# Third Misconceptions Seminar Proceedings (1993)

Paper Title: STUDENTS' MISCONCEPTIONS IN BIOLOGICAL SUBJECT AREAS AND CONSEQUENCES IN TEACHING BIOLOGY

Author: Gerhardt, Almut; Piepenbrock, Christiane & Rusche, Gabriele

Abstract: Students' misconceptions in biology have been rarely investigated in Germany (SCHAEFER 1983 a, b, HEDEWIG 1988, GRAF 1989, GERHARDT/PIEPENBROCK 1990, 1992). In our research group (GERHARDT, PIEPENBROCK, RUSCHE) we are studying students' misconceptions in different biological subject areas (Fig.1). Grades 1 and 4 of the primary schools and grades 5, 7 and 10 of the secondary schools I (Sekundarstufe I) in North Rhine - Westfalia are involved in these studies.

Keywords: Misconceptions,Constructivism,Learning Processes,Tests,Data Interpretation,Concept Formation,Qualitative Research,Educational Strategies,Classroom Techniques
General School Subject: Biology Sciences
Specific School Subject: Biology
Students: Secondary School

Macintosh File Name: Gerhardt - Biology
Release Date: 10-6-1994 I

Publisher: Misconceptions Trust
Publisher Location: Ithaca, NY
Volume Name: The Proceedings of the Third International Seminar on Misconceptions and Educational Strategies in Science and Mathematics
Publication Year: 1993
Conference Date: August 1-4, 1993
Contact Information (correct as of 12-23-2010):
Web: www.mlrg.org
Email: info@mlrg.org

A Correct Reference Format: Author, Paper Title in The Proceedings of the Third International Seminar on Misconceptions and Educational Strategies in Science and Mathematics, Misconceptions Trust: Ithaca, NY (1993).

original publication of this proceedings was supported by a grant from the National Science Foundation, and the transformation of this collection into a modern format was supported by the Novak-Golton Fund, which is administered by the Department of Education at Cornell University. If you have found this collection to be of value in your work, consider supporting our ability to support you by purchasing a subscription to the collection or joining the Meaningful Learning Research Group.
----- -----

# STUDENTS' MISCONCEPTIONS IN BIOLOGICAL SUBJECT AREAS AND CONSEQUENCES IN TEACHING BIOLOGY

Almut Gerhardt, Christiane Piepenbrock, Gabriele Rusche
University of Bielefeld, Bielefeld, Germany

## 1. INTRODUCTION

Students' misconceptions in biology have been rarely investigated in Germany (SCHAEFER 1983 a, b, HEDEWIG 1988, GRAF 1989, GERHARDT/PIEPENBROCK 1990, 1992). In our research group (GERHARDT, PIEPENBROCK, RUSCHE) we are studying students' misconceptions in different biological subject areas (Fig.1). Grades 1 and 4 of the primary schools and grades 5, 7 and 10 of the secondary schools I (Sekundarstufe I) in North Rhine - Westfalia are involved in these studies.

| | |
|---|---|
| **Primarstufe** | Basic phenomena of life |
| | concerning plants, animals and human beings |
| (grades 1 - 4) | reproduction; development; stimulation; motion |
| **Sekundarstufe I** | Energy in biological contexts: |
| (grades 5 - 10) | 1. A general basic study |
| | 2. Energy flow in ecosystems |
| | 3. Energy aspects of photosynthesis |
| | Diffusion/osmosis; photosynthesis; |
| | respiration; selected subjects in ecology |

**Fig.1:** Classroom topics in biological subjects areas investigated by GERHARDT and coworkers (see references) concerning students' conceptions/ misconceptions

Deepseated preconceptions and highly resistant misconceptions appear to be the general result of our comparative studies so far. There are indications of recognizable evolution of students' ideas with respect to their age, to the types of the secondary school system, and the weekly teaching hours concerning biology. In the first part of our paper we want to describe the structure of our investigation as well as the results mainly for grades 5 - 10, using one topic as an example. Our example will be "energy in the biological context". In the second part of our paper we discuss the consequences of this study for teaching biology to illustrate one attempt to minimize and/or correct students' misconceptions.

In order to enable a better understanding of our research results and the proposed consequences for teaching biology we first present a basic overview of the different types of the complex German system of public schools (Fig.2), which differs greatly from the American system of public schools.

## 2. THE BASIC STRUCTURE OF THE GERMAN SCHOOL SYSTEM EDUCATIONAL AND SOCIO-CULTURAL PREREQUISITES

In North Rhine - Westfalia for most students 10 years of school are compulsory: four years in the primary school (grades 1-4), and six years in the secondary school I (Sekundarstufe I with the types Hauptschule, Realschule, Gymnasium, Gesamtschule, each system with the grades 5-10). To obtain the University entrance qualification a student has to attend high-school for three more years the secondary school II (Sekundarstufe II, grades 11-13 ) either in the Gymnasium or in the Gesamtschule. At the end he has to pass a final exam (written and oral) to obtain the high school diploma ( university maturity: the Abitur) which makes him eligible for university.

Traditionally the German school system offered three educational streams, one more vocationally oriented for the later workmen, the second technical designed for the later craftsmen and the third more intellectually oriented mostly for the later academics. Theoretically every student could attend the Gymnasium, but in reality most Gymnasium students were children from academic families. Therefore in the sixties we had a thorough reform of the public school system. The main purpose was to give all students an equal chance in public education. The result is a very complex system ( Fig. 2). The four types of the secondary school I represent different educational intentions.

Most importantly, a student may switch from one type to the other, if he develops abilities in one direction or another. This also means that students from all types of secondary school I may attend secondary school II and qualify themselves for the University, thereby ensuring that they will qualify even if they develop intellectual abilities very late during the secondary school I - period.

Another innovation of our public school system which arose as a reaction to social changes was the addition of the new school type Gesamtschule (Fig.2). The socio- cultural changes in our society led to a different situation for children; these changes include the phenomenon of working mothers, quite often only just one child per family, the dissolution of the traditional family unit, a very high divorce- rate, single parents, media- related problems (too much TV watching by children) and commercialization of leisure activities. Since we have a multicultural society with great social problems we do have the responsibility to integrate students of different cultures into our educational system. This is rather difficult in light of our complex public school system (FÖLLING- ALBERS 1991).

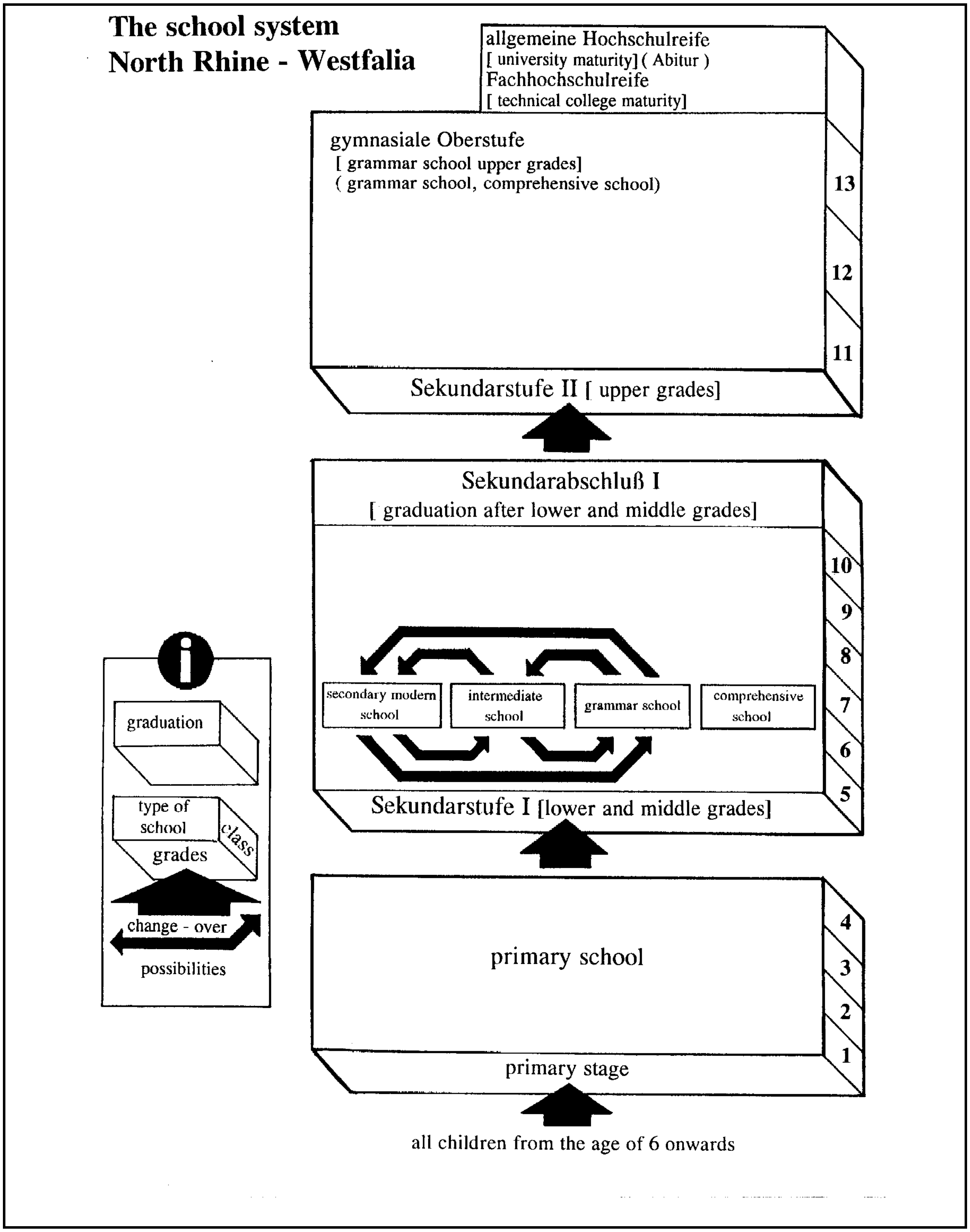



**Fig.2:** The basic structure of the German public school system, e.g. North Rhine - Westfalia (graph adapted from KM/NRW 1991, simplified ). Secondary modern school: Hauptschule; intermediate school: Realschule; grammar school: Gymnasium; comprehensive school: Gesamtschule

Most Gesamtschulen are all- day- schools, which the students attend five days a week. Thus they can stay there for lunch and get special help with their homework. Besides that, the main purpose of the Gesamtschule is the inner differentiation. There is no separation between the types Gymnasium, Realschule, Hauptschule. All students are organized in classes and study together according to their own ability. Furthermore in some subjects they are divided in small groups in which they are taught individually. For those who have learning problems special groups are formed, e.g. in German language or in mathematics.

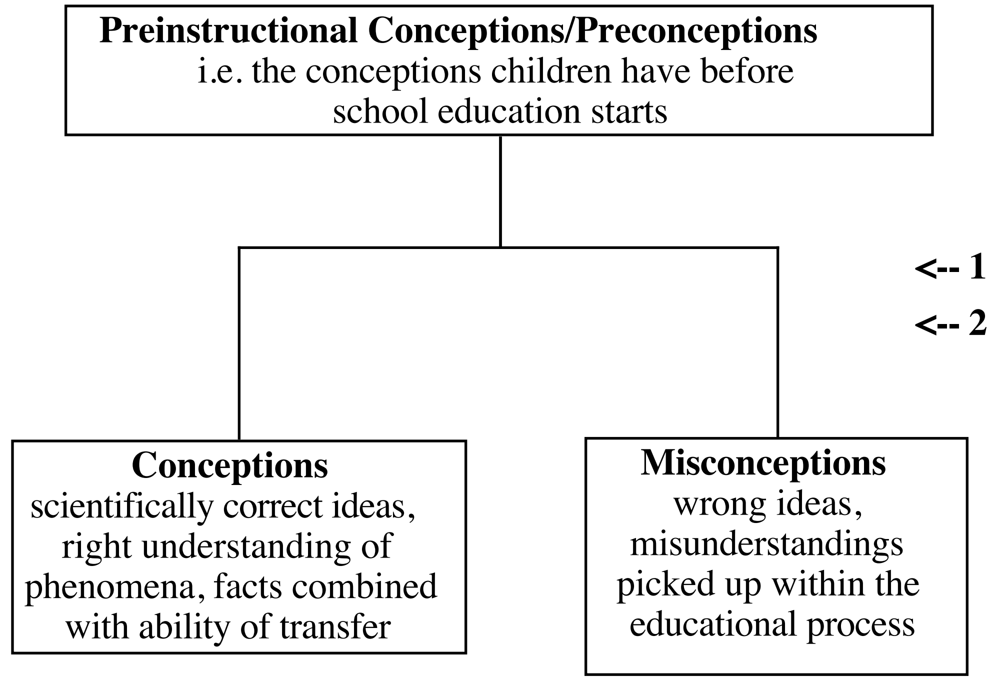
There is another difference between American und German schools concerning education in the natural sciences. In the German secondary school I ( grades 5 - 10) we don't have the subject "natural sciences"( except in the Gesamtschule). Biology, chemistry and physics are taught separately. Thus the students often do not have the necessary basic knowledge in physics and chemistry to understand certain biological subjects, e.g. energy. Biology is taught 1 - 2 hours per week in most of the grades. Only in grade 9/10 of the Realschule students can specialize in "natural sciences". Thus a student may have 3 or 4 hours of biology per week.

## 3. THE CONSTRUCTIVIST VIEW OF LEARNING

There are different opinions about how conceptions are generated in students' minds and how the ideas influence the process of acquiring new knowledge. The constructivist view of learning is a widely accepted model: the learner himself actively constructs his own knowledge (NOVAK 1980, 1987). In other words: each observation we make is attended by our own conceptions and prejudices. Our brain does not only register ideas in a passive way, but it is actively involved in what is recognized. That is: learning cannot only be limited to the cognitive aspect. If the learner is not willing to construct his own new knowledge, no learning takes place. The input data a person accepts are interpreted on the basis of already existant conceptions (DRIVER 1983). "The most important single factor influencing learning is what the learner already knows. Ascertain this and teach him accordingly" (AUSUBEL 1968). Contradictions are either not noticed or are neglected because they are of no interest for the learner. The constructivist view perceives learning as a thorough modification of our own concepts or even their complete dismission. For most people it is very difficult to give up opinions and beliefs that seemed to be true in the past and were very useful for them. The constructivist view of learning is not yet a well- defined theory but is a helpful working hypothesis (DRIVER/ERICKSON 1983).

Concerning students' education there must be a plan of instruction that incorporates the students' preinstructional conceptions or preconceptions (Fig. 3) or in other words their previous experience with the different subjects to be learned. If we want a student to transfer his newly acquired knowledge into an external situation he is confronted with in everyday life, we have to take into consideration that school instruction must be science- oriented on one side but must also be action- oriented. Creative thinking and independent acting of the students is what helps them to understand subjects. Knowledge is a network of conceptual structures ( VESTER 1982) and as such cannot simply be transferred through words, because it must be constructed by each individual knower.

In teaching his students, the teacher always influences them in one way or another. Since learning takes places in the student's own mind, the teacher - if he wants to guide learning - must have some notion of the conceptions/misconceptions the students already have and has to know how these conceptions/misconceptions are related to the students (GLASERFELD 1985, POPE 1985, DUIT 1992). Figure 3 illustrates the terminology which we use in our investigations.




**Building up of conceptions/misconceptions**

1 EXTRACURRICULAR INFLUENCES
- interaction with family members, friends, other people, peer - groups
- mass media
- language
- sense impressions
- social values and standards

2 SCHOOL CURRICULA
- quantity, quality and kind of educational staff ( education, self - perception, professional ethics, charisma)
- school - organisation
- curricula and their preparation in classes
- meta - communication between students and educationalists

**Fig.3:** Terms used in our investigations - their meaning and correlation

## 4. OUR INVESTIGATIONS ON STUDENTS' CONCEPTIONS /MISCONCEPTIONS

In order to analyse the kind of conceptions students have acquired during their school education and to reveal the change in their concepts (BELL/BROOK 1984, BELL 1985), it is necessary to learn about their preconceptions and their everyday experiences as well as about the conceptions/misconceptions they have either gained by school instruction or by the influences they are faced to otherwise ( parents, family, peer group). To verify this claim it is necessary to look at education from the students' as well as from the teachers' points of view ( STAVY et al. 1987). The following questions serve as a guideline for understanding this gap:

- Which conceptions/misconceptions concerning different subjects/ phenomena do students have due to everyday life experience?
- Which thoughts, memories, emotions does school- instruction release in students' minds?
- How do students perceive school- instruction and how do they evaluate it?
- How does the teacher perceive and evaluate different situations of instruction?
- How much of an expert is the teacher concerning science, didactics, and psychology?
- Is the teacher a charismatic person?

### 4.1 INVESTIGATIONS IN GRADES 1 AND 4 CONCERNING BASIC PHENOMENA OF LIFE

To find out about students' concepts based on their everyday experiences we carried out investigations on the Primary school level. The topics were phenomena of life such as reproduction, development, stimulation, motion. The students were questioned about these phenomena and were asked to compare plants, animals and human beings. To find out if the students' concepts about these phenomena changed during the Primary school period we investigated first and fourth grades.

## *METHODS*

The students were questioned in a personal interview. This interview concentrated on situational examples. Illustrations and other materials (e.g. fruits, animals out of fabric materials) were used to further deepen the understanding and to motivate the students. The fact that the first graders were not yet able to read or write was fully taken into consideration. A long written test was not suitable for the fourth graders. Focal points of the situational examples were selected with the following in mind:

- potential real life- situations
- conceptual ability of the students
- scope of the curriculum.

All interviews were video - taped and transcribed.

## *RESULTS AND THEIR EVALUATION*

160 students from two different primary schools took place in the study. Since it was not possible to have multiple interviewers asking the same questions at different time intervalls (MAYNTZ/HOLM/HÜBNER 1971) the investigation proceeded - almost simultaneously - in a first and a fourth grade class. It was not easy to evaluate the answers. We used a catalogue of terms to categorize the answers.

1. An answer was categorized as "*named correctly*" if the student
- named the term
- used a synonym instead of the term.

2. An answer was categorized as " *described correctly*" if the student
- transcribed the term with other words
- named examples to illustrate the term
- illustrated the term by gesture.

3. An answer was categorized as "*wrong* (*scientifically not adequate : a misconception*)", if the student
- used wrong terms
- wrongly explained the example
- did not understand the context of the example.

Since this investigation is not based on a standardized method and for each phenomenon there is a sample of only 40 students we consider the results of this investigation to be preliminary. The themes of the four phenomena can be divided into more or less abstract and more or less concrete subjects: e.g. "stimulation" (stimulus) and "development" are as such not existent in the mind of students of this age group. Only after relating them into everyday life situations and personal experiences do they become understandable to the students. Concerning the phenomena "reproduction" and "motion" the students own experiences are much clearer. For students from a rural area - and these were the students we investigated - reproduction of plants and animals is a frequently observed phenomenon. Concerning the phenomenon "motion" the students had fewer problems giving answers about active "motion" of animals and human beings. Questioned about plants' movement the students however came up with vague descriptions since they had no real perception about this phenomenon. Furthermore, the fourthgraders had problems talking about reproduction and related terms. Especially concerning human reproduction the students hesitated answering, which is understandable since this topic is still taboo, even though sex education is part of the curriculum at the primary school level.
In general it is obvious that the students of both grades have correct knowledge about the visible processes. An increased vocabulary and - consequently related to this - a better ability to articulate increased the level of description by fourthgraders. Altogether we found an evident decrease of misconceptions from the first to the fourth grade.

### 4.2 Investigations in Grades 5,7,9 and 10 concerning "Energy in The biological context"

In order to understand certain biological processes concerning "metabolism" and "ecosystems" it is necessary to learn about energy in the biological context. Since the subject " natural sciences" is not taught in secondary schools I (except Gesamtschule) the understanding of the phenomenon of "energy in the biological context" has to be acquired in the biology classes.

### 4.2.1 TRANSFORMATION OF ENERGY DURING MOTION IN LIVING SYSTEMS

Our investigation included different steps. We started with controlling the authorized school books, listed up the terms which were used, tried to find out in which context they were formulated and finally compared our results with the existing curricula. After that we developed the following tests.

#### 4.2.1.1 A PRETEST: THE KEYWORD "ENERGY" AND STUDENTS' ASSOCIATIONS

Because preconceptions and misconceptions significantly guide learning, it is helpful to investigate students' conceptions about "biological aspects of energy". Therefore we started our investigation by structuring the theme, listing essential terms and establishing their interdependence. To find out, if students see any correlations between the topics of "energy" and "biology" we made a preliminary study, a so called "Assoziationstest". The question was: What associations do you have, when you hear the keyword "energy"?

250 students in grades five and ten took part in this test. The fifth graders mainly associated energy with phenomena from their everyday life, e.g. electricity and electronics.In rank six (out of 20) "biological" examples were given, such as "motion" (e.g. dancing, running, sports). Other associations delt with animals. The answers of the tenth graders clearly showed a general increase in the capacity to cite examples. The personal world no longer plays an important role; instead the associations are more biologically oriented. On the basis of this preliminary study the theme for the main study was formulated: "Transformation of energy during motion in living systems". The following questions served as guidelines for the main study:

- "Transformation of energy during motion in living systems": Which concepts do students have
  at the beginning of the secondary school I (grade 5) and which do they have at the end of the
  secondary school I (grade 9/ 10)?
- Is there any conceptual change from grade 5 to grade 10?
- Are the students able to explain the terms "energy", "transformation of energy", "conservation

of energy", "metabolism", "reaction heat" and are they able to apply these terms correctly to

relate them to everyday phenomena of life and to use them for scientific explanations?

### 4.2.1.2 The Main Investigation

*METHODS*

In the main investigation students of the grades 5, 9 and 10 of different schools of the "Realschule" were involved. In grade 5 the students' average age was 10.9 years, in the grades 9/10 it was 15.9 years. All fifth graders had two hours of biology per week. In the grades 9 and 10 some classes had 4 hours of biology per week (differentiated courses), the others had one or two hours per week. To obtain a broad survey about the students' conceptions/ misconceptions concerning the investigated topic we chose five examples describing situations in everyday life and asking them a question concerning the problem posed in the example (Fig.4, DRIVER 1983a, GERHARDT/ PIEPENBROCK 1992).

**1.** After a period of physical education Judy who is totally exhausted returns to the locker-room. "Gosh, how hot I am! I'd really like to know why we got so hot by doing sports", she asks her friend. What would you reply to Judy? **period of physical education**

**2.** In February Jenny discovers the first crocusses in her snow-covered garden. At a closer look she notices that a little circle of snow arround each of the plants has disappeared. How would you explain Jenny's observation? **crocusses**

**3.** Every healthy human being has a body temperature of about 98.3°F in the state of physical rest. Try to explain how the body temperature is generated? **body temperature**

**4.** Danny has found out that on really cold days flies move definitely more slowly than on hot days. Can you explain to him why this is the case? **fly**

**5.** A little green Martian arrives in your schoolyard during the break. As Martians do not need any food the alien watches intensely how you eat your sandwiches. Shaking his head the Martian turns to you and asks:"Excuse me, could you tell me, why your body needs all this food?" Please answer the friendly guy from Mars in detail. **Martian**

**Fig.4:** 5 situational examples illustrating the "transformation of energy" - a test design

To obtain the data we applied two different methods. The students of one group had to write down the answers to the questions in the greatest possible detail without special guidance. The time limit was 45 minutes. The students of the other group took part in a personal interview. The

<table>
<tr><th>Grade 5</th><th>Grade 10</th></tr>
<tr><td colspan="2">Category 1: Answers containing factually correct solutions based on knowledge acquired at school or answers revealing central elements of understanding the factual chain of cause and effect.</td></tr>
<tr><td>No answer which can be grouped in this category</td><td>"The reason is that on cold days the generation of energy for muscular activities probably takes longer so that the fly can't move its wings as fast as on hot days."</td></tr>
<tr><td colspan="2">Category 2: Factually acceptable answers which, however, contain only secondary aspects of the phenomenon aimed at in the task or answers which contain central elements of the correct solution without naming the factual reasons or given within an inadequate context.</td></tr>
<tr><td>"Flies are poikilothermal insects. On cold days they are inert. On hot day they are nimble and quick."</td><td>"The blood of flies circulates more slowly when it's cold. That is why they become inert and can't fly fast. When it's warm their blood circulates more quickly and so the fly can move faster.<br>They are cold- blooded insects and their body- temperature corresponds to the outdoor temperature."</td></tr>
<tr><td colspan="2">Category 3: Answers which contain factually correct secondary elements of the scientific answer, but whose validity is diminished by misleading additions.</td></tr>
<tr><td>"Flies are poikilothermal insects. On cold days they crawl up the wall more slowly than on hot days perhaps because there are little nipples at their feet which run faster on hot days than on cold days."</td><td>"Their own generation of energy is fairly limited. That is why the fly depends on heat from outside to keep up its body temperature. If it's colder outside all the organs automatically function at a reduced speed."</td></tr>
<tr><td colspan="2">Category 4: Answers which are factually wrong or contain anthropomorphic approaches or answers which contain only the description of the phenomenon or which are based on stereotyped statements</td></tr>
<tr><td>"If it's warm they fly faster to provide themselves with fresh air by the movement of their wings. If it's cold they fly more slowly in order to warm themselves up."</td><td>"On cold days flies must use their physical energy to keep up their body temperature. So they lack the necessary energy which enables them to move energetically."</td></tr>
<tr><td colspan="2">Category 5: No answers or statements which are inconceivable or do not reveal any direct reference to the question.</td></tr>
</table>

**Fig.5:** Pattern of categories and classification of the answers concerning the example "fly"

**Fig.6a:** Energy - questions 1-5 : Schematic representation of students' responses in percent by question and category (grade 5)
**Fig.6b:** Energy - questions 1- 5: Schematic representation of students' responses in percent by question and category (grade 10)

time limit per question was 8 minutes. To minimize influences caused by different interviewing persons, the interviewer was always the same. In order to enable a correct evaluation the interviews were video -taped and later transcribed.

At the end of the test or the interview the students could give their opinion about the content of the examples and about the level of difficulty of the questions. Furthermore, they had to explain if they had noticed correlations between the test/interview and their own biological instructions. The main terms of "energy", "transformation of enery", "conservation of enery", "metabolism" and "reaction heat" were to be explained by the students as well. By doing so we wanted to know, if the students in school only learned empty phrases or if they learned in context and were able to translate the abstract knowledge in order to explain everyday life phenomena. In reference to DRIVER (1983a, 1983b) we tried to evaluate the answers using a pattern of five categories (Fig.5, GERHARDT/PIEPENBROCK 1992).

## *RESULTS AND THEIR EVALUATION*

The students' answers showed a great deal of misconceptions. Comparing the answers of fifth and tenth graders, there was a decrease in misconceptions (Fig. 6a,b). The fifth graders tried to explain the biological phenomena with more general experiences from their everyday life.

The tenth graders were expected to show better knowledge and a larger scientific vocabulary. But the results were rather disappointing. These students used many terms without understanding them (empty phrases) and were not at all able to explain how the processes of "metabolism" and "energy" are related to each other. This example indicates that there is no co-operation of

the three natural sciences, biology, chemistry, physics in the secondary school I. By analysing the present curricula of the three natural sciences our premise was verified. In the existing curricula of all school types of secondary school I there are almost no attempts to link the subjects and to try that they are built up on one other. Only in the latest curriculum of the gymnasium, North Rhine-Westfalia, grades 5-10 - published in June 1993 (after our investigation) - one can find some reflections on our problem.
Comparing the results of the two different applied methods - written test and interview - in this investigation they both have advantages and disadvantages, none is superior to the other.

Since this investigation was carried out with (totally 250) students from only one school type, the intermediate school, that type of secondary school I, that is primarily technically designed for the later craftsmen, we decided to expand our investigation on all four types of secondary school I. Furtheron we wanted to differentiate our test design.

### 4.2.2 ENERGY FLOW IN ECOSYSTEMS

The main theme to which the investigation of students' concepts concerning "energy flow" can be correlated becomes obvious in the framework of "nutrition of the world population". To understand the "energy processes in the ecosystem" the knowledge of the "food chains" and the "nutrient cycling" is necessary. In addition the students need basic knowledge about "energy processes" concerning the "metabolism of organisms", in order to understand the importance of the "energy flow" for organisms.

This investigation aimed to check what kind of conceptions/misconceptions concerning the aspects mentioned above the students had. With the help of the results we wanted to find out which subjects are difficult for them to understand.

*METHODS*

The inquiry of everyday concepts was performed with students of the different types of secondary school I (Hauptschule, Realschule, Gymnasium and Gesamtschule) in the Bielefeld area. In order to compare the concepts of students of different age groups the investigation took place in two parallel classes of the fifth, seventh and tenth grade. The empirical method was the written questionaire on the basis of situational examples (see chapter 4.2.2.1). This method seems to be appropriate to analyse the status quo at a particular time.

Investigations showed that with comparable questions this method is just as valuable as using an interview (DUIT et al. 1981, DUIT/PFUNDT 1991). With a carefully structured questionaire the test was standardized, so that a numerical comparison could be made between the different groups of testees.

As we were very much interested in learning about the contents of the students' answers without categorizing them in a pattern of "right/wrong" we took great efforts in getting substantial data. After having confronted them with the situational examples we therefore asked them to give their answers spontaneously and uncoached in order to get an obviously greater variety of replies. The disadvantage of these open questions is a less precise evaluation. This was accepted because of the advantage we saw in the greater diversity of answers. Another advantage of the written test was the fact that the testees had enough time to solve the problem. We had to take into consideration that foreign students, who knew little German, had a hard time to express themselves in writing. During the evaluation we had the problem that it was hard to decide if wrong answers were caused by the lack of language ability or by missing concepts.

The development of the questionaire made some basic decisions necessary about how the theme "energy flow in ecosystems" should be presented in the form of questions. A decisive problem for the empirical investigation developed out of the complexity of the theme: The knowledge about "energy flows" cannot be defined precisely like many questions in physics, which can be used to find out about the students' understanding . We had to investigate what the students knew about the individual factors that make up this process. The topic "energy flow in the ecosystem" was divided into different aspects. These concerned "photosynthesis", "nutrition of animals and human beings" and "food chain". The advantage of this method was that one could not only find out whether the "energy flow" was understood but also which partial aspects were difficult for the students to understand. With the differentiation of the contents the aim of the empirical study changed in part.

For reasons mentioned above it did not make sense to ask the students directly about the "energy flow". We had to ask them indirectly.

An analysis of partial aspects of the topic made it possible to find out, if the students had the basic knowledge to understand the whole process. The final aim of the study was not to find out, whether the students know the energy processes in the ecosystem, but rather if they have the prerequisites to understand these processes.

Guiding questions for the study were:

**A**. Do the students know that green plants are the only organisms that are capable to use sun - energy in order to produce energy- rich substances?

**B**. Do the students know that energy that enters the food chain originally comes from the light - energy of the sun?

**C**. Do the students know that animals and human beings take in energy by consuming food?

**D**. Do the students know that nutrients are carriers of energy?

**E**. Do students have concepts about what organisms need energy for?

**F**. Do students recognize that in the many life- processes energy is changed into different forms but is neither used up nor lost?

**G**. Do the student know that, despite this fact, there is a loss of energy within an individual food chain?

**H**. Do the students know why?

On the basis of these guiding questions we designed situational examples each with a question concerning the problem posed in the example - as well as in our first investigation. Besides that we asked the students questions concerning their knowledge and their personal interest in this topic.

## *RESULTS AND THEIR EVALUATION*

Concerning the non coached questions not all of students did answer them. Therefore the following percentages are related to the number of students who answered each question. On this basis the eight guiding questions could be answered as follows:

**Guide questions A and B:**

**A**. *Do the students know that green plants are the only organisms that are capable to use sun-*
*energy in order to produce energy- rich substances?*

**B**. *Do the students know that energy that enters the food chain originally comes from the light*
*energy of the sun?*

To the question,"Which sources of energy do plants use?", the answers of 155 fifth graders, 149 seventh graders and 174 tenth graders could be evaluated. It is evident that the students' understanding of the principle that "soil, water and air are sources of energy" dimished continously from grade 5 to grade 10. 48,7% fifth graders had the idea that plants receive their energy from rain. In the tenth grade only 16,4 % had this misconception.

Concerning the factor "soil" the percentage dimished from 38,5% (grade 5) to 31,3% (grade 7) to 23 % (grade 10). 11% of the fifth graders, but only 6% of the seventh and tenth graders cited "air" as a source of energy. The correct answer "The sun is the only source of energy for the green plant" increased continuously from 12,5 % in the fifth grade to 26,5% in the tenth grade (only 8,1 % of the seventh graders had this conception!). In combination with other so called sources of energy the radiation of the sun was cited by approximately 27% of the students of all three grades. Comparing the schooltypes the students of the Gymnasium showed the most significant increase of knowledge: The correct answers from the seventh to the tenth grade quintupled. In summary: although in the tenth grade 50% of the students knew that the sun was a source of energy, only 25% of the students saw this as the only source for plants. To most of the students the autotrophic way of plants must be unknown. Thus they could not recognize that the energy that is transported by nutrients in the food chain comes originally from the sun. Figure 7 demonstrates the answers of the students concerning "sun is a source of energy for plants". From the graph you can see the percentages of correct/partly correct answers. The correct answer "sun is the only source of energy for green plants" is considered under " sun 1". The "sun is one of many of sources of energy " is considered under "sun 2".

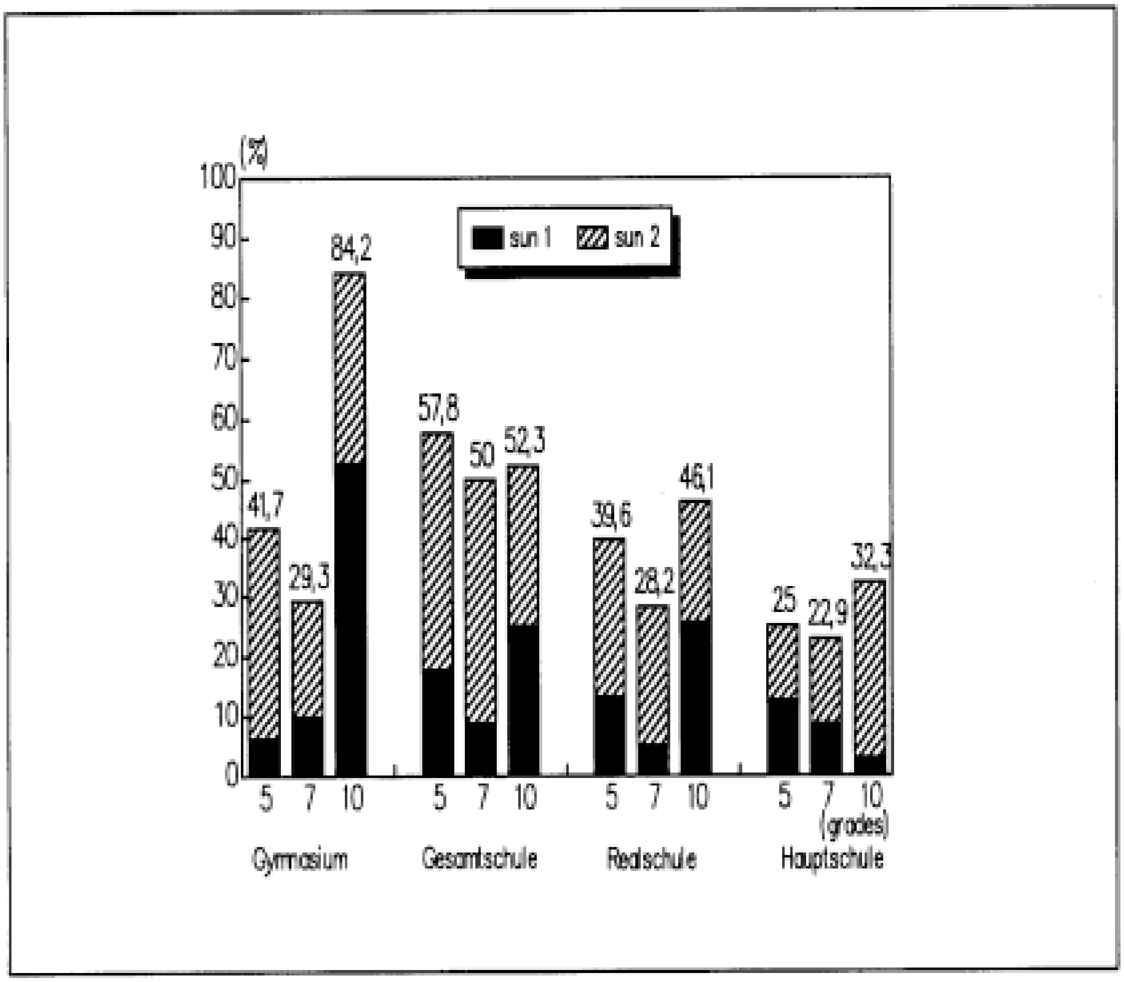



**Fig.7:** Schematic representation of students' responses to "sun as energy source for green plants". Students' responses in percent according to all secondary school I types: Gymnasium, Gesamtschule, Realschule, Hauptschule (see text for details)

**Fig.7:** Schematic representation of students' responses to "sun as energy source for green plants". Students' responses in percent according to all secondary school I types: Gymnasium, Gesamtschule, Realschule, Hauptschule (see text for details)

**Guide question C:**

***C***. *Do the students know that animals and human beings take up energy by consuming food?*

The question "Which sources of energy are animals capable of using?" was presented as a multiple choice question. Therefore all answers could be taken into consideration ( grade 5: 201, grade 7: 198, grade 10: 194 students). Basicly it became clear that the students know that animals are dependent on food as a source of energy. The frequency of this concept increased from 68,2% in the fifth grade, to 96,3% in the seventh grade and to 98,5% in the tenth grade.

In the higher grades the number of the students with the right concept that physical activity or air are not sources of energy for animals increased. However the percentage of wrong answers with 30%, 60% respectively is very high. Water as a source of energy was named by 90% by all students in all three grades. This very high percentages can be explained by the fact, that the testees assumed that there were energy- rich nutrients in the water. Comparing the four different types of schools one can see correct knowledge increase especially in the Gymnasium. In the Realschule and Gesamtschule we could not see a significant increase of knowledge. In the Hauptschule there was only an increase of knowledge concerning " food as a source of energy". A trend concerning the other factors could not be recognized.

**Guide Question D:**

**D**. *Do the students know that nutrients are carriers of energy?*

The question if students know nutrients as a sourcy of energy showed an interesting phenomenon. Besides the students' answers that carbohydrates, fats and proteins are sources of energy the students quite often cited vitamins as sources of energy for human beings.

These answers showed that the students assumed vitamins to be essential substances and in their understanding of energy the students thaught that a vitamin is something that keeps people "strong, fit and healthy".

Especially the younger students predominantly followed the idea that all substances that are essential for the human body also give energy. 71% of the fifth graders named vitamins as a source of energy. This declined in the higher grades to 47% of the seventh graders and to 35% of the tenth graders. The correct answers, according to which nutrients were cited as sources of energy increased continuously from 15% (grade 5) to 43% (grade 7), and 70% (grade 10).

The figures 8a- d demonstrate how many students name vitamins as a source of energy and

compare them with the ones who cite nutrients as a source of energy. The
topic" nutrients" leads
to a reflection about carbohydrates, fats and protein**s.** The graphs show that the correct answers increased during schooling. This can especially be seen in the Gymnasium. In the Realschule the students naming vitamins as energy source were about 60 % in all grades. By the answer of the students' in the Gesamtschule there is on the one hand an increase of correct answers and on the other a higher number of wrong answers in the higher grades than in the lower ones.

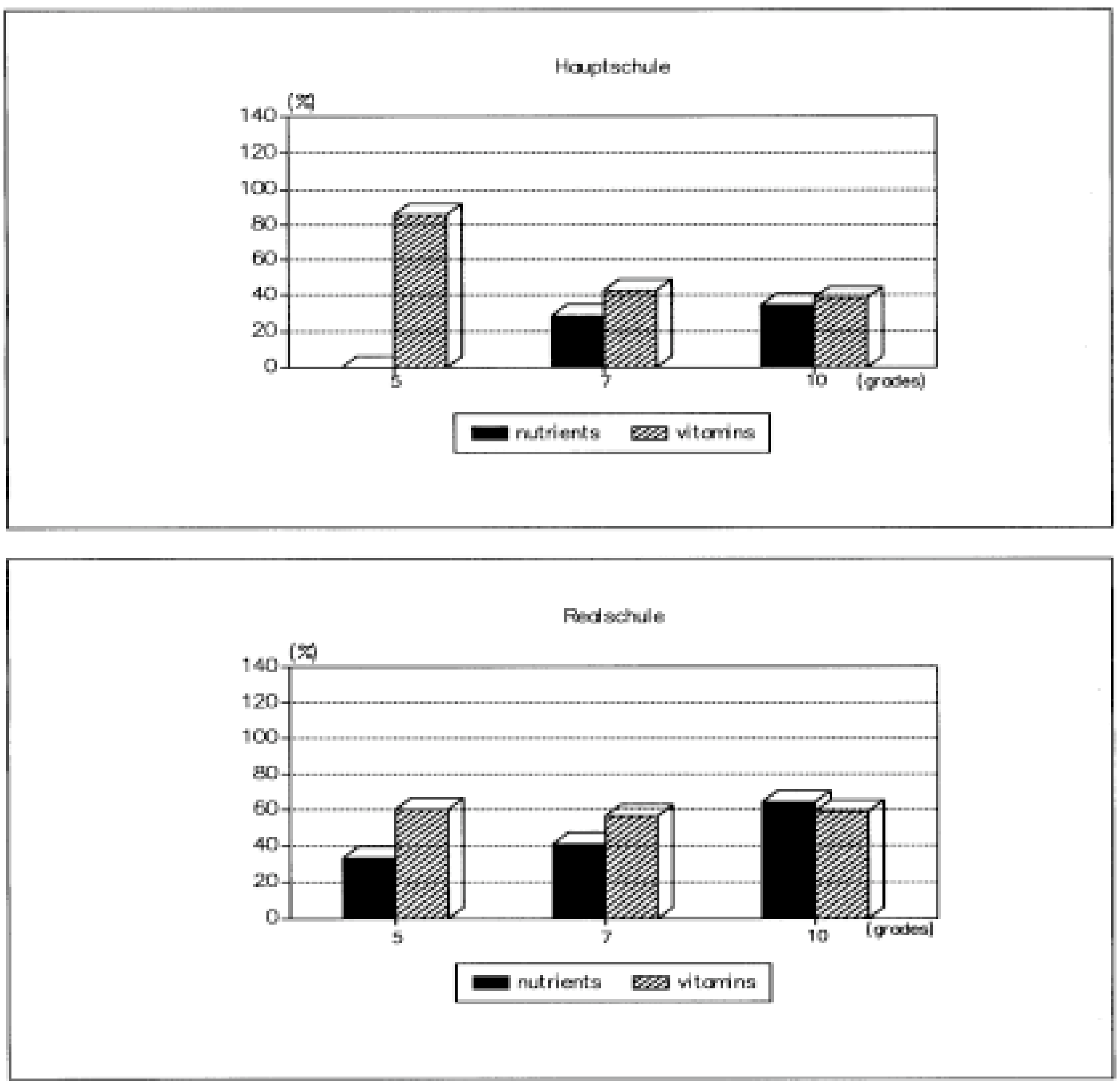



**Fig.8a / b:** Comparative represention of the answers in which nutrients and vitamins were mentioned as energy sources. Students' responses in percent.

**Fig.8a / b:** Comparative represention of the answers in which nutrients and vitamins were mentioned as energy sources. Students' responses in percent.

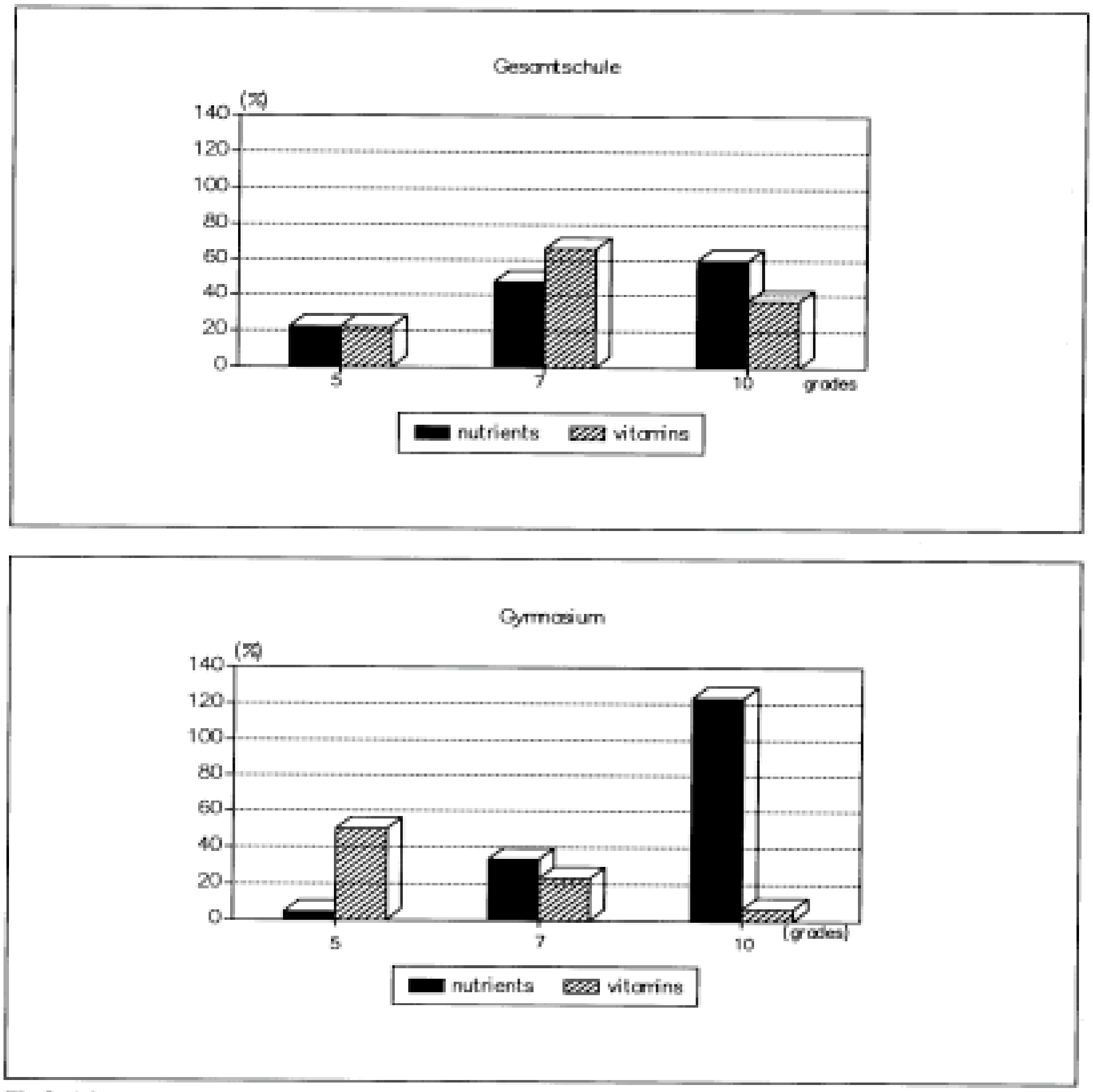



**Fig.8c / d:** Comparative representation of the answers in which nutrients and vitamins were mentioned as energy sources. Students' responses in percent.

**Fig.8c / d:** Comparative represention of the answers in which nutrients and vitamins were mentioned as energy sources. Students' responses in percent.

**Guide question E:**

**E.** *Do students have concepts about what organisms need energy for?*

Almost all students knew that organisms need energy. They associated everyday life activities as "running, dancing, thinking and being very much concentrated" with energy. "Metabolism", "the activities of muscles and organs" and the "maintenance of the body temperature" were associated with the "need of energy" by only less than 10 % of the students (n= 402).

**Guide question F:**

**F**. *Do the students recognize that in many processes in life energy is changed into different forms but is neither used up or lost?*

Only 13 % of the students in the sample had basic concepts of energy. Out of these 13% many students (80% of the fifth graders and seventh graders and 53% of the tenth graders) believed energy is something that is used up. It is important to underline that only very few answers concerning the physical aspect were correct.

Further, the students were questioned about different forms of energy. Only very few students knew different forms of energy. They only talked in general terms about carriers of energy as a source of energy. Of all 553 answers "sun" (44%), "water" (34%), "wind" (25%) and "atomic energy" (25%) ranked in the highest. With the terms "wind - energy", "water - energy" many students did not associate concepts of a process of transformation in a physical or technical way. Mostly they associated those factors with the term energy which they thought to be essential for the life of human beings and animals. Figure 9 shows for all four schooltypes how often the misconception of "using up" of energy occured in the three grades.

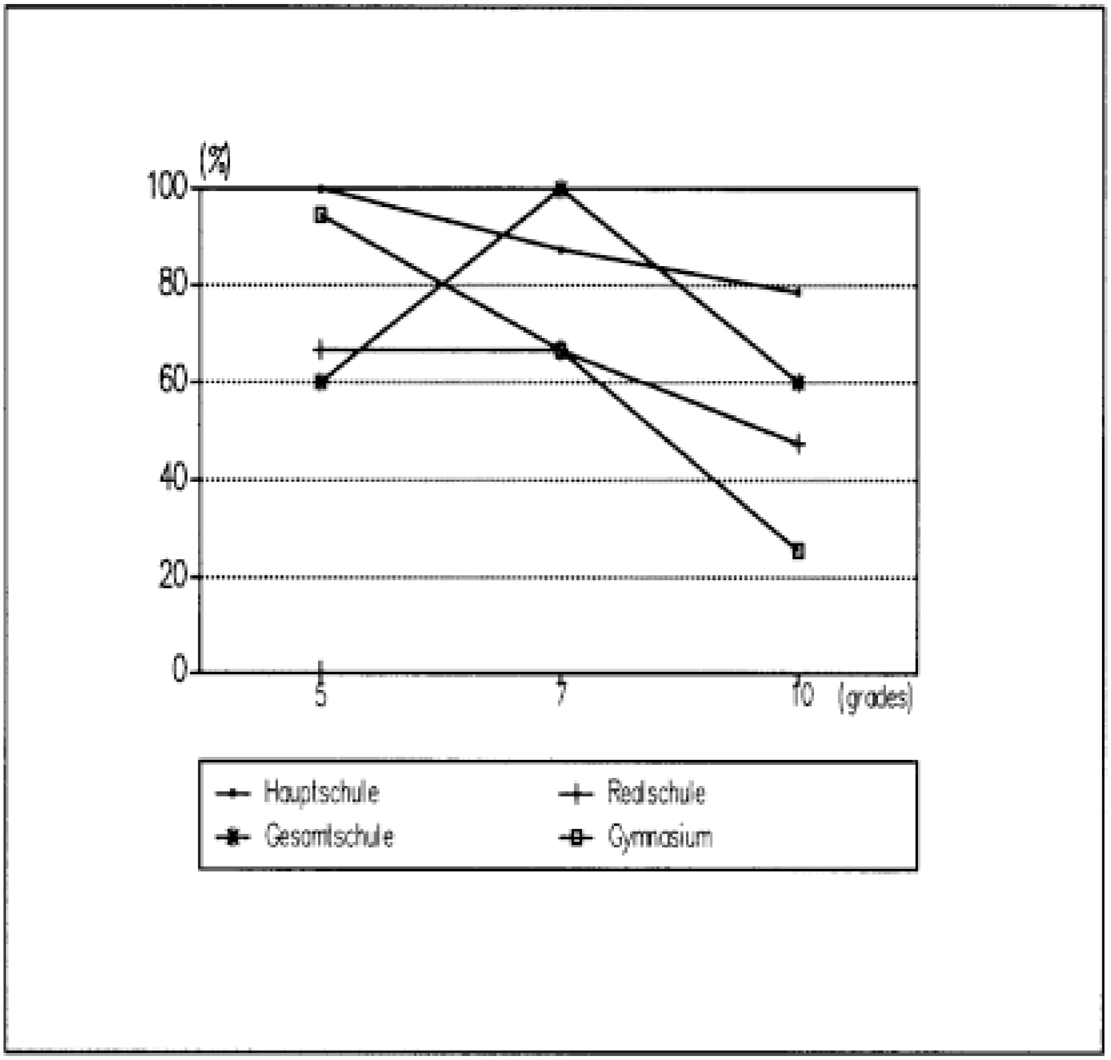



**Fig.9**: Total count of the misconception "using up of energy" - a cross - school comparison

**Fig.9**: Total count of the misconception "using up of energy" - a cross - school comparison

**Guide questions G and H:**

**G**. *Do the students know that despite this fact within an individual food chain there is a loss of energy?*

**H**. *Do the students know why?*

The results show that only a third (n= 546) understood that within the food chain there is a loss of energy. The other students were not able to see a relation between the turnover of nutrients and energy of an organism and the need for energy that belongs to a higher level in the food chain. This complex concept was cited most frequently by students from the Gymnasium, whereas students from other schooltypes explained the higher need for energy with the directly visible factors of "bodysize" and "activity". The fact that organisms give off energy to their environment - e.g. in the form of warmth - was hardly known to the students.

### *DISCUSSION OF THE RESULTS*

The investigation tried to find out, if the students questioned had the prerequisites needed to understand the process of of "energy flow" in the ecosystem. In the fifth to tenth grades, students are supposed to learn according to the official guidelines and textbooks about the subjects: "nutrition of human beings and animals", "photosynthesis" and "food chain in the ecosystem".

The investigation showed that the students' knowledge about these topics had deep gaps. There was often not enough basic knowledge to understand the topic "flow of energy in the ecosystem" and to create a scientifically acceptable conception. The students of the Gymnasium showed in all three grades that they had more and better knowledge about these topics than those of the other secondary school I types.

From the data of the investigation we can draw some conclusions about the reasons for the lack of understanding demonstrated. The term "energy" was very abstract for many students. In this phenomenon they saw a necessity for the physical function, encouraged by the biology books which the students use. At the same time they have the concept that energy is located in substances that transport energy. The students know that energy is the prerequisite for the life of plants, animals and human beings. They derive from this concept that all things and factors are connected with energy which they consider to be essential for life. Thus the answer to question two showed that the young students named all factors, which a plant needs in order to grow as a source of energy.

The answers to question one showed similar results. The vitamins the students concidered to be very effective and essential were named as "sources of energy". The answers to question three confirmed this assumption. All students knew that food is a source of energy for animals but they also named air and water as sources of energy. The fact that most students mentioned water as a source of energy for animals showed a further and very decisive misconception. The students showed great insecurity as they could not explain, if water contains nutrients which are used as a carrier of energy or not. Many, especially older students, knew that animals and human beings cover their need for energy with the help of nutrients. A great percentage of these students though seemed to transfer this concept to plants. Altogether 50% maintained that plants got their energy from the soil. In this process the misconception that soil contains nutrients, which are necessary for the growth of plants must play a big role. If the topic "photosythesis" is treated in classes, teachers should watch out that it is necessary to distinguish between the terms "mineral substances" and "nutrients".

Besides that the result shows that the meaning of sun- energy for the production of biomass was underestimated by the students. Some answers show that the students often associate the concept "heat" with the concept one. This phenomenon which they could experience directly was often given by the fifth graders as a reason why the plants need sun in order to live. Concerning the theme "energy flow in the ecosystem" is could be seen that the true origin of heat was hardly recognized by the students. Further, they were very uncertain about the carriers of energy. The "process of the transformation of energy in the food chain" was understood by up to one third of the students. They often gave the wrong explanation for the loss of energy, occuring along the food chain. Most of the students had the notion that energy is used up by the organism. Only a small number of students understood that organisms free energy through their excrements. The concept that organisms transfer energy to their environment in the form of heat was not mentioned by any of the students.

In general one can say that few students were aware of the aspect that energy can be transformed and preserved. Thus the most important principles of the flow of energy in the ecosystem were not recognized.

## 5. INNOVATIONS OF SCHOOL TEACHING AND LEARNING

The present situation in the German school system is very unstable. Parents, educational staff and school administrators take all claims in an attempt to restructure this system, to modify and to refom it. The attempt to innovate natural science teaching is part of this understanding.

## 5.1 CONSEQUENCES RESULTING FROM OUR INVESTIGATIONS

All investigations of our research group have demonstrated in primary schools as well as in all school types at the secondary I level that students do not gain sufficient knowledge which would allow them to classify and to explain everyday phenomena in a competent, skilful and correct way. Therefore we conclude that only by innovating both areas of teaching and learning will it be possible to diminish and/or to correct students' misconceptions, to improve students' knowledge and understanding. Besides changing structures of school organisation (e.g. by lowering the class frequencies, improving the age-structure of teachers by employing young colleges, enlarging the space of classrooms and rooms where specialized subjects are taught, increasing all efforts to build more schools where children can stay all day in order to reduce social caused deficiencies, engaging school pychologists and additional assistants) and altering of the framework for biology lessons (e.g. further reducing of the wealth of information, eliminating the constant change of subjects in a 45- minute rhythm, disallowing of the strict separation of subjects- as already introduced in the Gesamtschule- allowing of the admission to courses based on performance or natural talent) these innovations mainly demand a change in the understanding of teaching and learning. Teachers and students have to define their targets and their tasks in a new and meaningful way.

In this connection especially the self-perception of teachers and the way they understand their own role in the learning process has to be altered (BÖNSCH 1986). That means that one big step towards a solution can and has to be taken by the teachers themselves: in the way they regard their students, in their own willingness to welcome new ideas and to invest time and work. Most importantly teachers must begin to see students as they are and not as they would them like to be, except the given classroom situation and what realistically and specifically their students contribute to it. Learning processes may no longer be seen as linear-additive organized learning courses but have to be understood as learning units which are linked to one another, build upon each other and complement one another.

## 5.2 "FREIE ARBEIT": AN APPROPRIATE WAY TO REORGANIZE BIOLOGY TEACHING IN SCHOOLS

"At the beginning of every conquest you would not find abstract knowledge - it usually grows in the same proportion as it is used in life - but experience, practise and work" (FREINET 1980). This understanding of FREINET is of immediate interest, as ist reflects the ideas of many people in the reform movement of education (Reformpädagogen: FLITNER, GAUDIG, MONTESSORI, PETERSEN, see FLITNER 1992), who have been claiming for a long time that new ways of teaching should be instituted in schools (WINKEL 1992). In our opinion "Freie Arbeit" - the promise that derives from their ideas is an adequate way to reform biology teaching to the extent that misconceptions are avoided or eliminated and scientific knowledge and understanding is effectively imparted to the students.

In the understanding of all authors "Freie Arbeit" is an individual space - including educational and scholastic aspects - where students get the opportunity of work picked out by their own choice and done in their own rhythm within a self chosen social frame. "Freie Arbeit" means both: open instruction and didactical and methodological differentiation. In order to consider it in its entirety it is often necessary to surmount the limits of the subject. Students select their work out of various options respecting their own interests in - more or less - close connection to the contents of their lessons. "Freie Arbeit" is characterized by both terms: freedom and work.

**"Freie Arbeit"**

| **freedom** | **work** |
|---|---|
| - of aims | - search/ research |
| - of subject-matters | - decisions |
| - of materials | - plannings |
| - of presentation | - realization of work, results |
| - of surroundings | - control |
| - of social structures | - reflection, settlement and satisfaction |

**limits**

- freedom of others
- impairment of the situation, in which work is done and of the results

**Fig.10:** "Freie Arbeit": A methodological innovation of teaching in the classroom - contents and conditions (adapted from MÜLLER 1989)

Students have the freedom to choose a task and a method, to solve this task working single-mindedly, systematically, indepentendly and responsible to themselves (e.g. "self- responsible"). "Freie Arbeit" derives from a pedagogy, that puts the child at its centre. On the basis of a deep- seated confidence in the developmental potential of children, students are taken serious, their interests and questions are positioned at the center of the instruction. By executing their work in a self-responsible way with self-chosen time limits students change their role: Instead of being receptive and passive they suddenly develop to be active and productive members of their classes (SENNLAUB 1985). This is valid with a view to the cognitive, the pragmatic and the social level. Students learn by doing, by constructing. Knowledge is no longer urged on the students, ways or methods of learning are no longer forced onto them, but are self-decided and self-executed. Besides an increase in competence and self-reliance children realize and appreciate the fact that they can work successfully even if they are not too intelligent. While they are learning they can individually use their different perceptions of what constitutes success to expand learning (HELMING 1977, HOLTSTIEGE

1978, HÖVEL 1993). On the other hand they can connect the subject- areas in a meaningful way and relate them to their own concepts.

During "Freie Arbeit" the teachers' role is multifunctional (KAYSER/SCHÄKEL 1986). He is the connecting link between his students and prepares the learning-situations and -environment, he is both assistant and interpreter. As a spectator he evaluates the students' attitudes towards work, their needs and their problems and draws his conclusions in order to extend and to pinpoint the so- called "prepared field". At the same time he introduces new ideas and contents. He demonstrates how new materials can be used in a logical and skilful way (MÜLLER 1989).

| A | B | |
|---|---|---|
| **teacher** ( as instructor) | **student** | |
| advancing problems | self - responsible decisions | **teacher** ( as connecting link, assistant, interpreter, spectator, introducer) |
| material, media | material | |
| **student** solving problems | new ideas and understanding | |

**Fig.11:** Comparison of the traditional (A) and the innovated (B) way of teaching and learning, especially regarding the aspect of "Freie Arbeit"

At the beginning of a learning unit a situational example could be discussed as well as an article from a newspaper or a discovery the students have made outside the classroom. Everybody is asked how he would answer the question or tackle the problem and is encouraged to pick out a way to find a solution. In this phase the teacher offers different materials (e.g. books from the school-library, cards on which experiments are demonstrated, illustrations, data). The children can either accept this material or look for something else (e.g. they decide to interview an expert, get into contact to an offical person). They work alone, with a partner or in a group. Before work starts a strict schedule is agreed upon. The teacher discusses the proceeding and the results with the students, tries to give them help, but never forces them to follow his ideas and never persuades them to use a different approach. After a specific time the results are presented and discussed. It is necessary to compare the results with the ideas expressed initially as well as to place them to ideas delt within the past or to be delt within the future. An evaluation of the results and of the effectiveness of the completed work is a good way of learning self-control/self- discipline.

At the moment attempts to transfer "Freie Arbeit" to classroom situations are rather rare. Only on the level of primary schools have some teachers started to introduce these ideas and to consider them. So it continues to be difficult to find schools and teachers willing to cooperate. After introducing "Freie Arbeit" to them in special courses they have to invest a great deal of preparation and work to explore their students' ideas, noting them, interconnecting them, preparing material and media to select from. Yet it seems to be a worthwhile endeavor, because it enables students to work by themselves and thereby enriches them (HELMING, 1977 in reference to MONTESSORI).

## REFERENCES


AUSUBEL, D (1968): Educational Psychology: A Cognitive View. New York

BELL, B./ BROOK, A. (1984): Aspects of secondary students' understanding of plant nutrition: Summary report. Leeds: University of Leeds, Centre for Studies in Science and Mathematics Education, 1-23

BELL, B. (1985): Students' ideas about plant nutrition: What are they? J. of Biol. Educ. **19**, 3, 213-218

BÖNSCH, M. (1986): Lernökologie. Zur Konstruktion von Lernsituationen. Essen

DRIVER, R. (1983): Changing perspectives of science lessons. Leeds: University of Leeds, Centre for Studies in Science and Mathematics Education, manuscript, 1-16

DRIVER, R. (1983a): The Pupil as Scientist? London

DRIVER, R./ ERICKSON, G.L. (1983): Theories - in - action: Some theoretical and empirical issues in the study of students' conceptual frameworks in science. Studies in Science Educ. **10**, 37-60

DRIVER, R. (1986): The approach of the children's learning in science project. Paper presented at the annual meeting of the American Educational Research Association, San Francisco

DUIT, R. (1981): Übersicht über einige allemeine Probleme der Erfassung von Vorstellungen. In: Duit, R. et al.: Alltagsvorstellungen und naturwissenschaftlicher Unterricht. Köln

DUIT, R./ PFUNDT, H. (1991[3]): Bibliography. Students alternative frameworks and Science Education

DUIT, R. (1992): Forschungen zur Bedeutung vorunterrichtlicher Vorstellungen für das Erlernen der Naturwissenschaften. In: RIQUARTS, K. et al. (Hrsg.): Naturwissenschaftliche Bildung in der Bundesrepublik Deutschland. Band IV: Aktuelle Entwicklungen und fachdidaktische Fragestellungen in der naturwissenschaftlichen Bildung. IPN-Kiel, 47-85

FLITNER, A. (1992): Reform der Erziehung. München

FÖLLING-ALBERS, M. (1991): Schulkinder heute. Auswirkungen veränderter Kindheit auf Unterricht und Schulleben. Oldenburger Vordrucke. Universität Oldenburg. Zentrum für pädagogische Berufspraxis, H.**133**

FREINET, C. (1980): Pädagogische Texte. Reinbek

GERHARDT, A./ PIEPENBROCK, C. (1990): Misconceptions im Fach Biologie bei Schülern der Sekundarstufe I - Möglichkeiten der Analyse. In: KILLERMANN / STAECK (Hrsg.): Methoden der Biologieunterrichts. Köln, 223-234

GERHARDT, A./ PIEPENBROCK, C. (1992): Untersuchungen zu Alltagsvorstellungen von Schülern im Biologieunterricht der Sekundarstufe I - Beispiel "Energie". In: ENTRICH/STAECK (Hrsg.): Sprache und Verstehen im Biologieunterricht. Alsbach, 257-266

GERHARDT, A./ RASCHE, B./ RUSCHE, G. (1993): Untersuchungen zu Alltags-vorstellungen von Schülern im Biologieunterricht der Sekundarstufe I. (in press)

GILBERT, J./ WATTS, D. (1983): Concepts, misconceptions and alternative conceptions: Changing Perspectives in Science Education. Studies in Science Educ. **10**, 61-98

GLASERFELD, E. von (1985): Konstruktion der Wirklichkeit und des Begriffs der Objektivität. Schriften der Carl F. Siemens Stiftung. In: GUMIN, H./ MOHLER, A. (Hrsg.): Einführung in den Konstrukivismus. München, 1-27

GRAF, D. (1989): Anwendung der Mapping-Methode zur Begriffsvermittlung und Begriffsüberprüfung am Beispiel einer

Unterrichtseinheit "Ernährung und Verdauung" für die Klassen 5 und 6. In: Der math.-nat. Unterricht **42**, H 7, 427-432
HEDEWIG, R. (1988): Naturvorstellungen von Schülern - Ergebnis einer Befragung von Schülern der Jahrgangsstufen 3-10 unterschiedlicher Schulformen. In: HEDEWIG/STICHMANN (Hrsg.): Biologieunterricht und Ethik, Köln 212-229
HELMING, H. (1977): Montessori - Pädagogik. Stuttgart
HÖVEL, W. (1993): Eine Schule nach Freinet organisieren? In: Freinet - Praktisch. Pädagogik **45**, H.2, 26-31
HOLTSTIEGE, H. (1978): Modell Montessori. Stuttgart
JUNG, W. (1985): Schülervorstellungen im Physikunterricht - Ein didaktisches Problem. physica didactica **12**, H 4, 11
KAYSER, A./SCHÄKEL, L. (1986): Kinder und Lehrer lernen: Freie Arbeit. Frankfurt/M.
KULTUSMINISTERIUM NORDRHEIN-WESTFALEN (1991): Die Sekundarstufe I und II. Düsseldorf
MAYNTZ, R./HOLM, K./HÜBNER, P. (1971): Einführung in die Methoden der empirischen Soziologie. Opladen
MÜLLER, W. (1989): Freie Arbeit - Ein Weg zum Selbst-Werden und zum Selbsterfolg. IN: STUFFER, G. (Hrsg.): (K)eine besondere Schule. München
NOVAK, J. (1980): "Eine Alternative zu Piagets Psychologie für den naturwissenschaftlichen Unterricht". physica didactica **7**, 17
NOVAK, J. (1987): "Human Constructivism: Towards a unity of psylogical and epistemological meaning making". In: NOVAK, J.: Proceed of the 2. Int. Seminar "Misconceptions and Educational Strategies in Science and Mathematics", Vol. I, Ithaca: Cornell University, 349-360
POPE, M. (1985): Constructivistic goggles: Inplications for process in teaching and learning. Paper presented at BERA Conference, Sheffield
SCHÄFER, G. (1983a): Der Energiebegriff im ökologischen Kontext. Pd N-Biol.**7**, 197-201
SCHÄFER, G. (1983b): Der Begriff Ökosystem in den Köpfen von Schülern und Lehrern. Verh. Ges. f. Ökologie **11**, 351-359
SENNLAUB, G. (1985): Grundlagen von Freiarbeit und Wochenplan. In: Erziehungswissenschaften - Erziehungspraxis, H.3, 24ff

STAVY, R. et al. (1987): How students understand Photosynthesis. Int. J. of Science Educ. **9**, no. 1, 105-115

VESTER, F: (1982): Denken, Lernen, Vergessen. München

WINKEL, R. (1992): Reformpädagogik konkret. Hamburg

STAATSEXAMENSARBEITEN Faculty of Biology University of Bielefeld, (Working group A. GERHARDT et al.) unpublished

BURGER, J. (1991): Fehlvorstellungen bei Schülern im Bereich der Biologie - untersucht am Beispiel des Energiebegriffes.

EICKHOFF, A. (1993): Untersuchungen zu Schülervorstellungen zur Thematik "Energiefluß im Ökosystem".

KNEMEYER, K. (1992): Fehlvorstellungen bei Schülern im Biologieunterricht - untersucht an der Thematik Diffusion/ Osmose.

KNIPPERTS, A. (1992): Fehlvorstellungen bei Schülern im Biologieunterricht - untersucht für Beispiele aus der Ökologie.

KÖNIGS, K. (1992): Schülervorstellungen zum Grundphänomen des Lebendigen "Fortpflanzung" - Eine empirische Untersuchung im Bereich der Primarstufe.

KREFT, M. (1992): Schülervorstellungen zum Grundphänomen des Lebendigen "Entwicklung" - Eine empirische Untersuchung im Bereich der Primarstufe.

MARZOLF, G. (1992): Schülervorstellungen zum Grundphänomen des Lebendigen "Reizbarkeit" - Eine empirische Untersuchung im Bereich der Primarstufe.

NOLTING, K. (1992): Schülervorstellungen zum Grundphänomen des Lebendigen "Bewegung" - Eine empirische Untersuchung im Bereich der Primarstufe.

**Address:**

Prof. Dr. Almut Gerhardt, Christiane Piepenbrock, Gabriele Rusche
University of Bielefeld, Faculty of Biology
Dept. of Didactics of Biology,
Postfach 100131, 33501 Bielefeld, Germany

**STUDENTS' MISCONCEPTIONS IN BIOLOGICAL SUBJECT AREAS AND CONSEQUENCES IN TEACHING BIOLOGY:**

Almut Gerhardt, Christiane Piepenbrock, Gabriele Rusche
University of Bielefeld, Bielefeld, Germany

**Table of Figures**

Fig. 1 Classroom topics in biological subject areas investigated by Gerhardt and coworkers (see references) concerning students' conceptions/ misconceptions
Fig. 2 The basic structure of the German public school system ,e.g. North Rhine - Westfalia (graph adapted from KM/NRW 1991, simplified). Secondary modern school: Hauptschule; intermediate school: Realschule; grammar school: Gymnasium; comprehensive school: Gesamtschule)
Fig. 3 Terms used in our investigations - their meaning and correlation
Fig. 4 5 situational examples illustrating the "transformation of energy" - a test design
Fig. 5 Pattern of categories and classification of the answers concerning the example "fly"
Fig. 6a Energy questions 1- 5: Schematic representation of students' responses in percent by question and category (grade 5)
Fig. 6b Energy questions 1- 5: Schematic representation of students' responses in percent by question and category (grade 10)
Fig. 7 Schematic representation of students' responses to "sun as energy source for green plants". Students' responses in percent according to all secondary school I types: Gymnasium, Gesamtschule, Realschule, Hauptschule (see text for details)
Fig 8a-d Comparative representation of the answers in which nutrients and vitamins were mentioned as energy sources. Students' responses in percent.
Fig. 9 Total count of the misconception "using up of energy" - a cross school comparison

Fig. 10 "Freie Arbeit": A methodological innovation of teaching in classroom - contents and conditions (adapted from MÜLLER 1989)

Fig. 11 Comparison of the traditional (A) and the innovated (B) way of teaching and learning, especially regarding the aspect of "Freie Arbeit"

# STUDENTS' MISCONCEPTIONS IN BIOLOGICAL SUBJECT AREAS AND CONSEQUENCES IN TEACHING BIOLOGY:

Almut Gerhardt, Christiane Piepenbrock, Gabriele Rusche
University of Bielefeld, Bielefeld, Germany

## Table of contents

1. INTRODUCTION
2. THE BASIC STRUCTURE OF THE GERMAN SCHOOL SYSTEM
EDUCATIONAL AND SOCIO- CULTURAL PREREQUISITES
3. THE CONSTRUCTIVIST VIEW OF LEARNING
4. OUR INVESTIGATIONS ON STUDENTS' CONCEPTIONS/ MISCONCEPTIONS
4.1 INVESTIGATIONS IN GRADES 1 AND 4 CONCERNING BASIC PHENOMENA OF LIFE
*METHODS*
*RESULTS AND THEIR EVALUATION*
4.2 INVESTIGATIONS IN GRADES 5, 7, 9 AND 10 CONCERNING " ENERGY IN THE BIOLOGICAL CONTEXT"
4.2.1 TRANSFORMATION OF ENERGY DURING MOTION IN LIVING SYSTEMS
4.2.1.1. A PRETEST: THE KEYWORD "ENERGY" AND STUDENT ASSOCIATIONS
4.2.1.2. THE MAIN INVESTIGATION
*METHODS*
*RESULTS AND THEIR EVALUATION*
4.2.2 ENERGY FLOW IN ECOSYSTEMS
*METHODS*
*RESULTS AND THEIR EVALUATION*
*DISCUSSION OF THE RESULTS*
5. INNOVATIONS OF SCHOOL TEACHING AND LEARNING
5.1 CONSEQUENCES RESULTING FROM OUR INVESTIGATIONS

5.2 "FREIE ARBEIT": AN APPROPRIATE WAY TO REORGANIZE BIOLOGY TEACHING
IN SCHOOLS
REFERENCES