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# Conceptual classroom environment - a system view of learning

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# Conceptual classroom environment—a system view of learning

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This paper examines the relations between changes in the beliefs of an individual student and the distribution of beliefs in a classroom. The distribution of beliefs among students is termed here 'conceptual environment'. Based on social views of learning, we suggest that conceptual environment is an indicator of the conceptual tension in a group.

We show that conceptual change of individuals does not necessarily result in changes in the classroom conceptual environment. Conceptual change is normally viewed as a personal process. We look at the relations between individual conceptual change (a microscopic view) and total classroom conceptual change (a macroscopic, system view).

We study changes in students' ideas of a food chain. Then we look for underlying ontological beliefs that may explain students' ideas, and examine changes in students' responses prior and consequent to the instruction sessions. Classroom concepts of a food chain reflect an underlying set of beliefs of a mechanistic nature. For instance the metaphor of a 'chain of beads' is employed to explain the relations among elements of a food chain.

Though more than half of the students changed their responses, ontological beliefs were hardly changed. Changes in students' responses apparently cancelled each other, thus from the classroom point of view, only a minor change was identified in the overall conceptual environment. The social-conceptual tension involved in conceptual change is not necessarily changed.

## Introduction

A large amount of research indicates that learning emerges through social interactions, clarifications, conceptual adaptation, generation of communication channels and interpretation routines, rather than in individual incubation processes only (Vygotsky 1978, Lave 1988, Newman *et al*. 1989, Rochelle 1992, Pea 1993, Reiner 1998). Learning through social interaction relies heavily on the tension between the views held by the interacting individuals. For instance, hardly any clarification is needed if all individuals in a classroom hold identical ideas. The tension between individual views, once recognized, may act as an incentive for discussion, clarifications, gradual conceptual convergence and generation of conventions (Rochelle 1992). Similar to sensory-based affordances (Gibson 1962, 1966, 1979) we suggest that learners negotiate and construct a socially acceptable meaning—*social affordance*—through an ongoing cycle of refinement. The distribution of views, that we term 'conceptual environment', is then at the heart of classroom learning processes. Being the reflection of students' ideas, it is also an indicator of the conceptual tension in a group. As such, the conceptual environ-

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ment shapes negotiation processes, therefore central in classroom learning.This paper takes a system view of classroom learning. This means viewing the learning process as changes in both the individual's concepts and in the classroom conceptual environment. Since school learning takes place in groups, we suggest that individual conceptual change is not a sufficient indicator for learning. Students' views may change in all directions. From the teacher's point of view, the change in classroom conceptual environment is crucial to designing curricular materials and learning situations (Rosenquist and McDermot 1987, McDermott and Schaffer 1992). Hence, we wish to explore the relations between changes in concepts of the individual and changes in the classroom conceptual environment. In other words, we wish to know the following—does individual conceptual change indicate changes in the classroom environment? Is individual conceptual evolution directional—towards a scientific concept? We suggest that some of students' views may change towards and some away from the 'correct' conventional concept, making changes in the conceptual environment unpredictable in the short run, yet a crucial factor in designing day to day learning activities.

The main goal of this study is to test the relations between changes in individual students' ideas and changes in classroom conceptual environment. We test changes from two points of view: students' concepts and students' ontological beliefs. These can be viewed as components of a system, the classroom conceptual environment being the system. Thus this study relates between the changes in the components of a system and changes in the system as a whole. We start by stating our view of a conceptual environment, then analyse changes in individual students' ideas and explore changes in classroom conceptual environment in order to test whether changes in the first necessarily indicate changes in the second. We conclude by discussing theoretical implications concerning the nature of science learning in a group set-up. The relations between individual learning and socially shared learning is discussed in view of Dawkins' (1989) theory of cultural memes.

## Conceptual environment—distribution of views

By conceptual environment we mean the collection and distribution of views held by the individuals of a particular community. We look at changes in the conceptual environment from two points of view. The first relates to changes in the distribution of students' concepts. The second relates to changes in the distribution of ontological beliefs and is based on the finding that students' concepts are rooted in well-defined underlying beliefs. The 'population' of the 'conceptual environment' is then both student concepts and underlying ontological beliefs. Ontological beliefs are deep, basic, and often tacit. They serve as anchors for assimilation and construction of new beliefs. For instance, a materialistic ontological belief may dominate students' concepts of light, electricity and heat: light is considered as substance, electricity is a fluid material, and heat is material fluid—'caloric' (Reiner 1991). In this regard we study the hypotheses that classroom conceptual environment is also dominated by one or more ontological beliefs similar to the materialistic belief students show.

We consider students' concepts as surface features of students' reasoning, while underlying beliefs, if present, are addressed as deep features. Within the domain of a food chain, an example that differentiates between the deep and surface structure beliefs would be related to the event of an extinct link. Extinction in this regard means the disappearance of an element in the environment while elimination means the disappearance caused by a particular artificial factor. One of students' beliefs reported in this study (see results) is that an extinct link in a chain, can be 'fixed' by attaching the previous and the following links to each other. This we call surface knowledge. Such a response may be based on analogy with an actual string of beads. When one of the beads breaks, its two neighboring beads can be mechanically reconnected to each other. The mechanical analogy is considered here a deep structure belief.

In testing the nature of the conceptual environment, we look at the relations between changes in distribution of concepts and ontological beliefs. We suggest that a change in students' concepts does not necessarily indicate changes in ontological beliefs. We further suggest that a change in individual students' concepts and ontological beliefs does not necessarily indicate changes in the classroom conceptual environment. Some students may move towards the scientific concepts while some move further away.



## Research questions

We studied three main research questions concerning students' concepts, students' ontological beliefs and conceptual environment:

1. Concerning students concepts: what are students' concepts of a food chain prior to and after classroom instruction?
2. Concerning ontological beliefs:
   - Are there any identifiable, underlying ontological commitments that dominate student concepts?
   - What are students' underlying beliefs prior to and after instruction?
   - Are the underlying beliefs reflected consistently across situations? What is the distribution of these beliefs prior to instruction?
   - How is the distribution changed after instruction? How is it related to changes in individual students' concepts?
3. Concerning changes in conceptual environments: what are the changes in the classroom conceptual environment of a food chain?

## Method

Twenty-eight ninth grade students (age 14.5-15 years old) were observed during 24 instructional sessions on ecology, in a well established urban school. The regular class-teacher, who also taught throughout the experiment, was experienced, knowledgeable, and was enrolled in a PhD programme in Ecology.

About three-quarters of the students in this class were from a medium to high socio-economic background, and were enrolled in the school after strict academic selection. The rest of the students were enrolled as part of an educational programme aimed at creating a rich learning environment, for 'inner city' students living in a less established neighbourhood. The educational programme included an extra afternoon session for further academic support. Number of boys and girls was about equal.

## Procedure

Twenty-four instructional sessions took place in a school biology laboratory, conveniently designed for teacher demonstrations, slide and transparencies presentations, and individual as well as collaborative learning set-ups. The teacher took advantage of all available facilities throughout instruction. All sessions were highly interactive.

Two hands-on activities were included in the learning experiment: a series of two hour sessions of laboratory activities focused on food chains, and an out-of-school, field activity, aimed at developing student familiarity with a-biotic and biotic elements as constituents of an ecological system. In both cases the learning environment was carefully designed to trigger teacher-student interaction, and collaborative student problem solving. Pre-test and post-test questionnaires were administered, and analysed. The questionnaire items are described in the following:

1. What is a food chain?
2. Are the following elements — nectar, butterfly, bird — constituents of a food chain?
3. What happens to a link in a food chain if the previous link is extinct?
4. Is a Bacterium inside the human body a part of a food chain?
5. If your answer to the previous question is ‘yes’, what would be the first element in the bacterium chain?
6. What determines the length of a food chain?

Students’ responses were analysed in order to identify their beliefs, both ontological and particular content. Yet, many of the beliefs are related to classroom discussions. In the following we briefly describe the context and topics of these discussions.

### *Topics for classroom discussions*

Two fundamental concepts were introduced: habitat and the ecosystem. An ecosystem was defined by the interaction among the biotic and a-biotic components comprising a given area. The cybernetic-dynamical principles of an open ecosystem were linked to the concepts of equilibrium of a system, set point, feedback processes, input and output. The concept of food was central. The special role of the producer in a food chain was related to cycles of elements in the biosphere, solar energy and its utilization by various organisms. The producer was introduced as the converter of sun-light into chemical energy, which is then consumed by other organisms, the consumers. Consumers are classified as herbivores, direct consumers of producers, and carnivores fed on other consumers. The decomposer, mainly bacteria and fungi, obtain their energy by decomposing dead organic materials. Thus a ‘chain’ of organisms, each of them using and storing energy is formed. Energy is transferred through an ecosystem, from light to chemical and heat energy. Since part of the energy is lost on heat at each transformation point, the higher the feeding (trophic) level in the chain, the less energy is available. The number of tropic levels is therefore limited to about seven levels. In order for the ecosystem to function, an ongoing input of energy is necessary.

Unlike the energy flow, materials are transformed cyclically in the ecosystem. Chemicals are obtained by the organisms from a-biotic components of the environment (inorganic materials) and are utilized for building their bodies. All natural materials return to their initial sources by the process of decomposition. A sequence of organisms in the ecosystem through which materials and energy flow, comprise a food chain. Examples of various ecosystems, biotic and a-biotic components, and interrelations in a food web rather than a chain, were discussed in detail.

### *Analysis methodology*

Students' responses were categorized according to two factors: content and underlying beliefs. To bypass our own interpretations of students' responses, we based our analysis on students' authentic terminology. Consistency of coding of two judges (content experts) was 0.97. The two judges were asked to code independently the underlying idea consistent with the response. Then we looked at internal consistency of underlying ideas, across questionnaire items. Consistency between the judges was 0.92.

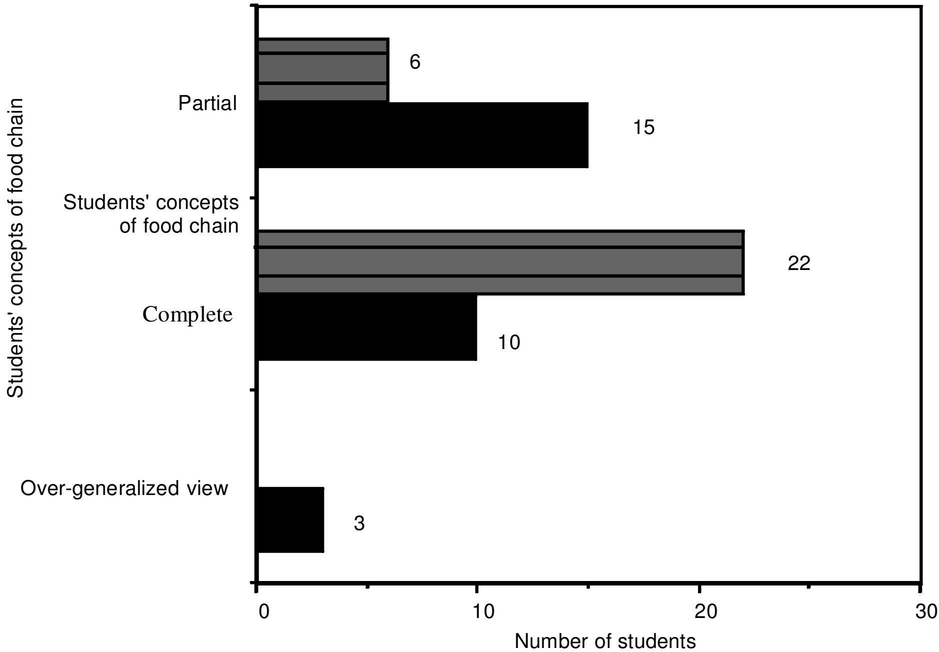
In the following, we describe the content distribution of student responses to each of the items in the questionnaire. Then we identify underlying beliefs and the consistency of their appearance in student responses across situations and content.

## Results

### *Analysis of student concepts of a food chain.*

Analysis of student responses reveals three main categories:

1. A complete description of a food chain — a response was recognized as such, if a producer and consumer were mentioned. Therefore, examples such as: grass eaten by a cow, which is ultimately eaten by humans, was considered legitimate for this category. No indications as to why students considered this as a food chain were provided in the responses. For instance, students may have included a plant because they recognized its function as a producer, or merely because they recognized its function as something that an organism could feed on. Though the plant was mostly mentioned as the first link, this should not be regarded as evidence that students considered the plant as a producer — this is merely a possible way to start a food chain.
2. Over-generalization of the concept of a food chain—this category is similar to the previous, with the addition of a-biotic elements such as sunlight, minerals, water, and soil. The chain was basically extended to include the supporting a-biotic elements present in the environment.
3. Partial food chain — indicates that students mentioned consumers only. Though three elements of consumers were mentioned, the producer (a plant) was not. For instance: 'a mouse eaten by a cat eaten by a dog' is considered a partial food chain.




**Notes:** Solid bars: students' views of a food chain in the pre-test.
Striped bars: students' views of a food chain in the post-test.

**Figure 1. Distribution of students' responses to: what is a food chain?**



Two major pre-post differences are reflected in figure 1. The first is that in the post-test more students included a producer and a consumer. The decomposer is absent from most student responses, both in the pre- and post-test. The second is that in the post-tests none of the students included a-biotic elements in the food chain. All of the students who added a-biotic components in the pre-test, left them out in the post-test, and shifted to a complete description of a food chain.

The formal notion of a food chain is generally based on the causal relations among the various elements in a chain. It implies that the availability of food of a specific organism in a chain depends upon the previous organism. According to ecological views, the features of a food chain are dominated by the following constraints:

- producer as the first link of a food chain;
- conservation of energy considerations;
- the role of the decomposer in the food chain.

Though more students constructed a complete food chain in the post-test, most responses in both the pre-test and the post-test, were based on the notion of 'feeding on'. The other constraints are totally ignored in the pre-test, and in most cases on the post-tests too. Students used several core features in recognizing a food chain. These also run in responses across various questionnaire items:

1. A hierarchy of sizes:

   'A big fish fed on a smaller fish fed on a smaller one'
   'Grass is eaten by a rabbit which in turn is eaten by a wolf'
   'Insects are eaten by plants, which in turn are eaten by a deer, then eaten by a lion, that is ultimately hunted by human beings'
   'A fly eaten by a frog, eaten by a cat'

2. A causal interdependency between the various links of the food chain, based on an eating order:

   'A certain organism is part of a food chain if in its physical environment there is food (another organism). One organism eats another and than survives at the expense of the other'

   This view was also reflected in responses to other questions. For instance bacteria were considered to be a part of a food chain because they are consumed (see analysis of students' responses to: is a bacterium part of a food chain?)
3. Total elimination of the consumed organism:
   Some students claim that for an element to be part of a food chain it must be totally eliminated after consumption:

   'A bacterium in our body is part of a food chain because it is eaten, which is like eliminated from the world . . . '

To summarize, it seems that the major factors students consider in identifying a food chain are: eating events, size hierarchy, and total elimination. They do not always include other major features of a food chain, such as a producer as the first link of the food chain. We believe these express a 'mechanistic nature' of students' concepts of a food chain. The nature of the causal linkage may vary: from a mechanistic assumption that larger organisms swallow smaller organisms to an abstract assumption of a hierarchical survival support system. As we shall argue in the following section, the mechanistic view that larger organisms swallow smaller organisms seems to be reflected in the responses to most questionnaire items.

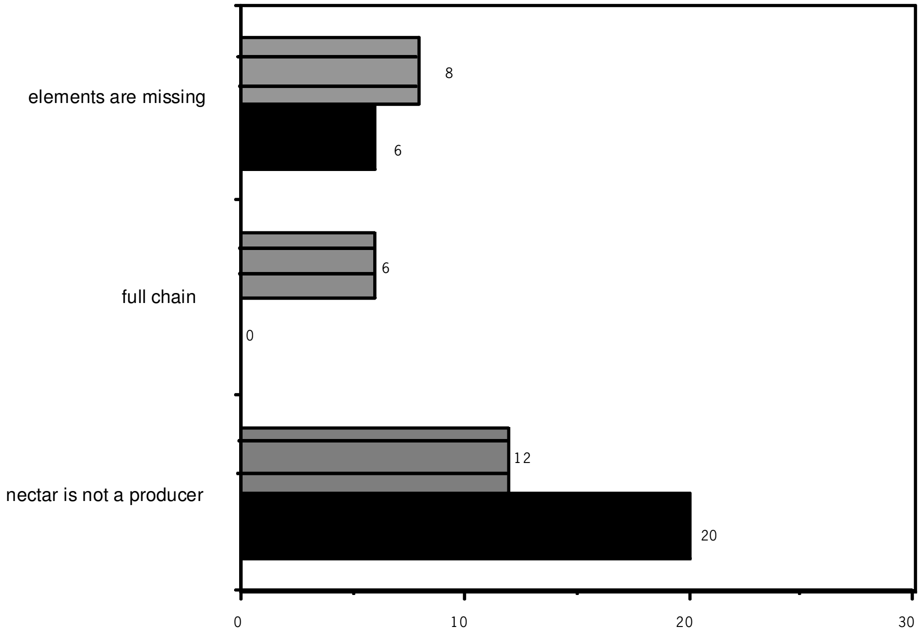
### *Distribution of responses to: are the following elements—nectar, butterfly, bird—constituents of a food chain?*

The purpose of this item was to validate the responses to the previous item. Though students realize nectar is a part of a plant, it is not always considered to be a producer, which makes this example somewhat trickier.

The following categories were identified in student responses:

1. Students do not recognize nectar as a producer; in most cases students claim that a producer must be a complete plant.
2. Full chain: the chain provided was recognized as such.
3. Elements such as a-biotic elements are not present in the given chain, therefore it is not a food chain.

The distribution of responses is described in figure 2.




**Notes:** Solid bars: students' views of a food chain in the pre-test.
Striped bars: students' views of a food chain in the post-test.

**Figure 2. Distribution of responses to: are the following elements—nectar, butterfly, bird—constituents of a food chain?**

Students included comments about the nectar itself. Some thought that this could not act as a producer because only part of the plant is consumed. *M* claimed that:

> 'This chain is not a food chain, because the nectar is only part of an organism. Lacking this part does not harm the organism'

*M* makes two claims: for an organism to be an element of a food chain it must:

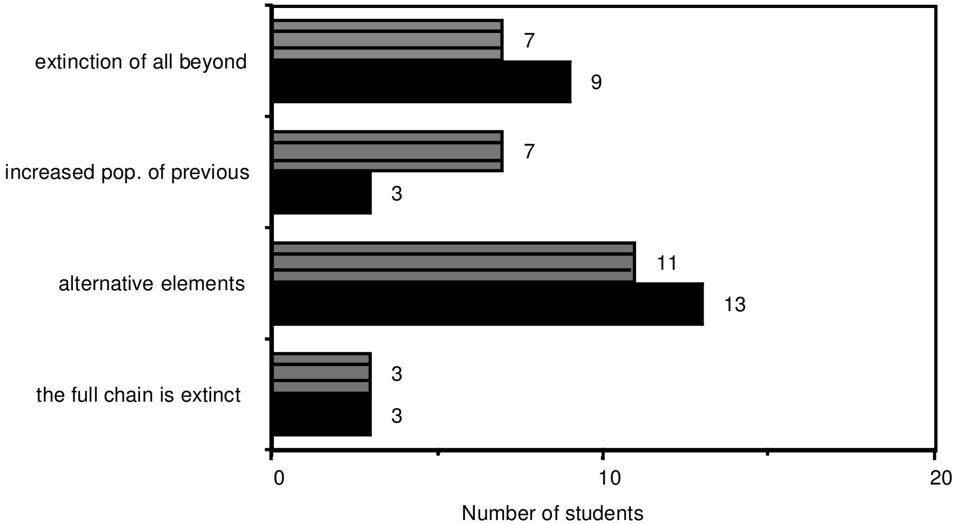
- be completely consumed;
- the consumed organism must be damaged.

Thus *M* and other students in this category may recognize the role of a producer in the chain, but do not recognize the nectar as such.

*Student views of the effects of an extinct element on the food chain*

Four cateogies were identified in students' responses:

1. All the elements beyond the extinct element, are eliminated too.
2. Increased population of the element previous to the one that was extinct.
3. Alternative elements are used to feed on: either alternative elements that were used as food prior to the extinction, or new elements.
4. The full chain is extinct.




**Notes:** Solid bars: students' views of a food chain in the pre-test.
Striped bars: students' views of a food chain in the post-test.

**Figure 3. Distribution of students' responses to: what happens to a link in a food chain if the previous link is extinct?**

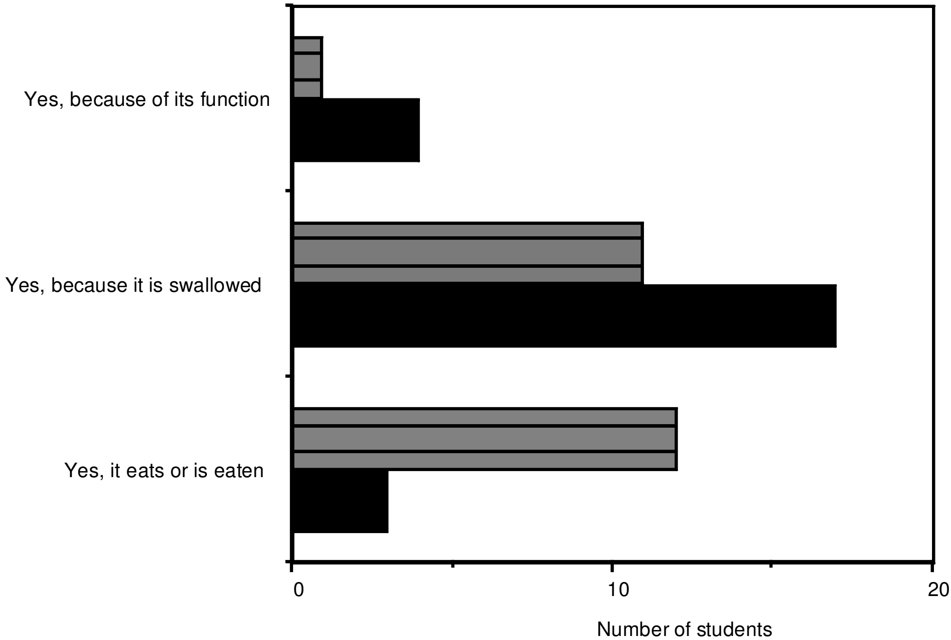
Note that both in the pre-test and post-test, most students tend to suggest that the organism could feed on alternative organisms instead of the extinct link. This may be correct if indeed the chain in question is not linear but rather a web. Analysing the content of students' responses shows that most students considered the chain as linear and suggested that a new element replaces the extinct element in the chain. The chain is still a linear chain, and the replacement is made possible, according to the students, by a mutation. This is supported by the idea students often reveal, that a mutation is a result of a need rather than a random phenomenon.

From a scientific point of view, the best response would include both the extinction of the elements of the chain beyond the extinct element, and an intense over-reproduction of the elements that are no longer consumed. Yet, none of the students mentioned both options. More students mentioned the extinction. This fits a mechanistic view of the food chain, as a hierarchy of support for survival. If the source of food is extinct (the extinct link) those that consume it, become extinct too.

*Students' views of a bacterium as part of a food chain*

We found that student judgments on whether a bacterium is a part of a food chain were based on three main views (see figure 4):

1. Function of bacterium in a food chain—some students perceived bacterium from the functional point of view: providing the human body with necessary factors for living, or; food for other organisms.




**Notes:** Solid bars: students' views of a food chain in the pre-test.
Striped bars: students' views of a food chain in the post-test.

**Figure 4. Distribution of students responses to: is a bacterium inside the human body, an element of a food chain?**

For instance:

> 'bacterium is a part of the food chain because it creates important substances for the human body, without which we cannot survive . . . Vitamin B for instance is provided by bacterium'
> 'bacterium is part of the food chain because it is eaten by humans. Some elements in the body, feed on bacteria such as white blood cells'
> 'bacterium decompose a lifeless body'

2. Bacterium is part of a food chain because it is swallowed by a larger organism and is present inside a larger object:

> 'bacterium is part of a food chain because it is eaten by a larger organism'

3. Bacterium is part of a food chain because:

> 'it is eaten in the body by some other organisms'
> 'it feeds on our body'
> 'because it is eaten inside our body and eats other parts in our body'

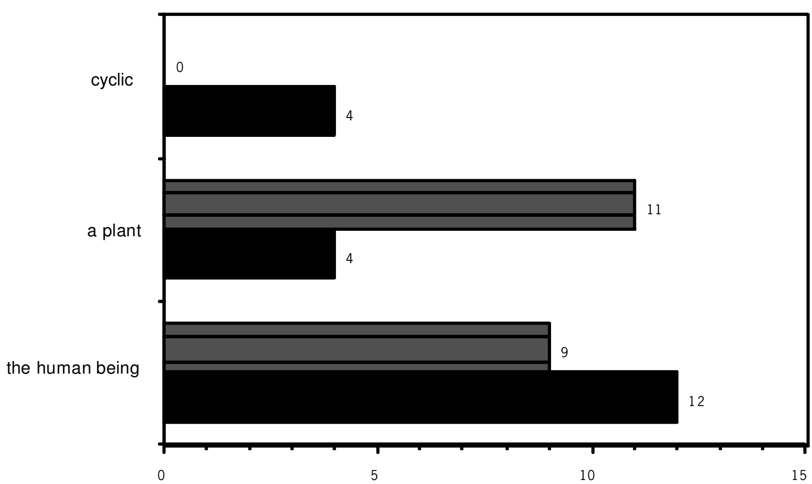
It may be interesting to note that all of the four students, who expressed a functional view in the pre-test, consistently expressed a non-mechanistic view, across the various items of the questionnaire.

Only few students recognized the role of bacterium as decomposer in the pre-test or post-test. This may be a reflection of the conceptual structure introduced in the classroom. It seems that the structure of the subject matter introduced through formal instruction, dealt with the function of bacterium as a decomposer in a food chain mainly in the context of lifeless bodies. This item in the questionnaire introduced bacterium in a new context, the context of a living human body. This unfamiliar context for bacterium is not obvious. It seems that the student turns towards his informal resources, which relate bacterium to illness. Thus bacterium is considered as an element of a food chain similar to any other element. The decomposing function is ignored. The justification mentioned in the responses is that bacteria live at the expense of the human body.

### *Analysis of students responses to: what is the first element in the bacterium chain discussed above?*

We identified three main categories. The first element in the chain is the human body; the second (see figure 5) a plant; and there is no first element because the chain is cyclic. A detailed description of each follows:

1. According to the cyclic responses there is no 'first' element. Obviously, for these students a plant is not necessarily a producer: 'I don't think there is a first or a last element because it's a cycle, and in a cycle you can't have a beginning and an end'.
2. The human body, organs or systems of the human body or whatever the human body consumes (air, food, water) were mentioned as the first link: 'The food consumed by the human body is the first link in the food chain. Then it is consumed by the bacteria'. 'The first element in this chain is the human body or a-biotic items, such as air, that decomposes and starts a new chain'.
3. A plant is the first link in a food chain. Many students changed their response from the second category to this one. This reflects some understanding of the plant as a producer.




**Notes:** Solid bars: students' views of a food chain in the pre-test.
Striped bars: students' views of a food chain in the post-test.

**Figure 5. Distribution of students responses to: if your response to the previous question is 'yes', what would be the first element in the chain?**

With the exception of the cyclic category that disappeared in the posttest, all the categories appear both in the pre-test and post-test.

*Analysis of student responses to: what determines the length of a food chain?*

Responses to this item are especially interesting if weighed against the previous responses. It may be of interest, for instance, to find out the relations between views about length and structure of the food chain. For instance, students who hold a cyclic view—what are their views of the length of a food chain?

Students' views of the length of a food chain may be determined by views of energy resources, material (food) resources, and what counts as food. Thus, responses to this item could help with the identification of patterns of consistency across items. In the following we briefly describe each of the categories identified (see figure 6):

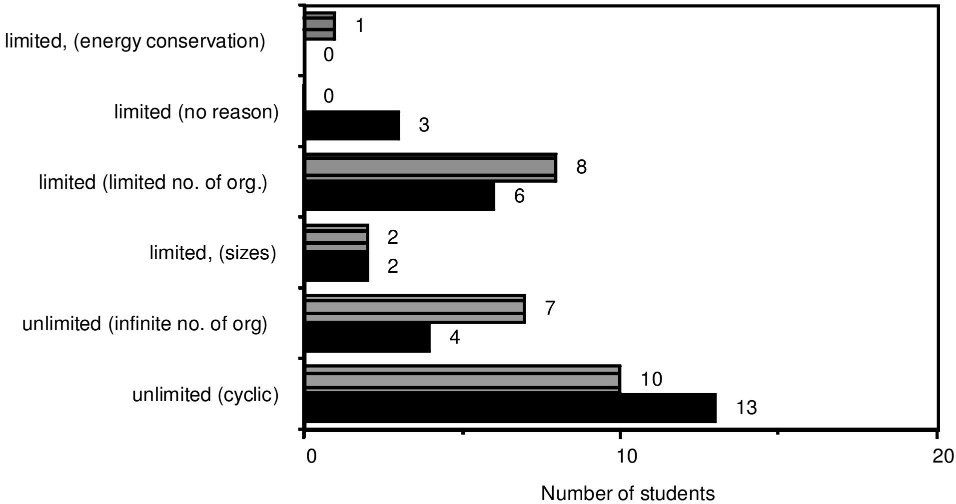
1. Students argue that a food chain is unlimited in its length, because it is cyclic:

   'The length of a food chain is unlimited because, for example, plants are eaten by insects, eaten by birds, eaten by carnivores, eaten by bacteria, again eaten by insects, then eaten by birds, by carnivores and so on'.
   'The length of the food chain is unlimited because in nature everything is cyclic and there is no last link to the cyclic chains'.
   '. . . unlimited, because everything in the world is ultimately decomposed by bacterium, on which other organisms feed, and that is how an infinite process is'.

   The idea that a food chain is cyclic was expressed in students' responses to item number 5 too (see figure 5). However, the number of responses to this item, based on the cyclic idea, was far larger than the number of corresponding responses to item number 5. This may be explained by the fact that some students may attribute the property of 'first' to an element in a cycle, or that students' views are fragmented and unrelated. Students may reject the cyclic idea in one situation (determine what the first link is) and adopt it for another situation (length of the food chain).
2. Number of organisms in nature is infinite, therefore the food chain is infinite too. 'The length of a food chain is unlimited, because there is always one to eat the so called last link in the food chain'.
3. The size of the organism is a key factor: the length of the food chain is limited because larger ones always eat smaller organisms:

   'The food chain length is limited because some organisms are so big, that there are no bigger organism to eat them'.

   This response is consistent with the mechanistic view that a food chain is a hierarchical series of organisms that eat each other according to their order of sizes.
4. The size and/or number of organisms is limited, therefore the length of the food chain is limited. Though this response may sometimes be considered as correct, the reasoning behind it, is not necessarily so. It is not based on the energy argumentation, but rather on the 'technical' argument of the size of the organism population:




**Notes:** Solid bars: students' views of a food chain in the pre-test.
Striped bars: students' views of a food chain in the post-test.

**Figure 6. Distribution of students' responses to: what determines the length of a food chain**

> '. . . limited. There is always a particular organism which is bigger than others. This means this is the ultimate "eater"'.
> 'The length of a food chain is limited by the number of organisms in the world'.
> '. . . limited, because the number of organisms in a habitat is limited'.

5. Energy considerations:

> 'The length of the food chain depends on the width of the base of the 'pyramid'. The number of the first producers is bigger than the number of the herbivores, and so forth. For the length of the chain to be unlimited, we need a very wide base of the pyramid'.

### Summary of changes in students' responses

It seems that there are no major changes in the categories identified in the pre-test and post-test. Yet we found it interesting to identify the number of students who changed their responses. Results are described in table 1. The numbers indicate the proportion of students that changed their response, relative to the total number of responses.

The second column in the table shows the number of students that changed their views in the post-test as a proportion of the total number of students that responded to the item. It seems that overall, more than 50% of the students changed their views in relation to the above items. Not all the changes were 'positive' in the sense that they were closer to the 'scientific' idea. The changes reported in the second column of table 1 do not necessarily reflect a change in their deeper beliefs. The distribution of deep underlying beliefs may be significantly different from the distribution of students' responses to particular items.

**Table 1. Proportion of students who changed their responses**

| *Content of item* | *Proportion of students who 'changed' their response* | *Proportion of students who 'corrected' their response* |
|---|---|---|
| Definition of a food chain | 14/28 | 12/28 |
| Identifying a food chain | 13/26 | 6/26 |
| Effects of an extinct link on a food chain | 19/28 | 4/28 |
| Bacteria as part of a food chain | 17/24 | 1/24 |
| Identification of the first link in a bacteria chain | 16/20 | 7/20 |
| Factors determining the length of a food chain | 17/28 | 1/28 |



The third column in the table displays the proportion of students who displayed a response closer to the scientific view in the post-test. On the average, this proportion is only slightly more than 20%. This means that some students change their response towards the scientific view, and some change their view from one naive/scientific response to a different 'naive' idea. The point we consider as central is that the classroom conceptual environment hardly changed. The teacher may still be working within a conceptual environment very similar to the one he had started out with before instruction.

### Students' ontological beliefs

As stated before, both students' concepts and ontological beliefs define a classroom conceptual environment. The first was analysed in the previous section. Here we focus on analysis of ontological beliefs, reflected in students' responses across content. We look for a common core to the various responses. The following core beliefs were identified across items:

#### *Food chain describes a hierarchical chain of eating events*

According to this view, food chain is a series of organisms, which support each other's need for food. Basically it means that an organism of a higher link eats the previous link. It is a mental causal model that explains why an element is part of a food chain. This belief is reflected in students' responses to all items in the questionnaire. A food chain, as a process through which matter and energy are transformed and conserved through the ecosystem, is ignored.

Earlier studies on naive ideas identify teacher's instruction and 'popular sayings' as major sources of such ideas (Adeniyi 1983). Thus, it may be interesting to associate a student's concept of a cyclic food chain to the teacher's representation in the classroom. Both the cycle of matter and the energy flow were presented. Yet the conservation of matter, in the wide sense, was not recognized as such.

Our findings, that students view a food chain as a hierarchy of eating, is consistent with the findings of Smith and Anderson (1986). They found that a food chain is viewed simply as a series of eating events: the $n$th consumer eats the $n$1 consumer which eats the $n$2 consumer until a producer is eaten.

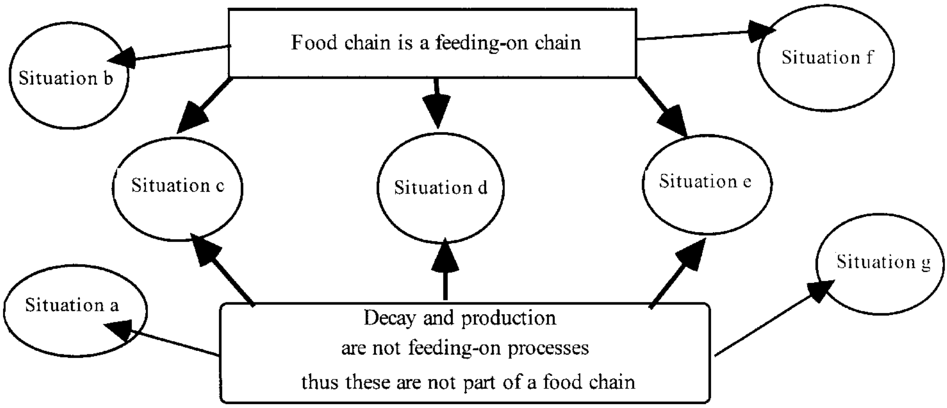



**Figure 7. Two incoherent beliefs applied consistently across situations.**



**Table 2. Ontological beliefs identified across items**

| *Underlying ideas* | *Questionnaire items* | | | | | |
|---|---|---|---|---|---|---|
| 1. Food chain is a support chain | 1 | 2 | 3 | 4 | 5 | 6 |
| 2. Feed-on means to physically swallow | | | 3 | 4 | 5 | |
| 3. A food chain is based on a size hierarchy | | | | 4 | 5 | 6 |
| 4. A consumed element is eliminated | | 2 | | 4 | | |
| 5. Food chain is seen as a bead chain | | | 3 | 4 | | 6 |

Eating order relationships among elements in a food chain are based on students' ideas of 'fate' of food: digested food in the body is used for growth and/or is 'used-up' for energy and/or turns into waste. (Adeniyi 1985) According to the scientific view, feeding-on, decay and production are all matter and energy conversion processes. Since students tend to view a food chain as an eating order rather than a conversion process of matter or energy, decay and production are not necessarily part of a food chain. Matter conversion is not related to the processes of a food chain.

Examination of student responses shows indeed that decay and feeding-on are perceived as two fragmented instances. While eating is part of the food chain by definition, decay is viewed as elimination of matter (Smith and Anderson 1985).

This raises a general issue of 'consistency and fragmentation'. Students view feeding-on and decay as two fragmented unrelated processes. However, the idea that a food chain is an eating order is applied across questionnaire items, across situations (see table 2). Thus the two beliefs are fragmented and unrelated, but applied in more than one situation. We conclude therefore, that students express fragmented beliefs. Yet these are consistent in the sense that they are applied in more than one situation. We suggest that student beliefs are *incoherent*, but *consistent*.

### *Feeding-on means to physically swallow*

The concept of 'feeding-on' seems to be based on a mechanical process of putting the eaten element physically inside the body of the eating element. This differs from the notion of consuming by the fact that the eaten element is not necessarily utilized. This is consistent with the idea that a bacterium dwelling inside the human body is considered as 'eaten'.

### *A food chain is based on a size hierarchy*

A chain is a food chain only it its elements are ordered by a size hierarchy, meaning that a larger element would feed on a smaller one. Adeniye (1985) reports a similar result: a stronger organism feeds on a weaker one. For instance, students tend to believe that carnivores are stronger then herbivores and thus able to kill and feed on them. The ferocity and size relations were reported as 9-10 year olds concepts of food chain (Gallegos *et al*. 1994).

This idea is consistent with all responses, but particularly was exhibited by students responses to items 4, 5, and 6.

### *A consumed element is considered as eliminated*

An organism is an element in a chain if it is totally eliminated when consumed. This is consistent with the finding that students do not view matter as converted in an ecosystem (Smith and Anderson 1986).

### *Food chain is viewed as a bead chain*

A chain of beads is a metaphor for a food chain (see analysis of responses to item number 3).

## Consistency and coherency of ontological beliefs

All ontological beliefs are reflected in more than one questionnaire item (see table 2). The set of underlying beliefs is not necessarily coherent, but it is consistent in the sense that these are applied in different situations. It is not an accidental slip in a particular situation, but rather a deep belief, ground for making sense of new situations.

Classroom concepts of a food chain reflect an underlying set of beliefs of a mechanistic nature. The causal relations of a food chain are based on eating events, ordered in a hierarchy such as sizes, in which the interrelations between the consecutive elements may be based on a mechanical concept of eating as swallowing, rather than energy and matter consumption. Eating means in some cases, elimination of the eaten element. For some purposes such as dealing with an extinct link in the food chain, it seems that the metaphor of a chain bead, is employed, to conclude about possible methods to bridge over the missing link. We term this set of beliefs a *mechanistic schema*. The mechanistic schema excludes the roles of the producer, energy conversions, and decomposition, in a food chain.

## Summary and discussion

This study shows that though students' concepts are changed, underlying ontological beliefs are not necessarily changed, and the conceptual environment changes only slightly. Out of 50% of students who did change their views, less than half, about 20%, changed their views towards the scientific concept.

Conceptual change occurred in the classroom in *all directions*, from any category to any other category, not necessarily towards a more scientific view. Only few categories were completely eliminated in the post-test. We found that students did not include a-biotic components in the food chain, did not identity a full chain as such, and only a few abandoned the cyclic idea in the posttest of item number five, but 13 students mentioned the cyclic idea in the last item—length of a food chain. Thus changes are on the surface. We did not find any changes in ontological beliefs, and only small changes in the conceptual environment. Ontological beliefs are fragmented, internally incoherent, yet consistently applied to understand different situations.

Taking a view of the classroom as a conceptual system, it turns out that the behaviour of the system is not predicted by the behaviour of the individuals in that system. Therefore, viewing learning as conceptual changes each student goes through is probably only a partial description of the learning process. The learning process should be evaluated both according to changes in individual's concepts and in the conceptual environment. To explain this phenomenon, turn to the question of what determines the survival rate of a particular idea. What are the factors that determine the 'survival' of a particular idea, but reject a different one as not valid? What makes a particular idea more powerful and socially acceptable? We claim that the ontological beliefs reflected in the conceptual environment dominate the generation of new ideas. For instance, one of the more frequently found beliefs is based on mechanistic schema.

The mechanistic schema reflects the classroom beliefs as a whole. It describes the 'conceptual environment' in which the teacher acts. Negotiations and clarifications are made in a conceptual environment, which is dominated by a mechanistic schema. Within this type of environment, students construct their concepts. They judge the validity of their concepts by the degree of 'fitness' to the conceptual environment. It is a process of 'conceptual adaptation'. Not all concepts, or ideas survive in this conceptual environment. Only those ideas that are the fittest (Dawkins' 1989) survive. This is similar to Dawkin's suggestion to look at ideas as a memes. Memes are ideas, phrases, songs, etc., transferred socially either to offspring (vertically) or to members of similar generation (horizontally), Memes survive according to evolution rules. The fittest ideas, in this study, would be those that fit the mechanistic views. Thus students construct and use the ideas that function best, are easily understood and accepted by the classroom members. This explains why changes in students' concepts, do not predict changes in the conceptual environment of the system.

In a strange manner, the more student-centred and students-interactive the environment, the greater the chances are that the stability of the mechanistic view is not disturbed. The teacher is the factor that may generate situations in which the mechanistic view can be questioned. In this lies the importance of exploring the nature of the conceptual environment—to allow design of situations that question the existing, currently enrolled, conceptual schema.

Toulmin (1972) suggests that learners nest concepts within larger interconnected networks terms 'conceptual ecologies'. The learner relies on such ecologies to draws on socially shared ontological beliefs, metaphors, analogies, metaphysical beliefs etc. The learner's views are nested in a conceptual 'culture'.

The learning environment, is then described by its conceptual ecology. Thus the importance of identifying such conceptual environments lies both in understanding the nature of socially shared learning and in designing learning situations.

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