-learning culture.

The significant roles of biology teachers in interdisciplinary EE

In all schools the biology teachers played a significant role among their colleagues:

- School leaders first asked biology teachers to participate in the project
- Biology teachers were recognized as experts for EE among their colleagues in their schools
- Biology teachers were generally dominant in the discussions during in-service seminars and appeared to know ahead what kind of EE was appropriate and which was not.

Interpretation of the data leads to two main types of biology teachers' role in the interdisciplinary teaching-learning settings: the type of professional development and the type of persistence.

The type of professional development

Whenever a biology teacher made progress in his professional development he did it parallel to his colleagues. The question arises: Did the biology teacher influence his colleagues in their professional development or was he influenced by his colleagues? There is evidence in all cases that the biology teachers were not those who were most progressive but that they were rather hesitating and waiting for what would happen. From that it might be concluded that biology teachers learned from some of their colleagues who encouraged biology teachers to experience a new approach to EE. In the case of school C biology teacher CR persisted for a long time on his biological concept but finally significantly changed his view about teaching-learning culture in EE. It was probably him who made the most important progress in professional development.

The type of persistence

There can be recognized another type of biology teachers: remaining persistent during the whole project either by withdrawing (school D) or remaining indifferent towards new inputs (school B). However, our hypothesis, that persistent biology teachers blocked up their colleagues could not be verified. It has to be admitted that they played a crucial role influencing the atmosphere of the in-service seminars in a rather pessimistic way. But their colleagues seem to

have been still motivated and strong enough to go their own way in local curriculum development and in their teaching-learning development.

As a main outcome it can be summarized that the role of biology teachers was either making progress together and with the support of their colleagues of different disciplines, or withdrawing from the process respectively remaining indifferent. There was no case where biology teachers were more innovative and progressive than their colleagues. Biology teachers thus had not that leading position in a critical socio-ecological approach to EE which is generally expected they have in EE. The opposite was observed: where biology teachers were ready to make progress it was also - certainly not only - thanks to their colleagues who were open to new approaches. Biology teachers who were resistant to what we might call a new paradigm of EE first retarded the interdisciplinary curriculum development process but finally did not really make it a failure. In all schools there were finally some teachers of different disciplines who were convinced of the new approach to EE and judged it promising for future interdisciplinary teaching and learning in general.

Discussion: Subjective conflicts as a cause for professional development

Some biology teachers came to make significant progress in their professional development and others did not. How to explain this phenomenon? What may be causes for professional development at all?

One of the reasons for persistence may be seen in the socialization process of biology teachers: They are natural scientists and have developed a self concept of a science teacher being responsible for the transmission of objective scientific facts. Their understanding of environmental problems is based on natural science. It is interesting to see that interdisciplinary environmental science research is currently regarding environmental problems as social issues (see e.g. Fuhrer 1995). We did not meet biology teachers in our research who were aware of this paradigmatic change. Furthermore they did not seem to be interested in questions concerning social science knowledge about environmental issues. And they seemed to be afraid of losing their identity and their image as science teachers while working with social questions.

Changing the perspective from persistent biology teachers to those who professionally develop it can be reasoned that professional development was possible where biology teachers met a striking situation: They suddenly were exposed to the situation that they - in their view - did a good job as biology teachers but the students did not accept the teaching mode of their biology teachers any more. It was a cognitive conflict that forced those biology teachers to reflect on their self concept as a biology teacher. This happened where students took the initiative to participate in the process (school C) or where biology teachers attempted to ask their students about the teaching-learning process (school A). Reflection turned out to be an important means of professional development to overcome the cognitive conflict. It is the active learning of the

teachers which enabled them to handle the challenging interdisciplinary teaching and learning. The mere transmission of a new concept for EE did not bring significant progress in teaching and learning. This outcome has to be taken in account planning in-service training courses.

Conclusions

The various steps in analyzing the dense data material allowed us to come to some generalization concerning the situation of biology teachers in interdisciplinary teaching-learning settings. In discussions with students we recognized that it could be exactly the interest of biology teachers for social processes that might bring biology more closely to the life reality of the students. As a student expressed it like that: To realize that our biology teacher does not know all was a very good and significant experience important for our own future as teachers. What could be a constructive role of biology teachers within interdisciplinary teaching-learning settings? Social aspects in environmental problems open up a range of interesting questions for biology teachers as for example: How do human beings construct their knowledge about the environment and how do they develop themselves in relation with the social and natural environment? How do different social groups perceive and interpret nature? Which size of a social group does influence individuals in direction of a pro-social acting? Working on such questions needs openness and courage from the part of the biology teachers. Regarding current developments of society it can be guessed that biology teachers are anyway forced to face new questions may be pretty soon.

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WORK IN PROGRESS

MAPPING ACCESS TO FOOD IN DEPRIVED AREAS: AN EDUCATIONAL PERSPECTIVE

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Abstract

The issue of access to cheap and healthy food for those living in poverty is now part of the social and health agenda in the United Kingdom. The pilot study described in this paper is investigating access to healthy food in a deprived area of London. The study has three interrelated elements: the local community, the school as part of the community and geographical mapping. The paper focuses on the work that has been undertaken with primary schools in the study area, identifying the strategies being used to collect data and outlining some preliminary findings.

Introduction

'if the nearest supermarket is miles away or the bus doesn't go there when you can, it can be difficult to buy food that is cheap and healthy.'
(Department of Health, 1998)

The United Kingdom is, by world standards, a relatively wealthy nation. However, one in four of the British population (13.8 million people) live in households with incomes below the European poverty line of half average incomes; 9.6 million are in households receiving income support and the rest live on low or insecure wages (Department of Health, 1995).

The national (household) survey, that is published annually by the British government (MAFF, 1996), consistently shows that nutrient intakes are less likely to be adequate in the lowest income groups compared to the highest. There is also evidence that those living in poverty, including children, are more likely to have significantly lower intakes of many vitamins and minerals (MAFF, 1996; Gregory et al, 1995; Department of Health, 1989; Bolton-Smith et al, 1991). Whilst intakes below the Reference Nutrient Intake (RNI) (the amount of a nutrient that is

sufficient to meet the dietary requirements of almost all individuals) are cause for concern such children may still have an adequate intake to meet their requirements. The diets of children from poor families also tend to be high in fat and sugar (Department of Health, 1989).

It appears that individuals who are poor are more likely to suffer from ill health and to die at an earlier age; diet is one of the contributory factors (World Health Organisation, 1990). A key aim identified in the recently published consultation paper, *Our Healthier Nation* (Department of Health, 1998) is:

"To improve the health of the worst off in society and to narrow the health gap." (p 5)

In order to achieve this aim the government intends to develop a national contract for health. Schools are identified as having a key role to play in promoting health in the community through their work with parents, guardians and carers as well as children. This identification of the role of schools in developing health in the community is consistent with the aims of the 'Health Promoting Schools in Europe' initiatives (World Health Organisation, 1993). Health education is considered to encompass all aspects of the life of the school and its relationship with the community. The school environment is an intrinsic and vital element in the successful promotion of health and the importance of the aesthetic as well as the physical environment is recognised, for example in school dining rooms. All those involved in schools, teachers, caterers, parents and pupils have an important role in promoting health as active participants and role models.

The model of the curriculum that informs the Health Promoting Schools in Europe initiatives is a broad one that includes:

- the interaction of physical, mental, social and environmental factors;
- pupils as active participants;
- using a range of teaching methods;
- developing knowledge *and* skills;
- recognising factors that influence pupils' health;
- taking account of pupils' existing ideas, beliefs, values and attitudes;
- developing positive self-image;
- helping individuals to take control of their lives.

This model provides a useful framework for the health related research in schools and the local community that is described in the following sections of this paper.

Mapping access to healthy food

The research project 'Mapping access to healthy food in a deprived area', which began in September 1997, is a two year pilot study that has two broad aims:

- i. to develop indices of access to healthy food in a deprived area in inner London, using systematic quantitative and qualitative survey instruments with Geographic Information System (GIS) software to generate maps.
- ii. to examine the potential both for informing joint local health strategies and for contributing to health policy development in local schools.

The principal objectives of the project in relation to education are:

- i. to develop appropriate indicators of healthy food for different ethnic groups in inner city London;
- ii. to involve local communities in the measurement of food access, and identification of potential local solutions;
- iii. to work with local primary schools serving the research area, in generating information and developing Information Technology and other educational resources for health promotion in nutrition and food access;
- iv. to contribute to local health promotion strategies and the local council's anti-poverty strategies;

The first phase of the study has involved the collection of information on availability, suitability, cost and access to healthy food. Three broad approaches to data collection and analysis have been employed:

1. *Work with the local community;*
2. *Work with Primary schools;*
3. *Geographical food survey.*

During the initial phase of the study contacts were established with schools, community dieticians, the local partnership and research unit, Asian Women's Resource Centre, Tenants' Associations, a Housing Action Trust, the local Health Centre and various local community institutions. Through these contacts, preliminary work on beliefs about healthy diets has begun with key informants and local groups of tenants and users of local institutions. Information has been collected about the main places where people shop for food; how they get there, the cost, ease and reliability of transport, and perceptions on quality of local food and barriers to shopping for healthy food.

The plan is for local children to be involved in collecting and analysing information about food and nutrition's role in their own health, and about local food sources and varieties. Access to food has been defined in a broad way to include physical access, for example to school meals, as well as access through the curriculum. The study aims to contribute to teaching in science and health education as well as geography, including geographical literacy, and mathematics and to lead to the development of health education and health promotion materials for use in other schools.

A food price and availability survey has been carried out within a two km radius of the two estates that form the focus of the study, with partial extension to include well known superstores and specialist food shopping areas to which particular ethnic groups may travel. For each of the main ethnic groups in the area: White UK/Irish; Black Afro Caribbean; Black African (mainly Somalis) and Indian Asian (mainly Gujarati Hindu), a price/availability checklist for foods has been constructed drawing on local empirical research and the literature. Some foods are common to all lists, some are particular to specific eating cultures. Sometimes 'healthier' alternatives have been substituted but, in the main, the

foods are those which would normally be chosen, with emphasis on fruits and vegetables. The lists are not designed to be prescriptive but, if foods were consumed in the right quantities, would enable individuals to meet current dietary guidelines

The analysis of data is an iterative process. GIS is being used to map places used for food shopping and to explore distances travelled. In addition shop characteristics and locations can be compared with local socio-demographic and socio-economic data. A series of maps has been constructed using price and availability indices.

This paper focuses on the work that has been undertaken with primary schools in the study area, identifying the strategies being used to collect data and outlining some preliminary findings.

Work in schools

Four primary schools, which are representative of the area, participated in the project from January to July 1998. The schools are located in, or near, the study area identified for the price and availability survey and were selected in consultation with the local Inspector for Science and after discussion with the head teachers. Although each of the four major ethnic groups (White UK/Irish; Black African; Black Afro Caribbean; Gujerati Hindu) in the area are represented in each school there is variation in the proportion of each group in different schools. Furthermore, the school populations are changing as families move in and out of the area and there are new influxes of refugees e.g. from Kosova.

The children are mainly from poor families. One indicator of poverty is the number of children entitled to free school meals in the middle of the day. In the participating schools the number of children receiving free meals varies from two thirds to three quarters of the children having meals. These figures are much higher than the national average; in England it is estimated that one in three children are eligible for free school meals (Department of Health, 1998).

In each school, a *school profile*, that includes the role and usage of food, has been constructed to contribute to knowledge and understanding of the local community. We are particularly interested in what pupils say about their experience of eating in school and access to food. The school profiles provide information about:

8. The pupils and their background;
9. School meals and packed lunches (provision, uptake);
10. School policies regarding food;
11. Schemes of Work relevant to teaching about food and nutrition;
12. Extra curricular activities and clubs.

The profiles are designed to help us to assess "access" to healthy foods in the broadest sense. Information gathered on school meals and packed lunches tells us what children are actually eating, hence, a form of *physical access*. The number of

children entitled to free school meals is an indication of poverty in the area. The school policies provide us with valuable information on how the school and/or the Local Education Authority contribute to the *pupils' access*, for example policies on eating sweets or crisps on school premises. And finally, by analysing what is being taught in the schools about food and nutrition we are able to address the issue of *access through the curriculum*.

In developing the profiles a number of methods of data collection have been used including:

- analysis of documents, for example, Local Education Authority and school policy documents and inspection reports;
- interviews with staff, including teachers and caterers, and pupils;
- observation of children in a variety of school settings including classrooms and dining rooms;
- diagnostic activities used prior to and after teaching;
- children's work, for example, drawings and written work.

The research team have worked in association with teachers in developing and trialling activities with pupils from 7 years (Year 3) to 11 years (Year 6). The activities have been planned to fit in with the schools' programmes of work on topics such as Food. The researchers have been involved in support and team teaching and have participated in visits to local supermarkets with children to investigate prices and origins of different foods. One outcome is a draft *resource pack* for teaching about diet and health that draws on the ideas and materials developed during 1997/98. The pack includes:

- suggestions for teaching approaches,
- activities sheets,
- laminated food pictures for use in teaching,
- *The Balance of Good Health* Information Pack (Health Education Authority, 1996),
- *Guidelines on Educational Materials concerned with Nutrition*, (Department of Health, 1996)
- information about organisations providing educational materials.

Schools that are participating in the project are being invited to use and to evaluate the packs during 1998/99.

The next phase of the study will include an investigation of how the methods and findings of the other elements of the project, including maps showing the location of shops, might be utilised by schools.

Findings

The purpose of this pilot study is to identify strategies that can be used to assess access to healthy food and the data being collected are mainly qualitative. Furthermore, the project is ongoing and only preliminary findings are available at present. The findings include information about:

1. children's views about diet and health;
2. school meals - provision, presentation, and uptake;
3. out of school activities and after school provision.

1. Children's views about diet and health - healthy and not so healthy.

Information about children's ideas comes from a number of sources, including:

- writing about 'dream' day and 'healthy' food choices;
- children's analysis of food diaries;
- food grouping activities;
- observation and discussions with pupils in school settings.

Foods selected by some individual pupils aged 7 to 8 years (Year 3) and 9 to 10 years (Year 5) for a 'Dream Day' and 'Healthy day' menu are shown in Tables 1 and 2. In some instances the food items selected for the two menus are similar - for example Table 1, Dan's breakfast. Fruit and fruit juices appear more frequently in the healthy menus. There are differences between the foods selected by younger and older pupils; older pupils' choices are more specific and describe a range of foods. Younger pupils tend to name specific products, such as Nesquik (a proprietary brand name drink). The differences can only partly be explained by older pupils being more experienced and confident writers.

Table 1. Dream day and Healthy menus: Year 3 (7 to 8 years)

PUPIL	HEALTHY DAY MENU	DREAM DAY MENU
<i>Div</i>	apple (br)* cookies (ln) sweet, ice cream (sn) rice and chicken (din)	eggs and bread (br) Nesquik and fruits (ln) sweets and chocolate (sn) rice (din)
<i>Mac</i>	apple (br) milk, carrot, broccoli, rice (ln) apple, pear, banana (sn) rice, carrot, broccoli (din)	cornflakes (br) beans, egg and toast (ln) cup of Horlicks and cake (sn) rice and chicken (din)
<i>Dan</i>	coco pops and milk (br) carrot, Tango# (ln) coke (sn) chapati, Tango (din)	coco pops and milk (br) pasta, coke (ln) sweets (sn) rice, Tango (din)
<i>Lyn</i>	cornflakes (br) fruits (ln) pear, apple (sn) rice (din)	juice (br) ? and coke (ln) cake and Tango (sn) apple and sweets (din)

* br= breakfast; ln=lunch; sn=snacks; din=dinner/supper

Tango = fizzy drink

Table 2. Dream day and Healthy menus: Year 5 (9 to 10 years)

PUPIL	HEALTHY DAY MENU	DREAM DAY MENU
<i>Shan</i>	mash potatoes with chicken (br) fruit cocktail (ln) biscuit and orange juice (sn) corn with pickles (din)	chilly dog and milkshake (br) McDonald's and milkshake (ln) chilly burger and more milkshake (sn) pizza and coke
<i>Ama</i>	cornflakes with warm oatmeal and milk (br) vegetable samosa, carrots, coleslaw, orange juice (ln) fruits and apple juice (sn) rice with vegetable sauce (din)	pancake with chocolate sauce and chocolate (br) crispy fried chicken and some big juicy chips (ln) ice pop, tuna sandwich and lemonade (sn) pizza, chicken nuggets and burger, can of Tango (din)

The *Balance of Good Health* plate, was introduced by the Department of Health after research into the most acceptable and useful representation of the balance of foods required to maintain health. Previous research (Turner et al 1997) has indicated that ten and eleven year olds recognise the plate as a pie chart which shows the relative amounts of different types of food that should be eaten in a 'balanced' diet. The sections on the plate correspond closely to groupings that pupils make when allowed a free choice (Turner, 1997). For pupils of this age the plate is therefore readily understandable. In the present study the plate was used as a starting point for teaching about food choice and food groups. Pupils were given blank pie charts and allowed to select foods to place in the different sections; they also analysed food diaries and placed foods eaten in the five food groups. The activities provided a means of assessing pupils' understanding and ability to apply their knowledge in real life situations.

2. School meals - provision, presentation and uptake

Meals served in the middle of the day are a feature of British schools (Coles and Turner, 1993). All four schools have meals supplied by the same caterer. A typical week's menu is shown in Table 3.

Table 3. Example of a typical school lunch menu

Week 4	Monday	Tuesday	Wednesday	Thursday	Friday
Main course: one	Chicken hot dog with BBQ sauce	Chicken casserole	Lamb roast with gravy	Alu Gosht with rice (mutton and potato curry)	Pasta Bolognese
Main course: two	Macaroni cheese	Cod fish cakes	Cheese and tomato pizza	Turkey burger	Tuna, egg and rice
Vegetarian	Veg. Curry with rice	Pasta Pommodore	Pakora	Vegebangers	Vegetable samosa
Vegetables	sweetcorn garden peas	carrots broccoli florets	spring cabbage mixed salad	baked beans	mixed vegetables coleslaw
Carbohydrate	potato smiles	creamed potatoes	roast potatoes	boiled potatoes	chipped potatoes
Sweet one	apple crumble and custard	American cookies	Chocolate sponge and choc. Custard	Bakewell tart and custard	Chocolate crispies
Sweet two	chocolate mousse	cheese and biscuits	fruit yoghurt	raspberry ripple mousse	fruit yoghurt
Sweet three	Seasonal fresh fruit	Seasonal fresh fruit	Seasonal fresh fruit	Seasonal fresh fruit	Seasonal fresh fruit

The menu indicates that there is a choice of main meal everyday, including a vegetarian meal, and that vegetables and fruit are always on offer. In addition bread and butter are available each day, as are orange flavoured drinks (squash) and tomato sauce. There is a four week menu cycle (Table 3 shows week 4). Copies of the menu are provided each term for children to take home to parents/carers; these are attractively produced with coloured cartoon characters designed to appeal to children. Information is provided about the energy value and nutritional content of a typical meal. The caterers stress the healthier choice that the menus provide: 'lower sugar options, more fibre', salads and vegetables, plus fruit. Interestingly no mention is made of fat content.

The menus reflect the multicultural background of the pupils and the need to be 'appealing', for example, 'smiley' potatoes. Some items, such as macaroni cheese and vegetable curry, are 'homemade' but most are bought in. Children are free to choose what they want to eat from the food available. In some schools children must select a vegetable (other than potato) but whether they eat it is up to them. Despite the range of foods available our observations in schools suggest that the

foods selected by children rarely include vegetables other than potatoes and may be limited to one or two items:

One in five pupils take fruit for dessert e.g. pear, orange. Very few pupils take the vegetables unless they are fried e.g. fried veggie sticks or fried smiley potatoes. One boy chose yoghurt and juice only, another baked beans and dessert; another baked beans and bread; another only custard. (McLellan-Arnold: Unpublished data)

Some of these selections are inadequate in terms of energy and specific nutrients (although this would only be of concern if the whole diet was inadequate).

The dining rooms, as in most primary schools, serve also as the school hall and gymnasium. Meals are supervised by 'dinner ladies' who help to serve food and to supervise children as they eat. Teachers in the four schools rarely ate school meals; some of those teachers who did commented on the poor, inconsistent quality of the foods provided. Lunch tends to be a noisy, rushed affair (see Turner et al, 1995) which can be daunting for younger children. The following observations in one school are not atypical of other schools in the study:

The school has a small kitchen, off the gym, from which the school meals are served. The small kitchen has a sink, refrigerator, cupboards. They also have portable hobs/ovens which are used in the classroom whenever cooking is done and also used by the after school club for their food preparation. But as these facilities are not adequate for whole school meal preparation, the school meals are brought in from outside.

Children eat in the gym where the school assemblies are held. Tables with attached stools are set up. The children use brown, plastic, moulded trays. The main dishes and the vegetable of the day are in unattractive, large, metal trays and the children specify what they want and the dinner ladies put it on their plate. The desserts and drinks are located on a separate table. The fresh fruit is in an unattractive metal container and served whole (i.e., not cut up or sectioned), the desserts, like cupcakes, are on metal trays and the pudding is in a tall metal saucepan which the younger children are too short to see into.

(McLellan-Arnold: Unpublished data)

One of the schools has a large kitchen that was used to prepare meals for five schools; these meals were transported in containers to the other schools.

In all of the participating schools pupils can either eat the meal provided or bring their own 'packed' lunch (the numbers vary in different schools from 10 to 100 pupils). The policy about where these children eat packed lunches varies between schools. In one school children bringing packed lunches sit separately; another school has abandoned this policy as they decided that children were having to sit apart from their friends during the meal. Observations during lunch indicated that a lunch box typically contained a sandwich (ham, chicken, peanut butter), fruit juice, fruit, chocolate or cake and crisps (or similar products). Two of the head teachers, who monitor lunches, expressed concern about the foods in some of

the packed lunches. They have tried to advise parents about packed lunches and to suggest changes, for example, a reduction in the number of sweets/chocolate provided. However, the suggestions are not always accepted or acted upon. One head, concerned about possible vitamin deficiencies in pupils, is attempting to reinstate milk for pupils (at a cost to each child of 10p per carton).

3. Out of school activities and after school provision

'Breakfast' and 'After school' clubs for children whose parents are working are increasingly commonplace in many areas of London. Food is normally provided from money paid by parents whose children attend the club. Three of the schools we worked with ran such clubs. In one school parents pay £1 for the breakfast club that runs from 8.00 to 8.50 in the morning and £3 for the After School Club (15.15 until 18.00). In this school up to 100 children are on the register, although generally only about thirty-five are present at any one session.

The observations on Breakfast and After School Clubs in one school provide insights into food provision:

Breakfast club: toast - lots! and cereals. 'Healthy' cereal were tried but children were not interested so they now have frosted and chocolate types. Milk and orange juice with no added sugar are available..

After school club: toast - lots; beans on toast; spaghetti on toast; chicken hot dogs. Fruit is also available although the person responsible thought she should serve more. She finds that when the fruit is cut up or sectioned the children fight over it but if served whole they tend to leave it alone. Sometimes they are served "cookery stuff" (i.e., what other classes have made during a cookery lesson). There are also plans to do some cooking with the group.

(McLellan-Arnold: Unpublished data)

For children who attend the Breakfast club, eat a school meal in the middle of the day and then attend an After School Club food eaten in school could be the only food consumed during weekdays. Thus schools play vital role in food access for some pupils.

Discussion

Schools are complex and multifaceted social organisations. The Government's Consultation paper *Our Healthier Nation* (Department of Health, 1998) and the Health Promoting Schools in Europe initiatives (World Health Organisation, 1993) emphasise the importance of health education and health promotion in schools as part of the community. School meals are currently the focus of what has been called by the Department for Education (DfEE) a 'Nutrition Mission for Schools' (DfEE, 1998) that is considering new nutritional standards for school lunches.

' Healthy schools need healthy school meals. That's not about making school meals boring or stopping children from enjoying what they eat. But it is

about applying some imagination to make sure children can enjoy what they eat and that what they eat is good for them.'

Tessa Jowell Minister of Health DfEE (1998).

Despite the government recognition of the importance of health education our work in schools has indicated that primary schools have other priorities at the present time, including raising standards in literacy and numeracy. These other priorities are not necessarily in conflict with the ideals of the health promoting school, rather they tend to divert attention from it. Thus health education, school meals provision and healthy eating may not be high on the agenda for action in the short or medium term. Parents too have other preoccupations; in the area of the study few attend Parent Teacher Association meetings or become actively involved in activities in school. Finding ways of encouraging greater involvement by the local community in school action plans in relation to healthy eating is one of the challenges facing us at present.

At the time of writing the school profiles and the findings of our work with pupils during the past year that are being discussed with schools. Staff are being invited to evaluate the teaching strategies and materials developed during the first phase of the project and to explore ways in which data from other strands of the research study, in particular the mapping activities, might be incorporated into work in science and geography.

It is our intention to extend the research to one of the local secondary schools in the area, preferably one that is attended by former pupils from the primary schools who have participated in the study during the past year. This work will enable us to investigate physical, social and curriculum access to food during secondary education.

Conclusion

Recent government consultation papers (Department of Health, 1998; DfEE, 1998) indicate that this project is both timely and important. The outcomes of our work in schools is providing evidence of access to food that has relevance to the targets set out in *Our Healthier Nation* (Department of Health, 1998) and will inform initiatives including the consultation on food provision in schools (DfEE, 1998).

At this stage it is too early to gauge how successful the project will be in achieving its main aim of informing joint local health strategies and for contributing to health policy development in local schools. However, the willingness of schools to participate in the project and to share their concerns and thinking about food related issues provides an encouraging indicator of what might be achieved during the second year of the project.

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*LEARNING FROM WORKED-OUT EXAMPLES
IN BIOLOGY: EMPIRICAL ANALYSIS OF
SELF-EXPLANATIONS*

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Introduction

It is one of the standard themes of genetics instruction especially on the upper secondary level how hereditary characteristics are transmitted from generation to generation. In this context, students become acquainted with Mendel's principles and the chromosome theory. To explain these fundamental biological concepts and to solve general problems, teachers normally use examples from the plant or animal kingdom or from the inheritance of traits in human beings. In instruction, such examples usually have the function to illustrate and concretize biological concepts and to demonstrate how they can be used to explain certain phenomena.

In this paper, a research project investigating the potential of learning from worked-out examples will be outlined. The aim is to promote the use of examples in instruction, and especially in teaching problem solving.

Theoretical background: Learning from worked-out examples

Learning from worked-out examples has been one of the focal areas of research on expertise. This branch of research on learning and instruction aims to find out what enables experts in biology, chemistry or physics to solve scientific problems better than beginners. Seminal studies in this field have shown that actively reconstructing the solution of worked-out examples is an effective way of learning in the natural sciences.

Worked-out examples are tasks with an exemplary solution in the form of text, diagrams or calculations that can be used as learning material. Depending on the learners' pre-knowledge, the solution can be worked out in more or less detail. Studies on the effects of learning from worked-out examples have proved that the latter are more relevant to the acquisition of knowledge than one might expect from their minor role in science instruction. Research results have shown that novices prefer learning from examples to traditional instruction and to reading

instructional texts (Pirolli & Anderson 1985, VanLehn 1986, Recker & Pirolli 1995). This preference occurs irrespective of the characteristics and the quality of the examples (Le Fevre & Dixon 1986).

Many students are able to reproduce biological content correctly in the classroom, but they are usually unable to use this knowledge in solving problems. In this respect, worked-out examples can be a great help to novices as they bridge the gap between the existing knowledge and the new problem. Beginners learn more effectively from worked-out examples than by trying to solve problems on their own (Sweller & Cooper 1985, Ward & Sweller 1990).

Since the seminal works of Chi and her group (Chi, Bassok, Lewis, Reimann & Glaser 1989, Chi & Bassok 1989) self-explanations have been considered the most suitable type of elaboration for learning from examples in complex, but well-structured domains such as the natural sciences. The essence of self-explaining is that the learner tries to explain to himself step by step the rationale of the exemplary solution. He regards the worked-out example as a kind of task that he tries to solve on his own using the given solution as feedback. According to Chi, de Leeuw, Chiu & La Vancher (1994) self-explaining can be characterized as follows:

- It is a constructive activity, i.e. new knowledge is generated.
- It facilitates the integration of new knowledge into the learner's knowledge base.
- It is a continuous process not following a certain pattern, but progressing step by step through the interaction between the learner's pre-knowledge and the textual information.

The effectiveness of self-explanations when learning from worked-out examples has been affirmed for several domains, among them biology and physics (physics: Chi, Bassok, Lewis, Reimann & Glaser 1989; Chi & Bassok 1989; Chi & VanLehn 1991; biology: Chi, de Leeuw, Chiu & LaVancher 1994, Ferrari & Chi in press). Using instructional texts on the 'Structure, function and behavior of the human circulatory system', Chi et al. (1994) were able to show that only little guidance is necessary to elicit self-explanations which then lead to higher learning gains. 14 eighth-grade students were only asked to self-explain after reading each line of a text passage.

There is a positive relation between the number and quality of self-explanations and the application of the information given in the example to solving novel problems. Good and poor problem solvers qualitatively and quantitatively differ in their use of self-explanations in learning. Successful problem solvers generate more and more profound elaborations and devote more time to doing so than unsuccessful ones.

The effectiveness of self-explaining is based on the fact that self-explanations support the integration of new information into the learner's pre-knowledge. This means that the learner does not just acquire new knowledge, but also applies his prior knowledge in a different context, thus updating and decontextualizing it.

Many good learners spontaneously use self-explanations, but, on the other hand, self-explaining does not necessarily occur when learning from worked-out examples. Whether it occurs or not, probably largely depends on the learner's motivation (Reimann 1997). However, as self-explaining enhances the integration of the new information into the existing knowledge, there are grounds for supposing that the learner's pre-knowledge is another important factor. An extensive pre-knowledge should lead to greater self-explanation activity since the information from the example can be related to the knowledge base in manifold ways. Furthermore, in learners with a profound pre-knowledge this integration should be more goal-oriented and thus enable them to produce more and qualitatively better self-explanations. Accordingly, there should be qualitative (and quantitative) differences between the self-explanations used by experts and those used by novices in biology.

Studies conducted in this field, however, have had contradictory results. Sometimes a difference was detectable between the self-explanations of experts and novices (Ferguson-Hessler & de Jong 1990; Pirolli & Bielaczyc 1989) and sometimes there was not (Chi & VanLehn 1991; Renkl 1997; Renkl, Stark, Gruber & Mandl 1998a).

The goal of the research project and the design of the study

It is the goal of the study to qualitatively and quantitatively analyze the self-explanations students use when learning from worked-out examples in the field of biology. The self-explanations will be investigated in relation to the subjects' prior knowledge and their learning gains. The data will be assessed with regard to:

- a) theory-based categories of self-explanation,
- b) the quality of the content of the self-explanations, and
- c) individual preferences for certain types of self-explanation.

The first sample will consist of 20 participants in the biology olympiad (biology experts) who have a sound biological knowledge and considerable expertise in learning from worked-out examples on their own. The subjects will be selected from among those students who have taken part in the second of two national selection competitions and who, in addition, have passed a learning strategy test (MLSQ, Nenninger, Myberg & Pintrich 1990) and a verbal fluency test (L-P-S, Horn 1962). It is important that the subjects have sufficient language proficiency as their self-explanations will be recorded in thinking-aloud protocols and in

retrospective interviews based on the stimulated-recall method. Both these methods require subjects with communicative skills. The second sample consisting of 20 biology novices will be recruited from among the participants in the physics olympiad. These should be equally experienced learners as the biology experts (and therefore have comparable self-explanation skills), but their biological pre-knowledge should be much lower.

To train the subjects in thinking-aloud and to freshen up their pre-knowledge, there will be an introductory session in which each subject will be given a text summarizing the prior knowledge necessary to understand the examples. This session will last for about half an hour. After that each student will have to work on a sequence of examples. There should be no time limit. (According to Renkl (1997) and Renkl et al. (1998) it may well be assumed that the time spent on working on the example has little influence on the learning outcome.)

The examples will be constructed in such a way that the subjects need between 1 and 1,5 hours to study them. During this learning phase, the students will be allowed to make notes or sketches. In order to be able relate these notes or sketches to the thinking-aloud protocols, the session will be recorded on videotape. This tape will be shown to the learners after they have gone through the whole sequence of examples. It will be stopped at certain points and the subjects will be interviewed on their learning process.

After these sessions, each learner will be given four typical tasks taking up the content of the worked-out examples, but of different complexity. These tasks shall provide information on whether the subjects are able to apply the knowledge acquired from the examples in solving novel problems requiring not too much transfer. A concept map relating the terms from the area defined in the example to the basic terms representing the most important pieces of pre-knowledge for understanding the example solution will be used as second method of measuring the learning outcome.

All previous studies have used worked-out examples from textbooks. This project, however, intends to use examples particularly suited to elicit self-explanations. For this reason, it is necessary to develop on two different levels (one text for experts and one for novices) sequences of six to eight examples linked to one another from the point of view of content and connected by short texts so that they form a sort of instructional course. With regard to the necessary pre-knowledge, the examples have to be constructed in such a way that novices in biology can acquire a simple representation of the example and experts an elaborate one. For

this purpose, two solutions will be worked out that do not only differ in the degree of difficulty, but also in the following points:

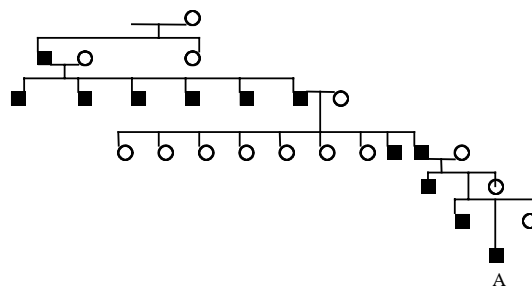
- 1) in the application of the underlying basic knowledge (the simple examples often specify the type of knowledge that is being used whereas the more difficult ones do not);
- 2) in the application of additional knowledge on how domain principles are used in the difficult examples (this knowledge is especially derived in the simple ones).

Worked-out examples for experts may contain more blanks than those for novices, i.e. the train of thought does not have to be described in detail.

In the following illustration, a worked-out examples with two solution variants is described.

A family in which a certain disease has occurred quite frequently has consulted a genetic counseling center. The young couple would like to know the risk of the disease occurring in their children.

In the course of the conversation, the following family pedigree has been drawn up.



(family pedigree from Jäckel 1993)

Task:

Try to predict the probability that the disease shows up in the children person A (person seeking advice) has with a phenotypically normal partner!

a) Solution variant for biology experts requiring a sound pre-knowledge:

Genes on the differential region of the human Y-chromosome are inherited only by males. The father transmits this region to his sons. In the above mentioned example the inheritance of the trait, a spontaneous mutation, is linked to the Y-chromosome. For this reason, person A will only have sons with the disease and daughters without it. Y-chromosomal inheritance is very rare. Only one human disease of the skin is supposed to be Y-linked and only the transmission of the

genetic character hairy ears, which is found with a relatively high frequency in India, seems to be a reasonable possibility of such a sex-linked inheritance.

b) Solution variant for biology novices requiring low pre-knowledge:

The first step is to find out from the pedigree how the trait is inherited. On this basis, the probability of the children having the disease can be determined.

- Even though looking at the parental and first filial generation it seems as if the disease were a recessive trait this is not likely because all children in the third generation are affected. (In the case of a recessive trait there would also have to be healthy children).
- In the case of a dominant trait linked to the X-chromosome, the disease would also show up in girls in the fourth generation as the father (third generation) would transmit his defective X-chromosome to his daughters.
- In the case of autosomal inheritance it would not be plausible why only boys should be affected.

It follows from this that autosomal or X-chromosomal inheritance can be ruled out. Only Y-chromosomal inheritance can explain that all and only the male members of the family are affected. It could be supposed that a spontaneous mutation has occurred in the second generation. As to the probability of the disease occurring in A's children, Y-chromosomal inheritance means that A (a male person) will transmit his defective Y-chromosome to all his sons while all daughters will be healthy.

In the project, the worked-out examples will be supplemented by texts suitable to trigger off self-explanation processes. These texts will be formulated with regard to a theory-based categorization system for self-explanations. The examples will be selected so that experts can spontaneously use self-explanations belonging to all theoretical categories. Taking the before-mentioned task as an example, the following self-explanations may occur:

Theoretical categories:

Examples:

- | | |
|--|--|
| 1. Accretion of information by retrieving relevant knowledge from the long-term memory
→ <i>Retrieval-oriented learning</i> | - clarification of the meaning of terms
- interpretation of the family tree |
| 2. Accretion of information by generating new knowledge
→ <i>Comprehension-oriented learning</i> | - detailed reconstruction and comprehension of the individual solution steps |

3. Knowledge reduction through deletion of insignificant details → <i>Extraction of main points</i>	- Inferring the solution from the recognition that the disease only occurs in males, without reconstructing the intermediate solution steps in detail
4. Knowledge reduction by generating new knowledge → <i>Analogy-based learning</i>	- Inferring the solution by using the analogy between X-chromosomal and Y-chromosomal inheritance

General hypotheses and expected results

a) The relation of pre-knowledge, degree of self-explanation intensity and learning outcome:

Generally, it is expected that the level of pre-knowledge positively influences the number of self-explanations, and thereby the learning outcome.

Students with high levels of prior knowledge should elaborate more intensively on difficult examples, students with low levels of prior knowledge on simple ones.

Like the number of self-explanations, the learning outcome should depend on the interaction between pre-knowledge and example difficulty. Biology experts who explain the solution steps of difficult examples to themselves should achieve high learning gains.

It is assumed that experts and novices alike will produce the greatest number of self-explanations in categories 1 and 2. In addition, however, experts should produce comparatively more elaborations in categories 3 and 4 and formulate long and interrelated example sequences. Given the same number of self-explanations altogether, a greater number of elaborations in categories 3 and 4 should positively influence the learning outcome.

b) Quality of self-explanations:

With regard to the content of the self-explanations, it is assumed that experts more often relate to fundamental biological principles, novices to everyday knowledge.

Furthermore, experts should be more successful in identifying the essential information given in the examples whereas novices tend to elaborate on interesting details rather irrelevant to the solution.

Last, but not least, novices' self-explanations should contain more errors than those of experts.

c) Self-explanation variants:

It is hypothesized that self-explanations belonging to categories 1 and 2 are constitutive elements of self-explaining and that their application is pre-determined by the character of the example and the learner's prior knowledge.

By contrast, self-explanations belonging to categories 3 and 4 may vary and be used in more or less effective ways that can be regarded as variants of the self-explanation strategy.

It is planned to investigate the subjects' individual preferences for certain types of self-explanations in a case studies.

The relevance of the project to research on biology education and to biology lessons

First studies on how to train self-explanation skills have shown that self-explaining can easily be taught when learning from worked-out examples. So far, however, only few studies have been conducted in this field.

Chi, de Leeuw, Chiu & LaVancher (1994) employed an indirect training method and managed to increase the number of self-explanations merely by using more stimulating learning material. Direct training had the same result (Bielaczyc, Pirolli & Braun 1995, from Renkl, Stark, Gruber & Mandl 1998b). It seems that self-explaining as such is not new to students of a certain age and that the relevant techniques do not have to be learnt from the beginning, but only be specified for the domain in question (Fischer, Gräsel, Kittel & Mandl 1997).

The results of this project should therefore make it possible to plan studies on training self-explanation strategies in biology lessons more carefully:

1. They should provide evidence on whether training self-explanation skills depends on certain contexts.
2. They should help to decide whether direct or indirect training or a combination of both is most effective. If the effective application of self-explanations proves to be independent of the students' prior knowledge, direct training of self-explanation abilities would be feasible. If the quality of the self-explanations is related to the students' pre-knowledge, it would be better to train self-explanation skills when teaching concrete biological concepts and to use worked-out examples for this purpose.
3. The more we know about how biology experts use self-explanations, the more the details of a training program for self-explanation skills can be improved. An important question in this context is, for example, if one should restrict oneself to training step-by-step elaborations by which the meaning of the example is deduced gradually or if one should rather encourage the elaboration of broader contexts like grasping the sub-goals and goal of the example or the example sequence.
4. Finally, our study should provide an answer to the question if self-explanation skills should be taught individually. Does it suffice to take the different levels of pre-knowledge into account or do we have to consider individual preferences for certain types of self-explanation that would be suppressed by unspecific training although it would be better to use them as a basis?

The practical relevance of this project to biology instruction lies in the fact that a new method of autonomous, problem- and application-oriented learning is investigated whose potential for learning scientific concepts has often been

affirmed, but has hardly been used in biology lessons. This is all the more surprising if one considers that:

- learners, and especially beginners, prefer learning from examples,
- self-explanations are often generated spontaneously,
- learning from worked-out examples can easily be trained in biology lessons.

Short verbal instructions and guided working on some examples usually suffice to increase the intensity of self-explanation activity.

The above-mentioned findings point out that self-explaining is an individual form of learning in the first place. However, one could also think of teamwork. Some students could, for example, explain the solution steps while others try to elicit the best possible explanation by asking pertinent questions.

The outlined study is the 'biological part' of a project on learning from worked-out examples, drawing upon examples from the fields of biology and physics and investigating the transfer of self-explanation skills from one domain to the other. The project is funded by the German Science Foundation (DFG).

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BIOLOGY TEACHERS' PERCEPTIONS OF LEARNING PROBLEMS IN MENDELIAN GENETICS

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Introduction

Mendelian genetics can be pointed out as the basic principles of heredity. Gregor Mendel suggested that cells had pairs of factors that determine a specific trait. He demonstrated that parents pass on these obscure units of segregation and independent assortment (genes) to their offspring. Mendelian genetics enables students to explain and predict genetic variation. Furthermore, mastering the principles of Mendelian genetics is a prerequisite for understanding molecular genetics and for making informed personal reproductive decisions.

Mendelian genetics, however, is one of the most difficult topics in general biology courses (Stewart, 1982). Numerous studies concerning secondary school and university students, have reported difficulties students encountered in understanding concepts of genetics and problem-solving (Smith & Simmons, 1992; Stewart & Hafner, 1994). A preliminary review of the literature on genetics education between 1989 and 1998 identified some main problems in learning and teaching Mendelian genetics (Vos, 1998; Rutgers, 1998). Collins & Stewart (1989) concluded that it is difficult to learn and teach genetics, because inheritance and the concepts in genetics are abstract and complex. Cavallo (1996) found that students insufficiently connect problem-solving with relevant biological phenomena. Simmons (1992) reported on students' misconceptions in genetics due to extensive genetic terminology and inadequate mastering of the process of meiosis (Brown, 1990; Kindfield, 1994; Moll & Allen, 1987; Smith, 1991).

Articles on genetics education are either research based 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 for practical problems without scientific explanations. So, there appears to be a gap between theory and practice. The developmental research paradigm may help to narrow this gap (Lijnse, 1995; Boersma, 1998).

Most of the reviewed investigations into genetics education have been carried out in the United States and Great-Britain. Besides a difference in language, the school systems in these countries differ from that in The Netherlands. Little information is

available about the problems students and teachers face in Dutch-upper secondary schools. Nevertheless, we expect that the teaching and learning problems in genetics will not differ that much. To verify this expectation we decided to arrange focus group interviews with Dutch biology teachers.

With this investigation a 4 years' PhD study on learning and teaching Mendelian genetics has been started in 1998. The identification of the main problems in Dutch-upper secondary school should enable us to plan further research activities within the developmental research paradigm, aimed at improvement of genetics education.

Materials and methods

The focus group method was used to identify problems Dutch biology teachers encounter in genetics education. The focus group interview or discussion is a qualitative research technique for gathering in-depth data about perceptions, feelings and opinions of small groups of participants on a given problem, experience or other phenomenon (Basch, 1987). Panels of 6-10 upper secondary school biology teachers with substantial classroom experience were selected. Group interactions may help to gain quantitatively and qualitatively richer data.

A letter of invitation was sent to 63 secondary school biology teachers who were already participating in our teacher education network. They were phoned to inquire whether or not they were willing to participate in a focus group interview. 24 biology teachers were willing to do so, and finally 19 participated. Upon enrolment, three groups were formed, consisting of 6 or 7 biology teachers each. Each 2 h session was audio-taped and transcribed. These records, along with the moderator's notes, provided the raw data used for analysis.

The overall goal of the discussion was made clear by the moderator by presenting the research question, i.e. which teaching and learning problems in genetics do Dutch biology teachers identify, and how do they explain and cope with these problems. Since some group members may dominate, the session started by giving each participant an opportunity to express the problems he or she was encountering in genetics education. The first hour of the discussion focused on inventory of problems the participants perceived. In the second part emphasis was on the explanations and solutions they could suggest for these problems. In co-operation with the participants the problems, explanations and solutions were defined and noted on the black board.

The audio-tapes were transcribed. By close reading of the transcripts a list of key ideas, words, phrases and concerns was compiled and 10 meaningful problem categories could be extracted. Next, participants' ideas and quotes were classified. The labels of the categories refer to relevant characteristics of subject matter and/or students, to which the teachers attributed the problems they identified.

Results

This poster presentation focuses on an inventory of teaching and learning problems and a preliminary comparison of these problems with those identified in the literature.

The classification of the data of the three focus group interviews resulted in 10 meaningful categories, which are shown in table 1.

Table 1. The main problems in teaching and learning Mendelian genetics perceived by Dutch-upper secondary school biology teachers (n= 19)

CATEGORY	DESCRIPTION
Abstract nature (1)	Alienation from real biological phenomena due to the disconnection of inheritance, sexual reproduction in general, and meiosis in particular.
Complexity (2)	Inheritance has to do with all levels of biological organisation and adequate understanding of genetics requires back-and-forward thinking between molecular, cellular, organism, and population level. Simplification of inheritance easily leads to conceptual problems.
Probabilistic reasoning (3)	Students who perform poorly in mathematics often also do so when solving genetic problems; see also differences between students (10).
Image (4)	Inheritance may be perceived as a difficult topic in biology, resulting in poor motivation or giving up behaviour.
Examination (5)	Mendelian genetics is just a small part of the final exam, consequently no much time is allotted to this difficult subject, although spending some extra time would be obvious. Current practice is to teach and learn tricks instead of insightful problem-solving behaviour.
Terminology (6)	Genetics is rich in terminology, but not all terms are necessary for adequate understanding. Furthermore, students are unwilling to memorise relevant terms; see also image (4). In addition, teachers and authors of curriculum materials do not always use terms consistently and explicitly. Inadequate translations of terms from English into Dutch (e.g. 'sex-linked') and politically correct language (e.g. 'genetic modification' instead of 'genetic manipulation') can also result in misunderstanding.

CATEGORY	DESCRIPTION
Pedigrees, Punnett-square diagrams & symbolising (7)	Students face problems in representing and reading genetic knowledge in(to) schemes and symbols; see also problem-solving (8). These problems may increase in connection with the abstract nature of genetics (1) and its richness in terminology (6).
Problem-solving (8)	Students not only have difficulties with the representation of problems (7), but they also lack problem-solving and reading skills.
Cell division (9)	Students have an inadequate understanding of the process of meiosis, and do not always understand the differences between mitosis and meiosis. Consequently, students acquire a poor conceptual basis of genetics.
Differences between students (10)	Relevant prior knowledge and cognitive maturity is required for an adequate understanding of genetics. Students may differ in these respects; see also image (4). Furthermore, differences may also be related to opting for or out chemistry and mathematics courses.

This investigation confirms our expectation that learning problems in genetics identified in the English literature are also being perceived by Dutch biology teachers. The categories of problems (Table 1) correspond more or less.

Discussion

In this report we have answered only part of the research question, i.e. Dutch biology teachers' perceptions of learning problems in Mendelian genetics. Explanations and solutions to these problems suggested by them yet have to be analysed in further detail. Furthermore, in-depth reviewing of the literature is still in progress. Comparison of our findings with those reported in the literature may be biased due to the data sources used and the nature of the data connected with them. For example, teachers' perceptions of students' problem-solving behaviour extracted from focus group interviews cannot just be equated with findings from observation studies. For that reason the focus group interviews will be completed with content analysis of school-books and classroom observations. Nevertheless, at first sight the main teaching and learning problems reported in the literature seem to be verified by these Dutch biology teachers.

The second aim of this study is to identify key issues to address in this PhD project. At this stage we are inclined to focus further research activities on the *abstract and complex nature of genetics* (see category 1 and 2 in table 1). The sequence of subject matter likely is the underlying key issue, which needs further study. In this context the relevance of genetics to the life sciences and its positioning within the biology curriculum has to be reflected and elaborated on.

We are not saying that the other categories of problems are less important, but some can be dealt with rather easily (for example *cell division* by using adequate visual aids frequently suggested in practical notes, and *terminology* by paying attention to it in teacher education). Other categories refer to more general learning problems in biology (for example *representation and symbolising* and *problem-solving*). Furthermore, in September 1997 a four year project started at our centre aimed at the tuning of subject matter content of mathematics, biology, chemistry and physics and co-operative teaching of common topics (Van der Valk et al., 1998). Mathematics and biology focus on *probabilistic reasoning* in the context of genetics.

Our research paradigm, referred to as developmental research, implies that in designing and testing adequate solutions to teaching and learning problems, teachers play an important role. We are very pleased with the willingness expressed by the teachers who participated in the focus group interviews, to co-operate with us in further research activities. This may help to narrow the gap between educational research and teaching practice.

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INTRODUCTORY LECTURE

*'ENERGY FLOW ON EARTH' –
AN ORIENTATION PATTERN
FOR TODAY'S WORLD*

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Göteborg University, Sweden*

Points of departure

People today live in a very dynamic world. Some trends are the following:

- The world population is increasing
- Consumption is increasing, particularly in developed countries
- Income per capita is increasing
- World economy is growing
- More and more matter and energy are transformed by humans
- Nature is affected more and more
- The north-south gap is still very large
- Knowledge and possibilities to communicate are increasing
- The flow of information is increasing
- There is more and more for humans to cope with
- The potential of possibilities is increasing

Today's students and ordinary people ask questions relating to these trends, e. g.:

- What is the enhancement of the greenhouse effect and how can it be stopped?
- Is there enough energy for everyone to have a good life?
- Why are 800 millions starving when there is enough food for everyone?

School has a responsibility to help students with analysing these and similar questions. Generally speaking, the growing amount and increasing flow of information makes it more important than ever to help students by creating, and teaching about, patterns into which the flood of details can be fitted. How is this to be done? The problem may be structured as follows:

The traditional school subjects cannot in themselves solve the individual's orientation problems, and the reason is fairly simple. The subjects and their academic counterparts have largely been evolved to describe and understand other phenomena and events than those presented in the media and relating to the trends listed above.

When trying to answer today's questions e. g. about how nature is affected by human activities one needs to put together knowledge of nature, technology and

society (system NTS). The problems associated with the use of fossil fuels and how to reduce them is a good illustration of this point. To support one's reasoning one may set up the following table:

NATURE	TECHNOLOGY	MAN-SOCIETY
<u>Problems</u> -resource consumption -anticipated climatic change due to CO ₂ emission -acidification	<u>Solutions, short-term</u> -cars with low petrol consumption -more efficient sources of light -well-insulated houses -better public transport etc <u>Solutions, long-term</u> -increased use of alternative energy sources, e.g. sun, wind, ground heat, biomass -nuclear power?	<u>Solutions, short-term</u> -more efficient energy-using behaviour -change in economic incentives <u>Solutions, long-term</u> -altered infrastructure -altered life-style

Of course, this table cannot be constructed without subject matter knowledge of various sorts. But the whole is certainly more than the sum of its subject matter parts.

Perhaps the role of school is to go on teaching subject matter, but now and then apply it to questions and themes that requires integration of knowledge from various subjects. However, the step from separate subjects to system NTS may be quite large. The question is if it is possible to invent intermediate systems of knowledge that reduces this step. I think of such systems as *orientation patterns* that helps students to orientate themselves in the world in a better way than pure subject structures or various types of everyday experience do. In other words, an orientation pattern is thought of as a more effective interface between the individual and the surrounding world than traditional subject matter and everyday knowledge. The pattern cannot, however, be built up in a stable way without knowing a good deal about various subjects.



School focuses on traditional subject teaching. The subjects do not answer today's questions but offer necessary knowledge.



Is it possible to develop intermediate knowledge systems that form a better man-world interface than traditional school subjects?



Today's questions about e. g. use of resources and environmental influences are answered in system NTS.

Energy flow on earth

In an attempt to begin answering the question about intermediate knowledge systems, a candidate for an orientation pattern called 'Energy flow on Earth' will be examined and discussed. Look at figure 1!

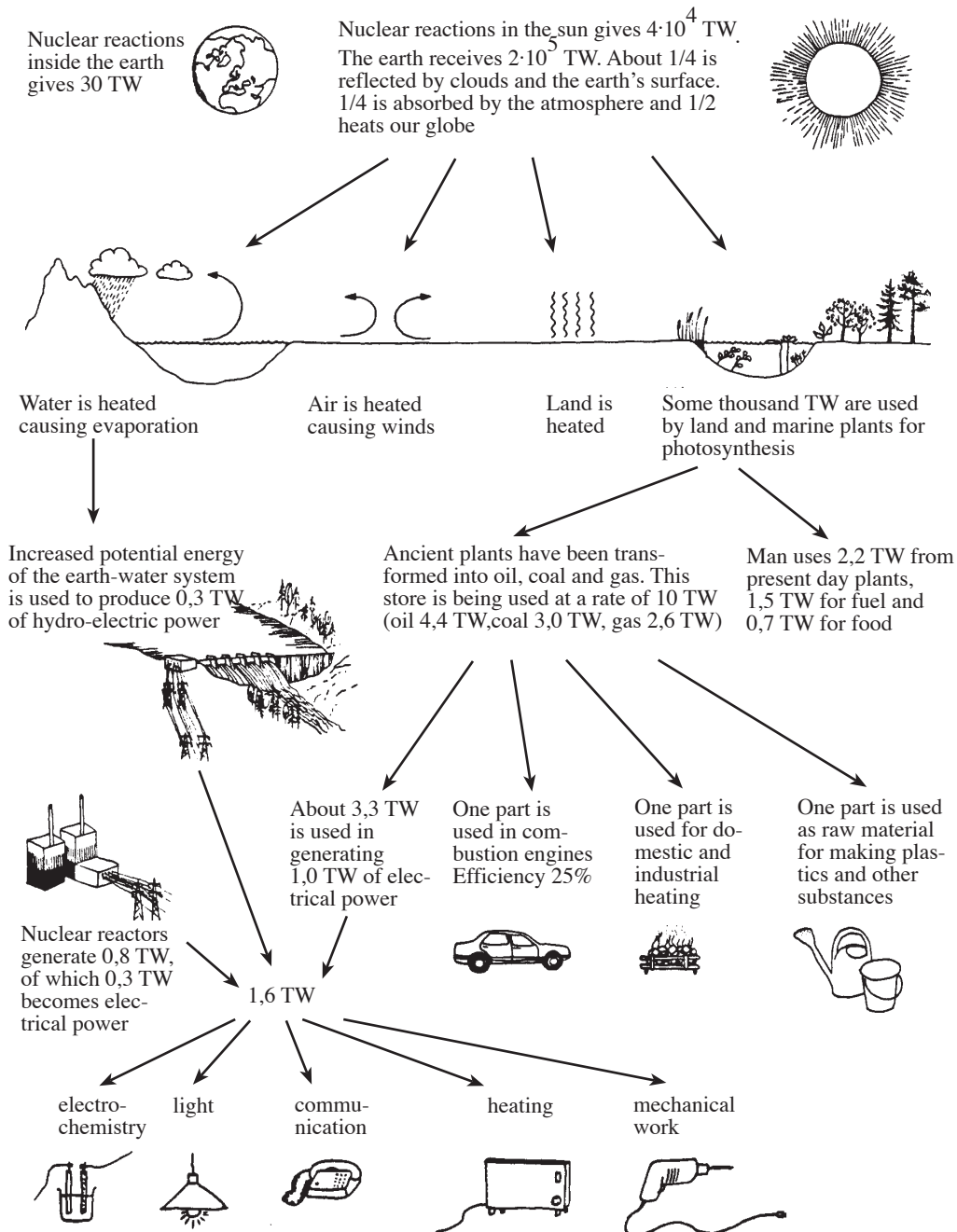


Figure 1. Average energy flow on earth. (Unit 1 TW = $1 \cdot 10^{12}$ W). (Adapted from Harvard Project Physics, 1968-69)

The figure gives a general picture of the energy flow on earth. The influx is several hundred thousand TW. We currently use approximately 13 TW, and of these, 10 TW come from limited supplies (oil, coal, gas) and only about 2 TW from renewable energy sources (essentially water power and biomass). According to the Brundtland report, it is, however, realistic to plan for taking out 10-13 TW as renewable energy (World Commission on Environment and Development 1987).

Every event on our planet is a link in the global energy flow. When the motorist drives, energy is obtained from the combustion of fossil fuel. As will be seen from figure 1, this energy originates from the radiant energy of the sun, which has been used by ancient plants for photosynthesis. Another example is switching on a light. This starts an energy transfer that can be traced back to the sun, too. Solar energy has been transferred to water, which has evaporated. Water vapour has risen, condensed, fallen as rain or snow and been collected in reservoirs at higher levels. The increased potential energy of the 'water-earth' system is then transformed into kinetic energy, thereafter to electrical energy, and then to light and heat.

In other words, you can say that figure 1 shows links between phenomena that are not obvious to the ordinary observer, e.g. 'solar radiation, photosynthesis, motoring', 'solar radiation, precipitation and domestic lighting', etc. Another thing that becomes apparent is that electric energy is not necessarily 'clean' and 'environment-friendly'. The greater part of it is generated through the combustion of fossil fuels – something to think about for anyone who advocates a transition to electric motor cars.

Figure 1 shows how nature, technology and society are linked together. The energy flow originates in nature, e.g. solar radiation and ground heat. It is linked into human society with the help of technical systems. How this is done depends on available knowledge, economic circumstances and political decisions. The rate of flow along different flow-lines is significantly influenced by the behaviour of individuals. The use of energy affects the shape of our society and living conditions and has repercussions on our natural environment.

Of the energy that flows from nature into human society, about 75% come from oil, coal and gas. The contribution from nuclear energy is about 6%. It is important to be aware of these numbers when discussing the adoption of alternative energy systems. It is also important to know about the problems associated with different types of energy use, e. g. the risk of global warming due to emissions of carbon dioxide.

With the general picture as the starting-point, one may acquaint oneself with the energy flow through various systems in more detail and reflect on how to economize on energy more efficiently. One example is the energy flow through a house. Another area is travel, dominated in Western countries by car traffic.

Roughly 500 million cars are being used on our planet. They transform very large amounts of energy and matter and change the conditions for life in Earth. Yet another aspect is our food. From the point of view of energy, modern food production runs at a loss. Altogether, one usually estimates that approximately five times more energy is required to get the food on the table than is supplied to the body by the food-oxygen system (Hubendick, 1985, p 150). The auxiliary energy is fairly evenly distributed among the items agriculture, handling/transport and preparation.

The 'Energy flow on Earth'-pattern is an interesting context both for applying and introducing science concepts. Photosynthesis is an example. By 'inserting' the teaching of photosynthesis into the orientation pattern the significance of this endothermic reaction to society becomes obvious. The same thing can be said about combustion of organic substances, an exothermic reaction.

Fossil and nuclear energy – what proportions?

Two multiple-choice tasks about fossil and nuclear energy were included in the Swedish national evaluation of 1998, namely 'What proportion of the energy used by all people on earth together comes from A. oil, coal and gas and B. nuclear power?' (Andersson, Kärrqvist, Löfstedt, oscarsson & Wallin, 2000)

Students greatly underestimate the proportion of human energy use that is made up of oil, coal and gas. For instance, in grade 9 (n=200) about half of the students state 40% or less. Use of nuclear energy is greatly overestimated. More than half of the grade 9 students state 40% or more.

An approximately correct idea of the relative proportions of fossil and nuclear energy may make it easier to understand the tremendous adjustment required to do away with dependence on oil, coal and gas, including the very large expansion of alternative systems that is needed. An important point is that oil and gas resources are limited.

Energy chains from the sun

The following task was given to a random national sample of 640 students in form 9. (Andersson, Bach & Zetterqvist, 1996).

The sun sends out a lot of energy. Some of it hits our earth. Go on following the energy that hits our earth in as much detail as possible and as far as possible. Write your thinking down!

The students' answers were analysed with figure 1 as a frame of reference. Typically, a student contributes a few components of the whole pattern that we call 'energy flow on earth'. Three main components (II to IV) were identified, and each has a number of sub-components (A to R). Below you will find the percentage of students who included a certain main component in their answer,

either in the form of one or more sub-components. The percentage of students including a particular sub-component is also shown.

- I NOT ANSWERED (31%)
- II THE SUN/RADIATION/SOLAR ENERGY INTERACTS WITH GEOPHYSICAL SYSTEMS (33%)
 - A Is reflected back (7%)
 - B Is absorbed in the atmosphere/part of the atmosphere (5%)
 - C Gives rise to winds and wind power (2%)
 - D Heats the earth/ground (10%)
 - E Heats water in various forms, e. g. oceans, ice, snow (10%)
 - F Gives rise to water power or wave energy (2%)
 - G Drives the water cycle (4%)
 - H The earth gives off energy/heat radiation (into space) (1%)
- III THE SUN/RADIATION/SOLAR ENERGY INFLUENCES BIOLOGICAL SYSTEMS (35%)
 - I Gives life/Is necessary for life/Is good for the living (10%)
 - J Makes things grow (7%)
 - K Is part of photosynthesis (8%)
 - L Goes to the plants, which are eaten by animals (11%)
 - M Solar energy is linked via plants to fossil fuels or bio-fuels (3%)
 - N Others (3%)
- IV THE SUN/RADIATION/SOLAR ENERGY INFLUENCES/ DRIVES TECHNICAL SYSTEMS (22%)
 - O Drives/is taken up by solar cells/sun panels (4%)
 - P Drives solar cells, which in turn drive something else, give electricity, etc (5%)
 - Q Heats houses, directly or via sun panels (8%)
 - R Others (6%)
- V OTHERS (10%)

It is 31% of the students who do not answer the question, while 34% provides answers with only *one* sub-component. The remaining 35 % give answers containing *two or more* sub-components. On average there are 1,7 sub-components per student, calculated from those who answered. This means that there are not so many steps or branches in the students' descriptions of the energy flow. However, some sub-components cover several steps, among others L and M.

As far as the details of the response picture are concerned, 35% of the students link solar radiation and plants. But in about half of the answers the link is vague –

the students expressing that the sun gives life or makes the plants grow. No students mention the chain sun → plants → combustion of wood.

Few students (4%) connect the incoming solar radiation with the water cycle. If this link is absent, then no link will be made to hydro-electricity either.

The answers obtained should be judged with some caution. I think for instance that it is likely that discussing the task a few minutes with some friends could make the student aware of more links and branches in the energy flow from the sun. That in turn could lead to an improved individual answer. Another way of saying this is that the answers to the task probably depend on certain contextual factors. One should therefore not draw the conclusion that the students' knowledge is poor from just one task.

Tracking energy backwards from petrol that is combusted

The following task was given to a random national sample of 640 students in form 9 (Andersson, Bach & Zetterqvist, 1996).

A car that is being driven gets its energy from the combustion of petrol. Does this energy exist before the combustion? (The student was asked to tick either a 'yes' or 'no' box.)

If your answer is yes follow the energy backwards step by step as far as you can, and in as much detail as you can. Write your thinking down!

If your answer is no, explain your thinking.

The following categories of answers were constructed. Each student belongs to one category only.

- I NOT ANSWERED (2%)
- II ALTERNATIVE 'NO' (58%)
 - A No explanation given (11%)
 - B Energy is formed (comes into existence) as soon as something happens (start, warming up, use...) and/or when nothing happens there is no energy (7%)
 - C Energy is formed (comes into existence) when there is combustion (when petrol is burned) and/or just petrol is no energy (24%)
 - D Indications that energy exists before combustion (2%)
 - E Other (13%)
- III ALTERNATIVE 'YES' (40%)
 - A No explanation given (14%)
 - B There is energy in some part of the car (usually the battery, sometimes the driver, occasionally unspecified) (3%)
 - C There is energy in the petrol (which is then transformed) (5%)

- D The energy existed in the oil (that was in the sea, ground) (3%)
- E Connection plants/animals – petrol. Oil may be mentioned as an intermediate link (1%)
- F Connection sun – petrol. Plants/animals and oil are generally mentioned as intermediate links (4%)
- H Other (10%)

It would seem that the formulation of this task invites a yes-answer, because this alternative is more elaborated than the no-alternative. However, 58% chose ‘no’. In many answers the thinking is clear enough. Energy comes into existence only when something happens, like when you run the car or when the petrol is burnt. When nothing happens there is no energy. Examples are:

- Energy arises as soon as you start the car and *not* before.
- Energy comes into existence when the petrol burns. The petrol is not in itself energy.

In other words, these students associate energy with activity and state that there is no energy when nothing happens. Several answers in category II D indicate that the task includes a linguistic difficulty. The wording ‘Does this energy exist before the combustion?’ refers to energy in general. But the students may have interpreted the words as referring to a form of energy, as in the following answer:

- The energy in the petrol is chemical energy, isn’t it? When it is burnt up in a car engine the chemical energy is transformed into, among other things, thermal energy, kinetic energy, sound energy and light energy.

The student probably thinks that the form/forms of energy that the car obtains through the combustion of the petrol (kinetic energy, thermal energy) did not exist beforehand. Then it was chemical energy. That is why his answer to the question is ‘no’.

It is 43% who have recognized that the energy already exists. When it is a question of following this energy backwards, however, it is very few students that come as far as to the sun.

All these results from national evaluation indicates that the pattern ‘energy flow on Earth’ is not an active element in the students understanding of the world around them. On the other hand the answers to the task ‘Energy chains from the sun’ provide suggestions for a teaching method. It is evident that the individual student generally does not have particularly detailed knowledge of the energy flow according to figure 1, but that the students as a group demonstrate a good breadth concerning the various details of the flow. So one may assume that there is a relatively good chance that a class with a certain basic knowledge of energy will produce something rather similar to figure 1. In other words, the collective breadth existing in a class may stimulate individual development of knowledge.

The results reported raise many questions e. g.

- What do students need to know about energy to be able to keep up with public debate in a reasonably informed manner?
- Is it reasonable to demand that most students in form 9 or 12 should be able to answer the questions described in this paper well?
- How could one teach to ensure that the students acquire knowledge of energy that is functional in life and society?
- Who should carry out this teaching?

It is beyond the scope of the paper to discuss answers to these questions.

Further thoughts on 'Energy flow on earth'

One of many interesting results of the developing satellite technology is a 'world map' that has been built up of night pictures taken at midnight and in clear weather. The satellite detector registers radiation in the range of 0,4 - 1,1 mikrometers. 0,4-0,8 is the wavelength interval that the eye can detect (0,4 - 0,8) and (0,8-1,1) is near infrared. The map, called 'Earth at night', is available as slide and poster.¹ Figure 2 gives a certain idea of what it looks like, although not as detailed as the slide or poster.



Figure 2. Earth at night

A first observation is that the contours of the continents are visible, indicating that humans tend to live by the sea. Further, three very light regions of the world stand

out, namely Eastern USA, Western Europe and Japan. Oil wells in northern Africa, the Middle East and Siberia are visible. It is heat from gas flares that leads to the large light patches (the technique used makes gas flares very overexposed). The light patch in the Sea of Japan is created by a fishing-fleet using floodlights to bring fish to the surface. The Amazons, Sahara, Himalayas and the Australian Wilderness appear as large black regions.

In order to make valid inferences from the picture you need detailed information about how it was produced. The number of light sources that appear depend on the sensitivity of the detector, its resolution and where you set the upper limit for what is to be counted as background radiation. Two equally large light patches may correspond to unequal amounts of energy, which is not observable on a black and white picture. Since we know that USA, Western Europe and Japan transform very large amounts of energy, we may nevertheless say that figure two is an approximate map of mans use of energy. The larger the proportion of white colour in a certain area, the more energy is transformed.

By linking figure 2 with other information, you may obtain a deepened understanding of humans use of energy and its consequences. Look at figure 3, which shows regions with acid rain. The locations of these regions coincide with high use of energy. The connection is that burning of fossil fuels generates sulphur dioxide and nitrogen oxides.

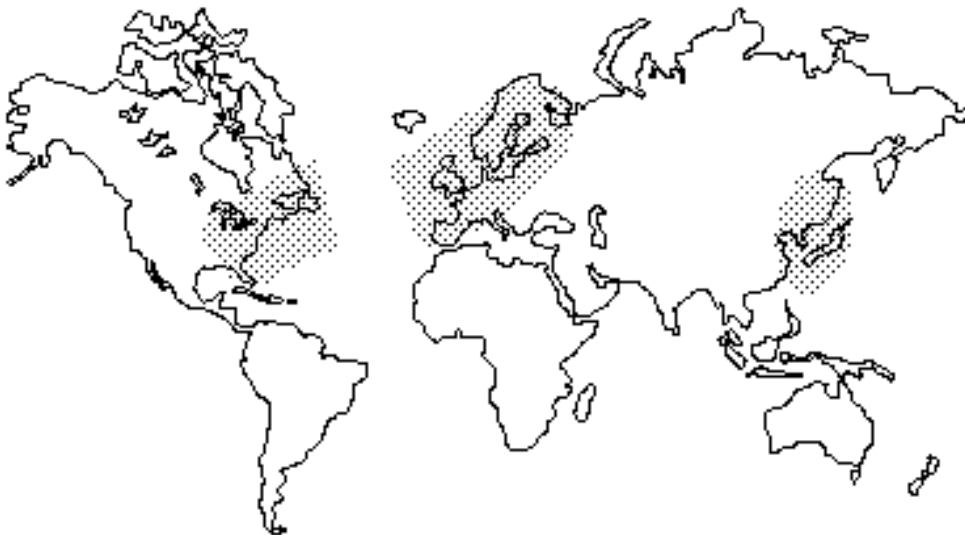


Figure 3. Regions with acid rain

There are other effects associated with high use of energy. One is large economic activity. This is illustrated in figure 4, which shows a world map where the area of a certain region has been drawn in proportion to its GNP. We can see that USA,

Western Europe and Japan dominates the world. Africa, this very large continent, is extremely small.

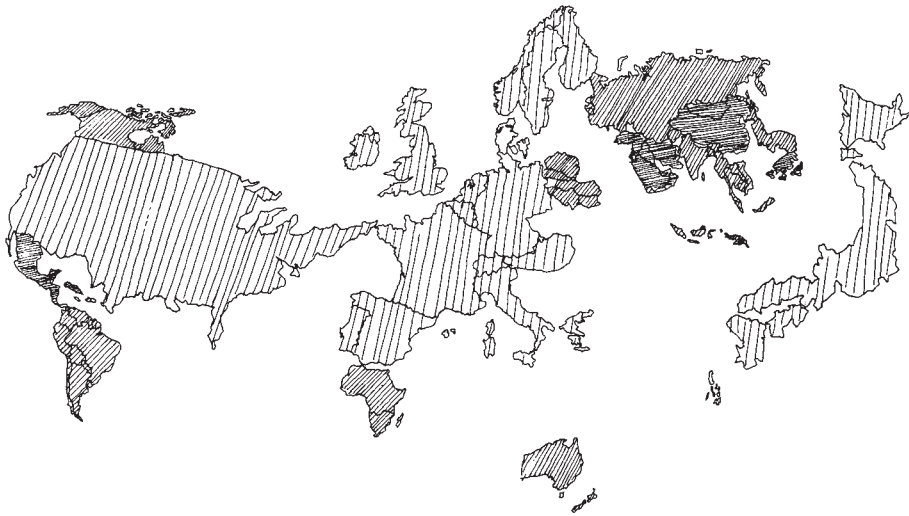


Figure 4. A world map where the area of a region is proportional to GNP.²

Several other possibilities to make interesting comparisons between the 'Earth at night'-picture and other maps exist, e. g. a map of population density and a map of coastal pollution.

Concluding remarks

To sum up, we can say that figure 1 and figure 2, which together depicts the energy flow on Earth, has a lot to say about how events and systems are connected and structured on our planet.

Humans use of energy significantly influences life on Earth. Change of environmental factors such as acidity and temperature, and the presence of new substances in ecosystems, change the life conditions for organisms, as does destruction and fragmentation of habitats. Therefore, the 'Flow on energy on earth' is not only a good orientation pattern for the students, but also a significant context for the teaching of biology!

Notes

1. A series of slides showing various parts of the Earth at night, including the picture 'Earth at night', may be ordered from

International Dark-Sky Association
3225 N. First Ave., Tucson, AZ 85719, USA.
e-post: ida@darksky.org
www: <http://www.darksky.org>

In teaching, colleagues have used a poster from
Hansen Publications
1845 South 300 West #A, Salt Lake City, UT 841 15 USA
www: <http://www.utah.edu/Planetarium/index.html>

As far as I know, this poster is being replaced by a more recent one.

Nice and up to date night pictures of various regions, such as Europe and USA can be found at <http://www.ngdc.noaa.gov:8080/production/html/BIOMASS/night.html>

2. The economic world map is from the Danish newspaper Politiken (September 18, 1991).

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