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Chapter 8

# The zone of proximal development as basis for instruction

*Mariane Hedegaard*

This chapter describes a teaching experiment combining psychological theory development with school teaching. The project took place in a Danish elementary school and followed the same class from third to fifth grade. Here I will report only on activities of the first year of our experiment, which was carried out in cooperation between researcher and teacher in a social science subject (biology, history and geography).

The aim of the project was to formulate a theory of children's personality development that considers development from a comprehensive point of view in a cultural and societal context and to formulate a related theory of instruction. We based our work on the methodology of the cultural–historical school, as formulated for Vygotsky (1985–1987) and developed by Leontiev (1978, 1981), Elkonin (1971, 1980), Davydov (1977, 1982), and Lompscher (1980, 1982, 1984, 1985).

In this chapter, I will focus on those aspects of the project that illustrate the importance of Vygotsky's concept of the zone of proximal development. I will show that, as an analytic tool for evaluation of school children's development in connection with schooling, this concept is of great value.

## THE THEORETICAL BASIS

Vygotsky's zone of proximal development connects a general psychological perspective on child development with a pedagogical perspective on instruction. The underlying assumption behind the concept is that psychological development and instruction are socially embedded; to understand them one must analyze the surrounding society and its social relations. Vygotsky explained the zone of proximal development as follows:

> The child is able to copy a series of actions which surpass his or her own capacities, but only within limits. By means of copying, the child is able to perform much better when together with and guided by

> adults than when left alone, and can do so with understanding and independently. The difference between the level of solved tasks that can be performed with adult guidance and help and the level of independently solved tasks is the zone of proximal development.
>
> (1982, p. 117)

Vygotsky wrote that we have to define both levels in the child's development if we wish to know the relation between the child's process of development and the possibilities of instruction. He pointed out that the main characteristic of instruction is that it creates the zone of proximal development, stimulating a series of inner developmental processes. Thus the zone of proximal development is an analytic tool necessary to plan instruction and to explain its results.

> From this point of view, instruction cannot be identified as development, but properly organized instruction will result in the child's intellectual development, will bring into being an entire series of such developmental processes, which were not at all possible without instruction. Thus instruction is a necessary and general factor in the child's process of development – not of the natural but of the historical traits of man.
>
> (1982, p. 121)

The zone of proximal development includes the normative aspects of development. The direction of development is guided by instruction in scientific concepts considered important by curriculum planners and the teacher. Through instruction, the scientific concepts relate to and become the child's everyday concepts. Leontiev describes the relation between scientific and everyday concepts as follows:

> The degree to which the child masters everyday concepts shows his actual level of development, and the degree to which he has acquired scientific concepts shows the zone of proximal development.
>
> (1985, pp. 47–48)

At the same time, this relation describes the connection between learning and development; the everyday concepts are spontaneously developed in a dialectical relation to the scientific concepts, which are mediated through the instruction. However, if the scientific concepts are not included, the child's entire development will be affected. Leontiev quotes Vygotsky to point out this relation:

> But when scientific concepts result in development of a developmental stage through which the child has not yet passed . . . we will understand that the mediation of scientific concepts may play an important role in the child's psychic development. The only good instruction received in childhood is the one that precedes and guides development.
>
> (1985, p. 48)



### Vygotsky's methodological basis

Vygotsky's theory integrates several approaches to form a comprehensive agenda for research of the genesis, development, function, and structure of the human psyche. These approaches include (1) an activity approach, (2) a historical societal approach, (3) a mediating instrumental approach, and (4) an interhuman genetic approach.

1 Vygotsky's successors have posited practical activity as a unit of analysis that allows for a comprehensive approach to the description of the development of the human pysche. This unit comprises all aspects of the genesis of the human psyche: social, cognitive, motivational, and emotional (Davydov and Radzikhovskii, 1985; Leontiev, 1985).
2 Vygotsky's methodology is based on the application of the Marxist historical societal approach. In psychology this approach emphasizes the concept of work activity: the relation between human beings and the world as mediated through tools (Leontiev, 1985, p. 33).
3 According to Vygotsky, the development of psychic tools determines humans' relations with their environment and with themselves. Psychic tools are analogous to industrial tools and are also characterized by being produced through social activity, rather than arising organically (Vygotsky, 1985–1987, p. 309). Psychic tools may be very complex systems; as examples, Vygotsky mentioned spoken language, systems of notation, works of art, written language, schemata, diagrams, maps and drawings.
4 The interprocessual aspect of the human psyche first appeared as practical activity between human beings. Shared and collective tool use is part of this interhuman practical activity. The interpersonal procedures for tool use gradually became acquired intrapsychic procedures. Through the procedures for tool use, humans are bearers of societal historical traditions; consequently, the interhuman activity, as it forms the child's inner activity, is always societal, historical, and cultural. Therefore, in order to understand the human psyche it is necessary to analyze it genetically as a societal and historical phenomenon (Hedegaard, 1987; Markova, 1982; Wertsch, 1985).

### Development, teaching

According to Vygotsky, human development is characterized by the ability to acquire psychic tools. Vygotsky does not deny biological development (cf. Scribner, 1985); however, human biological development is shaped and concretized through societal and historical development. In specific culture, it may be historically characterized as the development of traditions through human activity. The development of traditions has its parallel in ontogenetic development (cf. Elkonin, 1971), although the ontogenetic development can be characterized by stages of activity determined by the child's biological capacity as well as by the historical traditions in which the culture involves the child.

According to Elkonin, the child's development is characterized by three periods, each including a motivational and a cognitive stage of development. The first period, the infant and early play period, includes the development of motives for emotional contact, methods for socializing, and situational mastery. The second period includes the age of role play and early school age. This period is dominated by the development of motives for mastery of the adult world and acquisition of analytic methods and related goals and means. The late school and youth period is characterized by the development of motives for social and societal involvement and methods for mastery of personal relations as well as work and societal requirements (see Figure 8.1).

At every stage, the child's development is related to one of the societally determined activities and traditions. During the first stage, the tradition for childcare, the building of emotional bonds, especially with the mother, is the determining activity for development. The next stage is characterized by traditions for creating supportive surroundings for the child's explorative and imaginary play activity. Kindergarten and school are the institutionalized traditions for determining the dominant activities for the following two stages: development of motives and development of skill and knowledge for relating theoretically and reflectively to the world. The fifth stage is characterized by traditions for peer activities institutionalized in different forms of after-school activities. Work activity is the determining activity for the last stage described by Elkonin. By analyzing the tradition we can critically evaluate whether the stages are

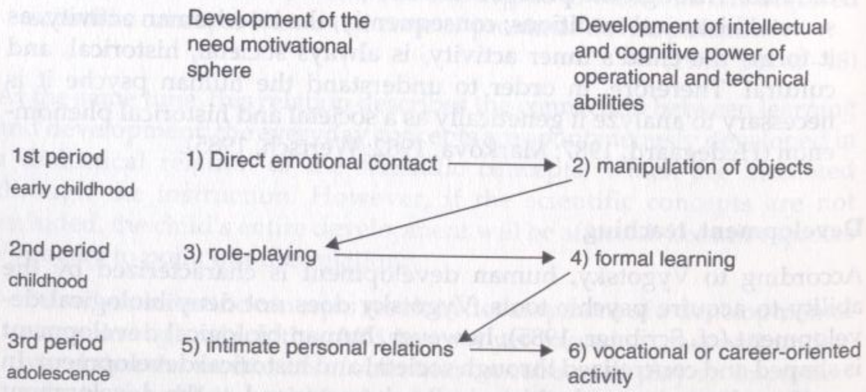



*Figure 8.1* The stages that, according to Elkonin's theory (1971), characterize the dominant forms of child development in Western society



relevant descriptions of child development today in Western society. For instance, one could argue that the period between late school age and work in today's society has become institutionalized as education for work. This evaluation of the stages underlines Leontiev's description of stages in child development as societally and historically determined.

The zone of proximal development can be related to Elkonin's developmental stages (Griffin and Cole, 1984). As stated, the qualitatively new structures that arise in the course of a child's development are related to the changing demands made on children by social institutions.

When children enter school, the teacher confronts them with the zone of proximal development through the tasks of school activity, in order to guide their progress toward the stage of formal learning. These tasks help children acquire motives and methods for mastery of the adult world, as mediated by the teacher.

The zone of proximal development can also be viewed from the aspect of action within a certain activity. To the school child, action is related to the learning/teaching activity (cf. Engeström, 1986; Rogoff and Wertsch, 1984; Schneider, Hyland and Gallimore, 1985; Wertsch, 1985). The teacher's role is to direct action within school activity in a manner appropriate to the child's present level of development, the cultural and social context, and the teacher's theories of what the central subject matter is. For instance, the teacher's theory of what language and reading are – and what characterizes the logic of language and reading – will influence the teaching and learning actions of mother-tongue instruction.

## Empirical knowledge, theoretical knowledge

The child is born into a society in which knowledge is available as the standard procedure for dealing with persons and things. It is important to distinguish between knowledge that exists independently of the child and the child's acquisition and development of this knowledge.

In a specific society, the standard procedures for solving societal problems can be seen as the culturally developed skills acquired and developed by each generation. Knowledge is accessible through different media, for example, language and pictures, and is the result of culturally and societally developed procedures for solving societal problems. The development of medicine is a typical example. According to Juul Jensen (1986), societal practices exist prior to societal knowledge, leading to a rejection of the assumption that knowledge is the essence of environmental phenomena and things existing independently of human societal practice. Societally developed skills are thus the basis for societally developed knowledge. Davydov has separated this societal knowledge into two forms of knowledge – empirical knowledge and theoretical knowledge – each with its associated epistemological procedures.

Empirical knowledge deals with differences and similarities among phenomena; has arisen via observation and comparison of phenomena; can be ordered hierarchically on the basis of formal characteristics; and the word or a limited term is the medium whereby it is communicated. Through empirical epistemological procedure, the individual object is grasped by isolating it from its spatial and chronological connections so that it can be observed, compared, categorized, and remembered. Imagery and language are the media used to this end. In the empirical exposure the individual object functions as an independent reality.

In contrast, theoretical knowledge deals with a connected system of phenomena and not the separate, individual phenomenon; arises through the development of methods for the solution of the contradictions in a societally central problem area; develops understandings of the origins, relations, and dynamics of phenomena; and models are the medium whereby this knowledge is communicated. Through the theoretical epistemological procedure, the object is observed as it transforms. By recreating the object in its relation to other objects, these relations are revealed. This reproduction has the character of experimental exploration of relations and changes, through both concretely changing the world and mentally imagining changes. Theoretical knowledge cannot be acquired via its verbal or literary form alone, even though it does appear primarily in verbal and literary forms at the scientific level.

Societal knowledge and skills are inseparably bound together. In the same way, the child's concept acquisition is tied to the acquisition of cognitive procedures. In teaching, if one wants children to acquire theoretical knowledge in the form of fundamental relations in a subject or a problem area, then the cognitive method in instruction must also characterize theoretical knowledge. If, on the other hand, one applies the epistemological method that characterizes empirical knowledge – that is, observation, comparison, categorization, and memory – together with a subject area's fundamental concepts, then knowledge acquisition will remain on the empirical level. School children have already learned the empirical epistemological procedure in their practical everyday activities; they have yet to acquire the theoretical epistemological procedures.

Theoretical knowledge must be acquired through exploratory activity. In school, this activity is controlled activity, consisting of the exploration of problems that contain the fundamental conflicts of the phenomenon. A prerequisite for theoretical knowledge acquisition is teaching activity built on tasks that illuminate the contrasts found in a phenomenon's fundamental relations. Through this exploration it becomes possible to gain insight into the development of the phenomenon.

As an example, I will discuss the problem area on which our teaching experiment is based: "the evolution of species." Darwin's theory of species and its elaboration in the more modern synthetic theory of evolution



(Gould, 1977; Mayr, 1976, 1980; Simpson, 1962) demonstrate how knowledge has developed through problems that, for science, have been urgent.

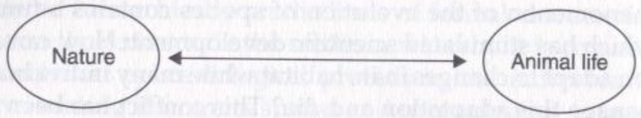
The phenomenon of the evolution of species contains a fundamental conflict which has stimulated scientific development: How can an animal population adapt to changes in its habitat while many individual animals cannot manage this adaptation and die? This conflict has been of central importance to a theory of the evolution of animal species and is therefore useful as the basis for instruction in the evolution of species. However, such a conflict cannot be presented abstractly to pupils; rather, it must be presented via analyses of concrete animal species. For example, pupils can analyze how the polar bear adapts to its Arctic surroundings to survive as an individual, how it breeds and ensures the survival of its young. Students can analyze limits to this adaptation as well. The teacher must set tasks for pupils so that they become aware of the adaptations of the polar bear as well as the different ways in which other animals in the Arctic survive, breed, or die. Through the resulting insights children can arrive at the formulation of general laws about the survival and change of an animal species.

### Theoretical knowledge as psychic tool

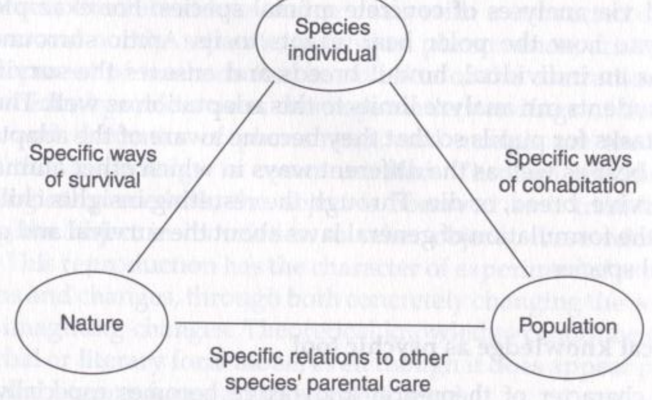
The tool character of theoretical knowledge becomes especially evident when formulated in a model. The model may become the tool that guides the teacher's instruction activity. This type of model is characterized as a germ-cell model (Davydov, 1982; Engeström and Hedegaard, 1986), which implies that every time the model becomes complicated by new relations it not only adds to the concepts already modeled but influences and changes their meaning, because the concepts are defined through their relations. The basic concepts in a germ-cell model are complementary in their explanatory value for the problem area being modeled. This means that the relation between the basic concepts in a germ-cell model is contradictory, and through explicating this contradiction related concepts are developed. This can be illustrated by the growth of the germ-cell model in the teaching experiment. The problem area to be modeled and explained was the evolution of animals. The basic concept relation in the modeling of this problem area was the relation animal – nature (see Figure 8.2).

The pupils may first acquire an external, auxiliary model that gives a general impression of the area taught. The auxiliary model then functions as a basic of information for the pupils' further work with the subject and for the development of their models of understanding, which in turn will become psychic tools for the pupils. Through experiencing the contradiction of their modeling of the problem area in their concrete problem solving, the pupils' concepts of their models become richer and new conceptual relations are included.

Stage I: The relation between nature and animal life, and animals' adaptation to a given/specific/particular nature




Stage II: The adaptation of different animal species to the specific nature which is characteristic of a particular biotope (the relation between genetic and functional inheritance)




Stage III: The development of a species is determined by changes in the nature and by changes in the estate of the offspring

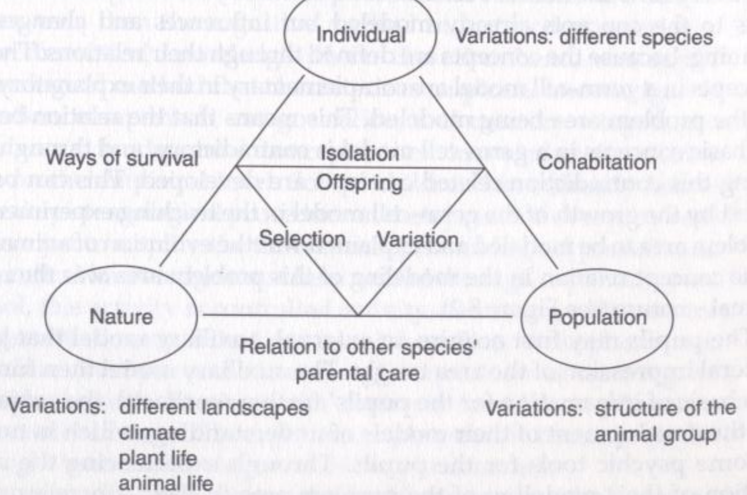



*Figure 8.2* The three stages of the development of the germ-cell model (these stages are also present in the teaching process)



The school's task is generally considered to be the passing on of knowledge and skills, but the children do not necessarily develop a theoretical orientation toward reality. Their orientation may remain on an empirical level. The difference between theoretical and empirical orientation is connected with Vygotsky's differentiation between everyday concepts and scientific concepts (see Figure 8.3). These pairs of concepts are not identical because scientific concepts can also be empirical; for example, the periodic system in chemistry can be empirically presented.

Theoretical knowledge that has become everyday knowledge can be found, for example, among young people who have both the electronic skill and the knowledge to build their own music equipment, or the mechanical skills and knowledge needed to repair their motorcycles, or the knowledge of both the composition and the history of their preferred type of music. Unfortunately, it is very difficult to find school knowledge that has become everyday theoretical knowledge and can be used as a tool for reflection and skilled activities. Most school knowledge is em-

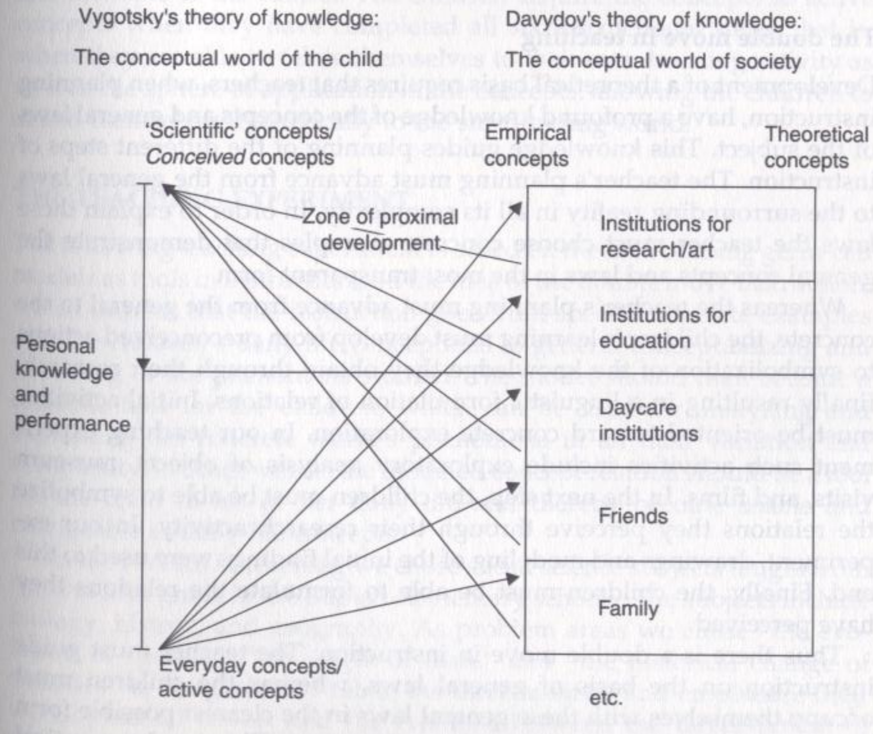



*Figure 8.3* The zone of proximal development, illustrated as the relations between empirical and theoretical knowledge, according to Davydov's and Vygotsky's theories of everyday and scientific concepts

pirical knowledge, which means knowledge in the form of facts or text knowledge, and as such it never becomes very useful in the pupils' everyday life, either during their school years or later.

The school's task should be to teach children scientific concepts in a theoretical way by applying a theoretical epistemological procedure. Children's everyday concepts are thereby extended to include scientific theoretical concepts. If scientific concepts are learned as empirical concepts, children will have difficult in relating what they learn at school to the surrounding environment. Only by learning concepts theoretically can this development take place. As mentioned earlier, teaching should create zones of proximal development through involving children in new kinds of activity. By relating scientific concepts to everyday concepts, teaching provides children with new skills and possibilities for action.

The concept of the zone of proximal development can be used to guide children from the learned and understood scientific concepts to the spontaneously applied everyday concepts through a method of teaching I have called a *double move*.

### The double move in teaching

Development of a theoretical basis requires that teachers, when planning instruction, have a profound knowledge of the concepts and general laws of the subject. This knowledge guides planning of the different steps of instruction. The teacher's planning must advance from the general laws to the surrounding reality in all its complexity. In order to explain these laws the teacher must choose concrete examples that demonstrate the general concepts and laws in the most transparent form.

Whereas the teacher's planning must advance from the general to the concrete, the children's learning must develop from preconceived actions to symbolization of the knowledge they obtain through their research, finally resulting in a linguistic formulation of relations. Initial activities must be oriented toward concrete exploration. In our teaching experiment such activities include exploratory analysis of objects, museum visits, and films. In the next step, the children must be able to symbolize the relations they perceive through their research activity. In our experiment, drawings and modeling of the initial findings were used to this end. Finally, the children must be able to formulate the relations they have perceived.

Thus there is a double move in instruction: The teacher must guide instruction on the basis of general laws, whereas the children must occupy themselves with these general laws in the clearest possible form through the investigation of their manifestations. This is why practical research activities with objects, films, and museum visits are such an important part of instruction, especially during the early periods.



The basis for instruction is the division of the learning activity into three different types of actions: (1) delineation of the problem; (2) problem solution and problem construction, which implies acquisition of capacities; and (3) evaluation and control. Davydov (1982) has described six steps in the learning activity, which can be seen as differentiating the phases in learning activity based on the use of models as learning tools. These steps are produced through the different structures of the instructional tasks. The steps are: (1) change or production of a problem so that the general relations are clearly seen; (2) modeling of these relations; (3) transformation of the model relations so that the connection is clear; (4) creation of new problems and tasks from model; (5) control of one's own learning action; and (6) evaluation of the model's sphere of application. As will be shown, these steps have influenced the planning of instruction in our experiments.

Children's learning activities may be characterized as guided investigations. Through working with the central conceptual relations and procedures that characterize a subject area, the children acquire the scientific concepts of the subject. The children acquire the concepts as active concepts when they have completed all six instructional steps, that is, when they are able to relate themselves to their own learning activity as well as the sphere of application of the concepts, allowing the children to orient themselves theoretically to the surrounding world.

## THE TEACHING EXPERIMENT

The following teaching experiment is based on the idea of using germ-cell models as tools in instruction and the idea of the double move instruction, which implies that the instruction goes from specific concrete examples and the children's daily-life conceptions to general conceptualizing and modeling of the phenomena studied. The model should then become a research tool for the children, which can be used for analyzing and explaining the concrete world's phenomena in all their variation and complexity; in other words, the modeled concept relation should be a tool for the child in his or her daily life and thereby become usable and changeable as daily-life concepts.

As the content of teaching we chose social science subjects taught from third to fifth grade in the Danish elementary schools. The subjects include biology, history, and geography. As problem areas we chose "the evolution of species," "the origin of man," and "the historical change of societies" to integrate and relate the three subjects and emphasize their developmental aspect and the relations between the development of nature and society. The results of the teaching experiment presented here deal only with the first year of teaching the evolution of species. The next phase of the teaching experiment is still in progress.

The concepts forming the basis for instruction are demonstrated in the germ-cell model shown in Figure 8.2. The content of instruction included the following subthemes:

Accounts of creation
Prehistoric nature, animal life
Research method: the use of fossils and analogies
Visit to the Department of Denmark's Prehistory at the Natural History Museum
Evolution of species
Arctic nature, animal life
Desert nature, animal life
Desert hare, polar hare
Moving the polar hare to the Faroe Islands
Moving chimpanzees to Estonia
Arctic nature, animal life
Project work: Africa's animals
Wolves: summer and winter living conditions
Evolution from wolf to dog
Evolution of the horse
The catastrophe: the extinction of the saurians

## The procedure for attaining theoretical concepts

One approach was based on the "scientific works" procedure described in Aidarova (1982) and also found in Kurt Lewin's work (1946) (see Figure 8.4).

The children were told to work exploratively like scientists. A goal-result board was used to record the steps attained in this exploration. Each teaching period started with a summary of the exploration related to the general problem area of research: the evolution of animals and the origin of humans. Furthermore, the teaching was built around the children's analysis of the concrete themes according to the questions in the scientific work procedure. For instance, in exploring the life of the polar bear, we wanted to address the following issues: What do we know and what do we not know about the polar bear's survival in Greenland? How can we model what we know, and how are we going to explore what we do not know? We developed specific questions based on the relations depicted in the germ-cell model at the start of this theme and by studying books and films about polar bear life. Through class discussions, we evaluated the germ-cell model and considered how it fitted with our knowledge: we also analyzed what our knowledge so far about the polar bear could tell us about why some animals survive, why some animals die, and why some change into new species.



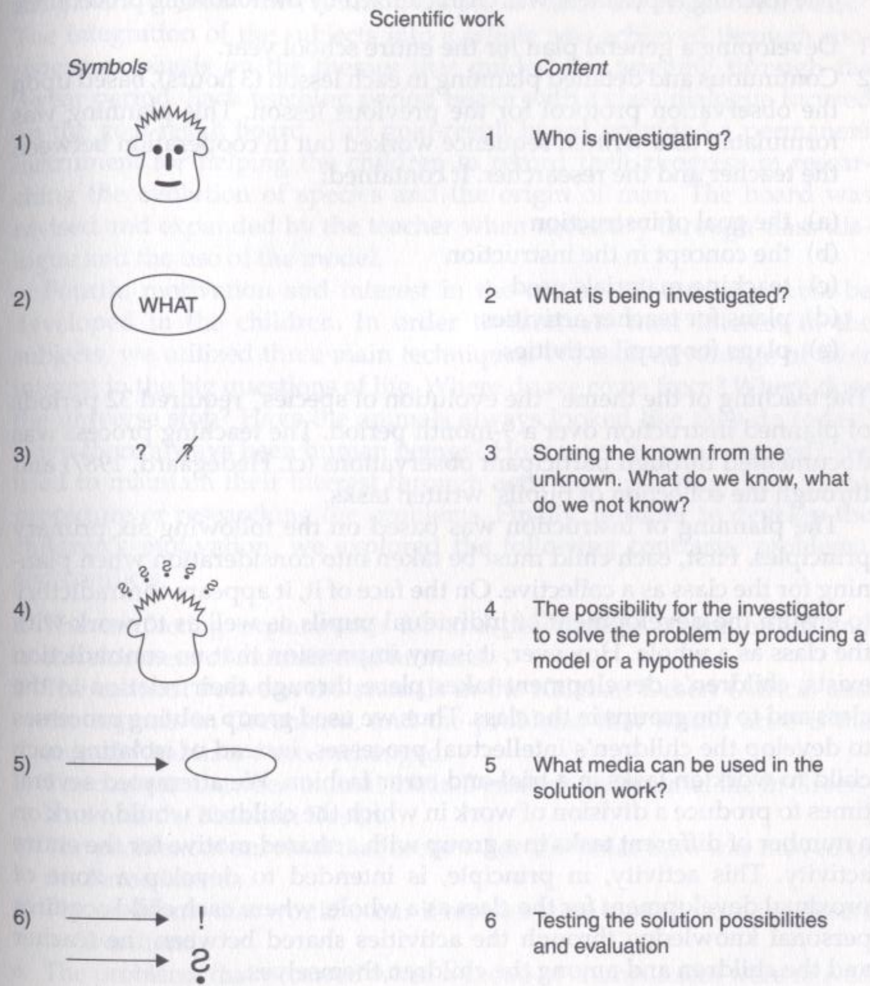



*Figure 8.4* The procedure of "scientific work" which we, in different ways, adapted to (1) keep track on the goal-result board of the steps in exploring the main problem, "evolution of animals", and (2) analyze subproblems, which were steps in exploring the main problem

## Research method

The teaching experiment is a concretization of Vygotsky's statement that the formative genetic method is a necessary research method for investigating the formulation and development of the conscious aspects of humans' relation to the world. The experiment included the total planning of instruction in the social science subjects during a 3-year period.

The teaching experiment was characterized by the following procedures:

1 Developing a general plan for the entire school year.
2 Continuous and detailed planning in each lesson (3 hours), based upon the observation protocol for the previous lesson. This planning was formulated as a written sequence worked out in cooperation between the teacher and the researcher. It contained:

   (a) the goal of instruction
   (b) the concept in the instruction
   (c) teaching materials used
   (d) plans for teacher activities
   (e) plans for pupil activities

The teaching of the theme "the evolution of species" required 32 periods of planned instruction over a 9-month period. The teaching process was documented through participant observations (cf. Hedegaard, 1987) and through the collection of pupils' written tasks.

The planning of instruction was based on the following six primary principles. First, each child must be taken into consideration when planning for the class as a collective. On the face of it, it appears contradictory to ensure the development of individual pupils as well as to work with the class as a whole. However, it is my impression that no contradiction exists; children's development takes place through their relation to the class and to the groups in the class. Thus we used group solving processes to develop the children's intellectual processes, instead of isolating each child to work on tasks in a trial-and error fashion. We attempted several times to produce a division of work in which the children would work on a number of different tasks in a group with a shared motive for the entire activity. This activity, in principle, is intended to develop a zone of proximal development for the class as a whole, where each child acquires personal knowledge through the activities shared between the teacher and the children and among the children themselves.

Second, the general content of the teaching must be related to the children's experiences. Class dialogue and children's drawings were the media through which children's experiences with the different subthemes were expressed in the class situation. Also, through the activity associated with these media their experiences were extended. The teaching was planned so that the children were active in investigating themes of instruction. It was not intended, however, that the children's investigations would result in blind trial and error or in an activity they had already mastered. We must emphasize that the teacher planned and gave direction to the activities to a certain extent but did not determine the concrete form of the activity or the results.

Third, the content of instruction must be clearly related as a whole to



the general themes "the evolution of species" and "the origin of humans." The integration of the subjects into a whole was achieved through consistent emphasis on the themes that guided the teaching through the 3-year period. Each teaching period began with a class dialogue focused on the goal-result board. This goal-result board provided a permanent instrument for helping the children to record their progress in researching the evolution of species and the origin of man. The board was revised and expanded by the teacher when necessary through class dialogue and the use of the model.

Fourth, motivation and interest in the content of teaching must be developed in the children. In order to motivate their interest in the subjects, we utilized three main techniques. We took advantage of their interest in the big questions of life. Where do we come from? Where does the universe stop? Have the animals always looked like they do today? Have there always been human beings? How were humans created? We tried to maintain their interest through activities involving them in the procedure or researching the problems. Finally, in order to develop the children's motivation, we explored the following contrasts, problems, and conflicts:

1 The conflicting explanations for and descriptions of the origin and development of animals and humans.
2 The contrast between the animals in the Kalahari Desert (Africa) and the animals in Greenland, and the problems that would arise if the animals' habitats were exchanged.
3 The contrast between animal life in Denmark and animal life in Greenland and the Kalahari Desert.
4 The problem of survival that arose when the polar hare was moved to the Faroe Islands.
5 The problems that would occur if reptiles were moved from the desert to Greenland.
6 The problems that occurred when a group of chimpanzees were moved to an island in Estonia.
7 The contrast in the wolf's living conditions between winter and summer and the problems that would occur if either season disappeared.

Fifth, the children's capacities for modeling knowledge must be developed so that the models can become tools for analyzing the diversity of problems encountered in the world they live in. The tasks given to the children were intended to guide them through the central concepts of the subjects. These concepts were integrated in a germ-cell model, which was to function, first, as an external tool for the children's analyses of the relations between animal and nature and, second, as a psychic tool for the children's understanding of these relations in all their complexity. The model becomes a psychic tool when a child can use it for analyzing, solving and creating new problems (when Steps 3 and 4 in the structure of learning activity are acquired).

Sixth, knowledge must be integrated with performance in the children's acquisition of the subjects biology, history, and geography. The integration of knowledge and performance was made possible through the children's modeling of their knowledge and, later, their use of this model for analyzing and producing questions. This integration was based on the six steps in learning activity described earlier. These steps move from actions connected to the general aspects of reality to actions connected to the concrete complexity of reality. At the same time, an opposite movement occurs in the children's learning, from exploration based on action activities to symbolizing and, finally, describing the concept relation explored (see Figure 8.5).

## ANALYSIS AND RESULTS

Our qualitative analysis is based on the observation protocols and on the children's task solutions throughout the year. The focus of the analysis of the teaching activity will be the problems encountered in the teaching process. In the learning activity, the focus will be on the concept learning of the children and the solution of motivational problems.

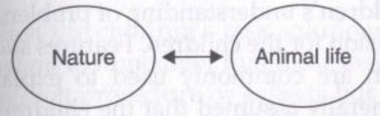
### Problems in the teaching activity

Two different types of problems were identified in our analysis. The first is connected to the content of the teaching and concerns the children's problems with understanding the concepts introduced in the teaching process. These problems emerged as important because they lead to insights into the nature of obstacles encountered by children in the learning activity and the strategies utilized for overcoming them. The teacher who seeks to deal with this type of problem develops teaching which, in our opinion, reaches into the zone of proximal development.

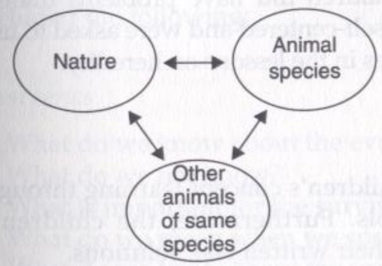
An example is the problem some children had in understanding the time dimension and in separating animals' adaptations from animals' development. There were also problems with categories in the model connected to the introduction and proper placement of new dimensions; for instance, when the categories *food seeking, parental care, cohabitation* were introduced the children did not quite know how to use them, and when the concept of desert was introduced they did not know what desert conditions were. The children had no problems, however, in accepting modeling or in modeling their knowledge. The problems concerning time and evolution are, then, the central problems related to the children's acquisition of content. Very few of the problems were related to using the model.



| *Content* | *Learning activities* |
|---|---|
| Animals' historic development (the origin of man) | Formulation of the aim via conflict |
| Parallelization to the researcher's work. Exploration as a method | Method formulation |
| Development – historical time<br>The time concept<br>The nature concept | Analyses of texts, pictures, films, museum visits |




| | |
|---|---|
| | Formulation of what we know |
| Why some animal species died out | Formulation of what we don't know |




| | |
|---|---|
| | Model formulation and application of the model |
| Different forms of adaptation: survival via food seeking, animal relations, parental care, defence against enemies | |
| The mutual relations among food seeking, cohabitation, parental care, defence against enemies | Hypothesis-formulation<br>Transformation of the model |
| Limits of functional adaptation | |
| Variation among members of a species<br>Selection | Question formulation via application of the model |
| The evolution of new species | Control of explanation in relation to the initial problem |

*Figure 8.5* Plan for integrating the two aspects of knowledge and performance in the whole-teaching experiment

The second type of problem is connected with the planning and realization of the teaching and concerns the problems that arise when instruction is not at an appropriate level. Some examples are the prob- lems we had in achieving a balance between providing an overview of the general problem during each period and becoming too repetitious. In addition, we had to choose between sticking to the goals of the class and following up on the children's comments. Most importantly, we found that it was extremely difficult to capitalize on the children's knowledge of heredity. They were not able to relate what they know about heredity in their family relations with their investigation of heredity of animals.

The problems have shown us that we must reject the common assump- tion that concretization will facilitate children's understanding of problems. On the contrary, the result is often confusion for the children. Features such as self-centeredness and concretization are commonly used to explain children's performance because it is generally assumed that the children's thoughts are concrete and self-centered. Our results indicate that the children's dialogues and use of models and task solutions contradict this widely held assumption. Moreover, children did have problems under- standing when they were allowed to be self-centered and were asked to use themselves and their families as examples in the lessons on heredity.

**Analysis of children's learning**

We can obtain knowledge about the children's concept learning through analyses of the observation protocols. Furthermore, the children's learning can be checked by analyzing their written task solutions.

One type of analysis focused on the children's learning actions as they acquired the conceptual relations of the germ-cell model. For example, we identified 12 types of learning actions during students' work with the evolution-of-animals theme. These actions are grouped under three head- ings: delineation of the problem, acquisition of capacities, and evaluation. They occurred in the following order:

*Delineation of the problem*

1 The children's comments are relevant to the themes of teaching.
2 The children precede the process of teaching in their comments.
3 The children keep each other and the teacher to the topic.
4 The children pose questions regarding the *why* of a phenomenon.

*Acquisition of capacities in model use*

5 The children look for relations instead of categorical solutions.
6 The children work with modeling of their knowledge.



7 The children want reasons for the relations in the model.
8 The children accept that the model changes and that they contribute to the changes.
9 The children's imagination and fantasy production increase.
10 The children produce tasks themselves.

*Evaluation*

11 The children become critical and evaluative of their own perform- ances and capacities.
12 The children become critical and evaluate the content of teaching.

When the children's task solutions are analyzed and evaluated, it is im- portant to remember that these tasks have been assigned not as part of the research procedure or as tests but as educational devices in the teaching process. The two most informative series of tasks were given in the middle of the teaching period just before and immediately after Christmas (December 12 and January 9). The tasks in these two series included the following:

*First series*

What do we know about the evolution of animals?
What do we not know?
What is important for the survival of a species?
What do we mean when we speak of nature?
What do we know about the origin of man?
Draw a model for the polar hare.
Draw a model for the desert hare.

*Second series*

Draw a model for the polar bear.
Draw a model that is valid for all animals.
Draw a model for the sperm whale.
When we write 'nature' in the model, what does that mean?
What does the model show as important for the survival of species?
Why can't a single member of a species survive without other mem- bers of the same species?

A conclusion from our observation is that the children did not solve the tasks connected to the procedure (the questions about what they know and do not know) as well as the tasks connected to the model. All the children could draw the models for the animals, and they could also draw the general model. Of 16 children, 10 could draw a model of the sperm whale, which had not been addressed in the teaching. From the tasks given immediately prior to the completion of the theme, it was quite clear that the children understood that changes in nature mean change for the reproduction and survival of a species and that changes in species are always reflected in their offspring (see Figure 8.5).

### Development of motivation

The results from the first year of the teaching experiment demonstrate a development in the ways in which the children related to the theme and sub-themes in the evolution of species. A qualitative change occurred in their interest in the content of the teaching. These changes in interest can be characterized sequentially as follows:

1 Interest in the problem formulation and the research methods.
2 Interest in the relationship between nature and animals in relation to the specific living conditions of the animals introduced in the teaching.
3 Loss of interest in specific animals when they became too familiar.
4 Interest in formulating general models for the adaptation of animals to their living conditions.
5 Interest in sticking to the general problem formulation in their research.
6 Interest in influencing the process and content of instruction as related to problem formulation.
7 Critical evaluation of the content of teaching.
8 Desire to finish the evolution-of-animals theme and to start something new.

These changes in interest can be seen as a developmental shift in the children's motivation, moving from interest in concrete material to interest in developing principles that can be applied to new concrete material. The development of motivation has its parallel in the development of concepts, delineation of the problem, model formulation/model use, and evaluation. And both the structure in concept development and development of motivation can be seen as derived from the steps of instruction (cf. Figure 8.5).

This result supports the conceptions in activity theory (Hedegaard, 1989; Leontiev, 1978) that motives and concepts are dialectically related. The concepts are the content and specify the object of the motives at the same time that the motives create the images and the objectives of concept learning.

## CONCLUSION

### The double move in teaching

Teaching that promotes children's theoretical concept learning must occur on a basis of profound teacher knowledge of the central concepts of the subject area. Knowledge of the general laws can guide the planning of the steps through which instruction must proceed. The teacher must guide the learning from the student involvement with general laws in the clearest possible form. Clearly, practical activities are an important part of teaching; however, these activities must, as mentioned, contain the general laws in their most transparent form. The conclusion from the teaching experiment based on this principle of the double move in teaching can be summarized as follows:



1 Teaching can be based on the central concepts of evolution whereby it integrates the different sub-themes into an exploration of the general problem the *evolution of animals*.
2 Furthermore, the children learn to integrate their knowledge into a general model, a germ-cell model, and to use this model on new and unknown animals. We found that the children had very few problems in modeling their knowledge; it was much more troublesome for the teacher and the researcher to do this.
3 The teaching resulted in qualitative changes in the children's capacities and interest in solving problems connected to the theme of the evolution of animals.

### The zone of proximal development

To work with the zone of proximal development in classroom teaching implies that the teacher is aware of the developmental stages of the children and is able to plan for qualitative changes in the teaching toward a certain goal. Although each child is unique, children obviously share common traits with other children. Being of the same tradition, children in the same class have a lot of knowledge and skills in common. Instruction can build upon these common features if it takes into account that the children vary in their speed and form of learning. In this way, we have worked with the zone of proximal development as a relation between the planned instructional steps and the steps of the children's learning/ acquisition process.

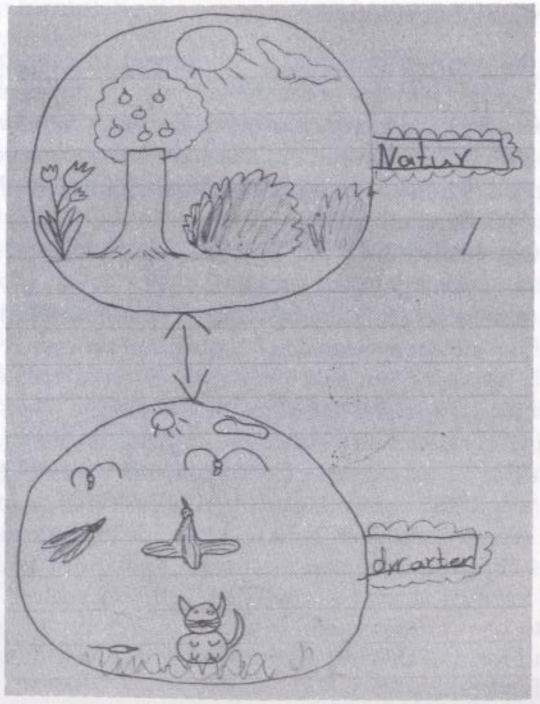
Elkonin (1971) pointed out that the stages in children's development are determined by the societal historical development. The conception of childhood as differentiated into separate life periods and as a quite large part of human life is only a couple of hundred years old. Before that children were taught to behave like adults; Ariès (1982) describes how, in the eighteenth century, children behaved like adults at the age of 4.

The fact that children have common traditions, prior to school and at school, in the form of shared knowledge and procedures for activities enables them to communicate and interact in shared concrete activities. The content and form of this interaction and communication should then be developed further in school.

A child is unique and individual, but children's individualities have common features. If these features are not developed, we tend to regard the child as deviant and offer special instruction to each child in a class. Instead, instruction must be based on development of common knowledge and skills.

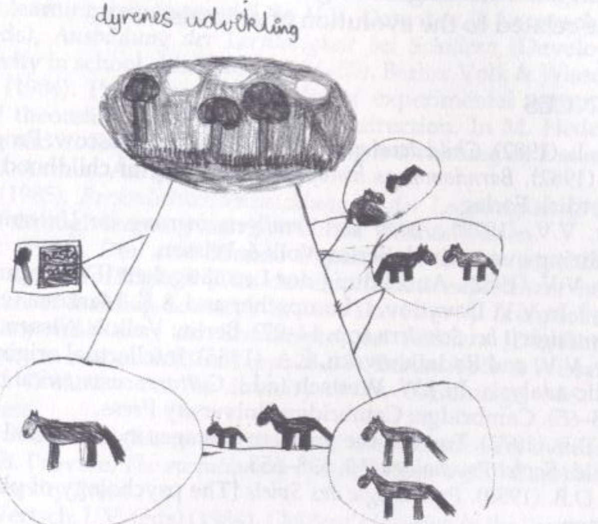
Consequently, the zone of proximal development must be used as a tool for class instruction. In our teaching experiment, we saw that it is actually possible to make a class function actively as a whole through class dialogue, group work, and task solutions. The teaching experiment differed from traditional instruction in that the children were constantly and deliberately forced to act. The children's research activity was central in these guided actions, which gradually led the children to critical evaluations of the concepts. We can conclude, therefore, that we have succeeded in building a common basis for the children in the class from which future teaching can be developed.

We are quite certain that the teaching has built a common foundation in the children; however, we also recognize that some children achieve a more differentiated content in their concepts than other children. For the fast learners, our teaching experiment neither destroyed their interest nor inhibited their development of motivation. For the slow learners, our




A



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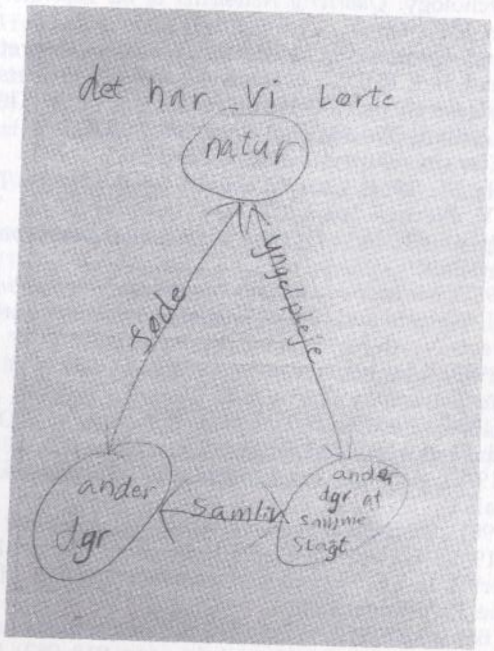


C

*Figure 8.6* (Opposite and above) Examples of the children's models: *A* is a pupil's generalization in symbol form of the relation between nature and animal species. In *B*, the generalization is differentiated and the relation of an animal to other animals of the same species is represented; the model symbolizes the relations for the horse. *C* is a pupil's representation of the relations in general form for animal species instruction has encouraged insight into and capacities for understanding the theme related to the evolution of animals.

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