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

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

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

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

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

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

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

Theory of learning

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

Piaget described a child’s conceptual development as passing through a series of stages: A sensory-motor stage (birth to two years), a preoperational stage (two to seven years of age), a concrete operational stage (seven to eleven years) and a formal operational stage (eleven plus years). He argued that a child develops
logical-mathematical cognitive structures that are context independent. Research during the last decades has shown that children’s possibilities to learn are not restricted to such stages. (Donaldson, 1978; Carey, 1985 and Novak & Musonda, 1991) Young children can think hypothetically and learn much more at an early age than the stage theory would suggest.

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

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

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

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

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

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

The process during which new concepts are assimilated into existing cognitive structure is called **subsumption** and the anchoring concepts are **subsumers**. Any learning task can be made meaningful if the teacher ascertains the learner’s prior ideas concerning the subject matter to be taught, and then uses these ideas as starting points for teaching.
Knowledge is hierarchically organised in a learner’s cognitive structure. That means that more inclusive, general concepts are superordinate to less inclusive, more specific concepts and propositions. Cognitive structure can become more elaborate and specific through assimilation of related concepts and the creation of new linkages. The whole matrix of concepts will in that way be modified. This process is called progressive differentiation and starts in childhood and continues throughout life.

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

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

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

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

Methodology

A longitudinal study

In order to more fully understand conceptual development, we must stretch the duration of conceptual change research and study the same subject over time (Arzi, 1988; Rudd & Gunstone, 1993; White, in press). The focus of my longitudinal study has been to characterise intra-individual changes in children’s conceptions in ecology across time and how their conceptions are influenced by different life experiences. A longitudinal study of the development of students’ conceptions in physics has pointed out the great possibilities there are to study such a development by using clinical interviews (Novak & Musonda, 1991).
The clinical interview
As a result of a pilot study, and several projects undertaken by student teachers investigating students’ conceptions, I argue that clinical interviews give the best information on children’s ideas about processes in nature. The flexibility of the interview makes it possible to repeat questions if the interviewee has misunderstood something. It is easy to follow up the questions carefully. The intimate and relaxed atmosphere makes it easier for a shy and sensitive child to talk. The interviewer can pose questions that open up and challenge the interviewee to think and express her/his ideas freely. The first question is formulated in advance; the first answer is then interpreted and a new question is posed. The interviewer is therefore an integrated part of the research procedure (Bell, Osborne & Tasker, 1985).

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

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

During the interviews I made it clear to the children that I was interested in their own thoughts, not whether their ideas were right or wrong. To show the children that I was primarily interested in their thinking, I usually started the first question of the interview with the words, ‘What do you think .......?’

Interviews about the role of the flower in plant reproduction
I first interviewed 24 10 years old children about plants in a meadow during a 3-day 'camp-school'. The interviews were carried out in early June in a verdant meadow with many different flowers, such as buttercups and cow parsley. I asked the children, ‘Why do plants have flowers?’ I then followed up with the question, ‘Why do flowers have colours?’
I wanted to know the pupils’ thoughts about ecological processes that were different compared with processes dealing with growth and decomposition. The children exposed a rich diversity of interesting ideas. During the following autumn semester, the children investigated flowers of different kinds and were taught about the importance of insects for the reproduction of plants. During the following spring, the pupils cultivated plants of different kinds in pots in the classroom. The pupils also studied plant reproduction at 13 years of age as a part of the curriculum.

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

Results

Interviews during a ‘camp-school’

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

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

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

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

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

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

At 10 years of age, Anders said, that the purpose of the colour was to make people think that the flower becomes prettier. He had a more detailed description of his ideas at 11, 13 and 15 years of age. At 11 years of age he described human-centred ideas with a practical example from everyday life but also a little about the plants’ feelings. He continued to describe the plants’ feelings in another dimension at 13 years of age, comparing them with human feelings. Even at 15 years of age, Anders described anthropomorphic ideas from a broader perspective.
It had not only to do with a wish to look nice and be admired but also our way of living including our houses and as company to other human beings.

Anders at 11y
‘I think the flowers have ..... 'cos they have colours to make you think they are nice and want to have them indoors. It gives you something to embroider the table with when you have guests. Then the food on the table and then you embroider the table with some brightly coloured flowers.’

Anders at 13y
‘I think there is a thought behind it just like we as human beings, that I want to look nice and that I don’t want .... So if you know to put on something, just as human beings put on things. We comb our hair and so on. So I think they have nice colours so that people and others they are nice. Just like we want other people to think that we..., that I look nice. That’s what I think.’

Anders at 15y
‘Well, actually I’ve wondered about that too, but I think it’s like a human being, they need all this growing around them and the leaves. Life’s a bit nicer and not so boring. It is like human beings. We live in our houses. We plant plants and have other things ‘cos it makes it nicer. I think that .... what plays a big part for them to have a flower is that the leaves are not alone. The flower is company for them which makes it nicer for them to grow up. Perhaps it makes them stay on longer. ‘They’re having a nice time.’

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

Ellen at 11y
I: ‘What is the importance for the plant to have gaily coloured flowers?’
S: ‘It gets more nourishment, doesn’t it?

Ellen at 13y
‘Cos otherwise ... For example then if the wasp comes, it must give the flower nourishment or it must do something else.... Otherwise the plant dies.’

Ellen at 15y
‘Well, there are stamens and pistils in it. And then, the petals protect them in some way.’
III. Undifferentiated ideas of pollination and seed dispersal

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

Helga at 11y
I: ‘What use has a plant of having gaily coloured flowers?’
S: ‘It’s .... attracts bees which can take pollen from the flower and then fly away to another flower. Then, such pollen is dispersed, and there will be more plants.’
I: ‘What will it be when the pollen is dropped there?’
S: ‘A plant.’

Helga at 13y
I: ‘Here is a bunch of flowers. Why do the plants have flowers with colour?’
S: ‘To attract bees and they take pollen with them. Then they fly away and other plants will grow there.’
I: ‘Why do other plants grow there? You said that they took pollen with them.’
S: ‘Seeds .....’
I: ‘How does it happen?’
S: ‘And they drop it and then it grows.’

Helga at 15y
I: ‘What is the importance for a plant to have a flower and a flower with beautiful colours? More intensive colours than this one.’
S: ‘It attracts insects which eat something? What is it called? Hm... disperse it .... pollen and sort of.’
I: ‘How do you think it comes about?’
S: ‘Well, the insects fly to a flower and then pollen is fastened to the insect’s feet. Then, when they fly away, they drop it. If the pollen falls down into soil, it stays there and grows up to new plants.’
IV. Towards a more or less complete description of pollination

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

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

Oscar at 11y

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

Oscar at 13y

S: ‘To attract bees and such so it can grow better.’
I: ‘What does it mean that it can grow better?’
S: ‘That there will be a bigger family. It will be more diluted and not extinct. Nobody wants to have anything to do with an ugly flower but you can try to plant a pretty flower more and so.’
I: ‘What role do the bees play?’
S: ‘They make it flower. Well, they suck out something. And there is a scale or something like that inside the flower of which they can make honey. And they spray something else in or something like that and it flowers in any case.’

Oscar at 15y

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

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

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

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

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

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

The 11 pupils in category IV had different features in a development towards a more or less complete description of the pollination at 15 years of age. Oscar, for example, had clearly expressed anthropomorphic ideas at 11 years of age. Even if he still had such features at the age of 13, he started to assimilate fragments of ideas about the pollination process, and then developed a more complete understanding of it at 15 years of age. Oscar’s reasoning was not like Anders,
deeply embedded in anthropomorphic reasoning. Rather Oscar used anthropomorphic reasoning as a part of his development towards a deeper understanding of pollination. In a parallel research project on the pupils’ understanding of ecological processes, Oscar also used anthropomorphic reasoning to describe his thoughts (Helldén, 1998).

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

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

References


