NATURAL SCIENTIFIC LEARNING IN PRIMARY SCHOOLS: THE ROSTOCK MODEL

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In the framework of an investigation of the scientific learning processes of primary school children, we have developed a didactic concept ("Rostock Model") that takes into consideration not only the psychology of learning and neurobiology but also research on cognition and brain function. The concept is based on the preposition that learning is a long-term process, based on instruction, independent activity, and cooperation, that considers the pupil as a learning subject and that, above all, prioritises the acquisition of interrelated and generative conceptual knowledge. The model is organized not on the basis of individual lessons but rather on the basis of more comprehensive and complex (thus interdisciplinary) teaching units. The practical organization of the lessons is characterized by ten features. The model is presently being tested and qualified in a long term international research study ("Scientific Learning in Primary Schools") [2]

Introduction

There have been a great deal of heated discussion about the demand placed on primary school teaching programs to offer an integrative approach (rather than an additive one) to teaching pedagogic aspects, didactic elements and the specialist knowledge of the field (Feige 2004, S. 87f.)

But the manner in which teacher-training students (and also teachers) plan their lessons—by the hour, giving each hour a comprehensive educational goal—goes against what we now know about learning processes, brain activity, and the emotional factors affecting learning. Complex goals cannot be realized within a 45- or 90-minute lesson. When planning a lesson, teacher-training students and teachers need to take into consideration that learning is a long-term process founded on instruction, independent activity and cooperation. They need an approach that regards the pupil as a learning subject and that, above all else, focuses on the appropriation of integrated, generative conceptual knowledge. The basis of planning lessons must therefore be larger, complex (also interdisciplinary) units, not small individual ones.

In this sense, we must also understand the urgent need expressed among German academics working in the field of science education for research into a new basis for the didactic of science education. (Einsiedler 2002, p.

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[2] Researchers from the Universities of Rostock (Germany), Debrecen (Hungary), and Vinius (Lithuania) are presently working on the research study focusing on grades one through four.

35). Structural and procedural-oriented conceptions (Spreckelsen 1971, Tütken 1973) focused on scientific subject matter and working method. These conceptions placed great weight on the goals of learning and were characterized by a concise and well defined lesson structure, which did not give too much attention to the position of the pupil. They did not, however, fulfil the understandable demand to establish the pupil's ability to conduct experiments as the "fourth cultural technique" (Lauterbach 2001).

The multi-perspective approach to science education (Giel 1974, 1975, 2001; Hiller 1994), which was developed as a clear alternative to the structural and procedural-oriented conceptions, was tied to a change in the kinds of subject matter emphasized in the classroom. Its preference for social themes arose from a demand for social awareness, and it thus necessarily neglected natural science-based topics. Primarily due its complexity and the breadth of the material it encompassed, this approach did not achieve any relevance in everyday school education.

In the field of general didactics, didactic thinking has been dominated to the present day by the educational-theoretical didactic approach developed by Wolfgang Klafki (1985, 1992) in the 1960s – which was reformulated in the 1980s as critical-constructive didactics. The didactic analysis of a lesson's topic, the construct of categorical education, and the concept of key problems remain particularly important for science education. At the initial stages of lesson planning, all teachers must consider the present and future significance of topic at hand, along with its structure, exemplary significance and accessibility in order to determine its relevance to educating their pupils. In the same manner, Klafki dialectically integrates formal and material educational demands in his construct of categorical education. In his critical-constructive didactic theory, he speaks out in favour of a problem-based form of learning, whose subject matter is oriented to the key problems of a period. As a consequence, he does away with the traditional 45-minute lesson and conceives the whole school as a place of learning. At the same time, both teachers *and* students are asked to take responsibility and become engaged in creating and structuring the teaching and learning processes.

In the present didactic discussion, there is an increased tendency to discuss the perspective of children alongside questions of goals, content, and methods. It would seem that we need to reconsider the theoretical idea of a relative discrete, staggered development from concrete to abstract thought processes. Considering their previous experiences and their present knowledge, children, from eight years of age on, are definitely capable of thinking abstractly, even if they primarily express the results of such thinking using colloquial speech (Tomasello 1999¸ Stern 2003). Already when they start school, children can fully use symbols and, moreover, have an intelligence profile that is compiled from divergent kinds of intelligence and which has left its mark on the individual's learning process. Children have also developed relatively robust theories about animate and non-animate nature, not to mention themselves (Gardner 1994).

These positions have been taken up by exemplary-genetic science education (Thiel 2001; Köhnlein 1996). This approach has its roots in the didactic theory of Martin Wagenschein—which no doubt explains its marked preference for the natural sciences. It is oriented to an educational process based on understanding exemplary themes, during which the pupils are granted a good deal of freedom in choosing their own topics. The experiences and interests of the children are regarded as an essential prerequisite for learning and are consequently integrated into the lessons. According to this view, inductive and deductive procedures ought to be meaningfully amalgamated in the learning process.

Multi-perspective science education (u. a. Köhnlein 1990, 1999; Kahlert 1994, 2005; Schreier 1999; GDSU 2002) strives toward an integration of social and natural scientific topics adopted from different areas of life in order to foster an understanding-based form of learning. At the same time, it promotes a vigorous combination of self-guided learning and the transmission of knowledge through instruction.

The strategy of "unlocking formative assessment" has been described as a practical model directed at improving school-based learning at the primary school level (Clarke 2001). This approach stresses a number of key educational aspects: the presentation of the education goals in the classroom, the pupils' role in formulating education goals in their own language, the determination of educational criteria for self-assessment, on-going monitoring and feedback from the teacher, the conscious application of various kinds of questions, and the deliberate strengthening the self-worth of every pupil.

The framework plan "Teaching for Understanding Guide" (Blythe 1998) emphasizes the attention given to the subjective perspectives of teachers and pupils, an approach founded on investigating generative themes, determining education goals, offering constant opportunities to perform, and providing on-going assessment.

In a more pointed manner, Charles (2000) stressed the importance of subjective factors on the learning processes taking place at school. Children like to feel that they are competent; that is to say, they like to know and understand that they are able to complete the assigned tasks. The pedagogical-didactic reflection on subjective factors affecting learning has been summarized under the term "personalized learning" (Hodson 1998; Dean 2006).

The theory of "conceptual change" (Carey 1985; Posner, Strike, Hewson, Gertzog 1982) regards natural scientific learning as a change from everyday ideas to scientific conceptual knowledge, a shift in which motivational and emotional factors play a considerable role (West & Pine 1983; Pintrich, Marx, Boyle 1993).

Derek Hodson (1998) explains natural scientific learning not only in terms of "conceptual change" but also, in a more comprehensive manner, as "enculturation". The children must be introduced to the cultural field of the natural sciences by a competent individual, the "encultured" teacher. HODSON is clearly basing his argument on the work of LEW WYGOTSKI when he characterizes natural scientific education as enculturation founded on guided participation and structured practice. According to this approach, learning takes place in the zone of future development and instruction promotes mental development. By structuring the children's social interaction and setting their tasks in the zone of future development, the teacher directs the children's learning processes (Wygotski 1987).

Research goals

With the *Rostock Model* we have developed a didactic concept. The concept examines the question of how scientific learning processes can be didactically structured and organized in primary education. The following questions will be investigated in detail:

- In consideration of our current knowledge not only of the psychology of learning and neurobiology but also cognitive and brain research how are we to structure didactic learning processes?
- What are the special features of scientific learning?

- What kind of a structure is demanded of a didactic concept that actually helps the teacher in the everyday process of planning, carrying out and analysing a lesson?

Research methods

The Rostock Model is based on a selection of special texts which were chosen on the basis of a foundational understanding of the field. We rely on the learning theories of Wygotski (1987), Bruner (1973), Poddjakow (1981), on a variety of Anglo-American didactic concepts (Hodson 1998; Blythe 1998, Charles 2000, Clarke 2001), and on our own empirical studies (Toth 2006; Revákné Markóczi 2006; Schneider & Oberländer Ms.). The basic structure of the model is derived from our positions concerning the "learning pupil in the school" (Schneider, Hruby, Pentzien Ms.). The selection took place in an explorative manner; in other words, during the analysis and evaluation of texts we took unanticipated aspects into account if they proved applicable to the basic structure of the study.

The concept is being tested in schools as a cooperative effort between the Universities of Debrecen and Vilnius.

Fundamental presuppositions of the *Rostock Model*

The Rostock Model is a didactic concept based on the following fundamental assumptions:

- Learning is a socio-cultural process of acquisition.
- Learning processes have a long-term character.
- Learning is dependent on an intrinsically motivated individual activity of the learner.
- Sustainable learning is based on conceptual knowledge
- Scientific learning is a form of enculturation.

Learning – a socio-constructive process of acquisition

Learning can be understood as an activity associated with effort and tied to specific cognitive and social fields, an activity through which humans construct the world objectively, socially and conceptually, in a manner that is relatively durable and practically based. When humans learn, mental models (concepts) are constantly solidified, reformed, challenged, adapted and developed in a process of construction and reconstruction dependent on experience. To a great degree, this process of learning and knowledge acquisition is determined by ideological, cultural, sub-cultural, emotional and situational factors (Hodson 1998, Schneider 2003b). In the learning process, information is codified in the associational memory, from which the individual can recall contents according to the principle of similarity. The existing informational patterns thus extensively determine what is perceived and how it is interpreted. Even when information is not complete, the brain searches for suitable ("good") interpretational models and adds the missing pieces to the picture on its own, without the person necessarily being aware of this process. With respect to their nature, perceptions are both processes and products. They reveal themselves as processes insofar as they involve searching and comparing—both of which are guided by expectations and thus heavily influenced by "pre-conceptions". At the same time, perceptions manifest themselves as products because they are also interpretations and explanations, which, as "pre-conceptions", provide the structure for future perceptions (Singer 2003, pp. 35, 44).

Every teacher knows that they have to link their lessons to their pupils' previous knowledge and abilities in order to initiate an effective learning process. In other words, teaching in a manner appropriate for pupil means giving pupils the skills that will allow them to integrate their previous ways of acting with the new conceptions of the self and the world offered at school. The starting point for these endeavours is the current experiences of pupils, on the basis of which they can act independently. But these experiences, which Lew S. Wygotski (1987) terms *the levels of current development*, do not adequately describe the child's present state of development. In order to utilise the developmental possibilities of learning at school, *the field of future development* must also be determined for every child. In this manner Wygotski describes the difference between the level on which the child can solve tasks with the teacher's guidance and the level on which the pupil can solve the problems on his own. Tasks and exercises should take place in the field of future development. The main characteristic of this learning stage is *cooperation*. The field of future learning, in other words the field of learning, is dependent on social exchange and input: "Tomorrow the child will be able to accomplish on his own what today he can only complete with the help of others." (p. 448)

This view is supported by mathematical models. According to a theory of regulative dynamic developed by John Nash, the best result for each individual in a group is achieved when everyone in the group does what is best for him *and* for the group. In group work, individual self-realization and social comparison must go hand in hand. Learning is always an eminently social process. Social cooperation occurs in multiple forms. It comprises the practical and theoretical instruction offered by teachers, partner and group work among the pupils, the exchange of ideas with experts, and the use of media.

Learning - a long-term process

Children need time to develop ideas, and to discuss and test them. They need time to think and to formulate their thoughts. They need time to repeat, to practise, and to try things out. They need time for questions and conversations. Even in primary school, they need a great deal of time for playing and movements.

Children need stimuli in order to develop their ability to pay attention and to apply it to ever-larger fields. Patterns of expectations—as well as new impulses and the promise of new impulses—stimulate a *selective attention*. After their attention is awakened, children need time to guide, coordinate and enlarge the field of their attention. They must have the opportunity to spend a sufficient amount of time dealing with an object, concentrating on it, comparing it with other objects, and finding relations between it and other objects. The didactic response to the long-term nature of the learning process is expressed in a comprehensive planning process, that is to say, in the planning of *larger, complex learning units*. Learning goals and criteria are determined for these learning units, goals and criteria which are valid for all the lesson planning processes that go into forming a particular learning unit.

To this end, those involved in the planning process deepen and expand upon an exemplary theme, which must be treated with great attention and requires a corresponding investment of time. The process has a number of starting points which follow an initial phase of sensitization in which the children's previous knowledge is accessed: the elaboration of the meaning of the theme or subject the children are learning about, the determination of the goals of learning, and the determination of the criteria with which the children will be accessed. At the beginning of the exploratory phase, the teacher compiles a general cognitive orientation framework: it provides models and examples, gives reasons for the particular orientation, and holds explanatory information in readiness. The children receive the opportunity to carry out practical actions with the objects within a social learning context. The teacher motivates the children to work carefully, makes sure that all constitutive activities are carried out in full, gives ongoing feedback, and creates opportunities whereby the results of the learning process can be judged in a qualitative manner. In the presentation phases, in which the findings are summarized and which also has a monitoring function, the teacher encourages the pupils both to represent facts and realisations in a variety of presentation forms, such as models, drawing, overviews, schemas, and to describe their chosen activities in full, either through speaking or writing, or both. At the end of the learning unit, the children reflect not just on the learning process and the process they have made, but also on the feelings they experienced when they were learning.

The intrinsic, self-motivating activities of the children

The central matter here consists of having the children understand themselves as active subjects involved in a learning process and taking this fact seriously. This means integrating them into the teaching and learning processes in a conscious and responsible manner. To accomplish this, we must understand the needs of the children at school and take these into consideration in the creation of the learning activities. The desire and readiness to learn start to develop when the children

- understand for themselves that the tasks involved in the lesson have meaning and use,
- can hope that they will be successful and receive confirmation of their accomplishments,
- see their interests being addressed,
- know what the lesson is about and what it hopes or wants to achieve,
- feel that the demands placed on them by the lesson are challenging and, at the same time, achievable,
- feel that their expectation that they are learning successfully is being confirmed by others (Hodson 1998; Schneider 2003a).

Motivation is a crucial factor in the learning process. In this case, the pupil carries out the learning activity for its own sake because he is curious and the subject interests him because he feels encouraged, etc. At the same time, it must be taken into consideration that not every child is motivated in the same way. Each learner, and therefore each child possesses a distinct motivational profile. In determining what kind of learning is best for the child, it is helpful to know the child’s motivational type (Hofstein & Kempa 1985; Kempa & Diaz 1990).

Table 1: The learning process as influenced by a motivational model

Motivations Type	Preferred Learning
Performance-driven	A learning environment organized to enhance competition
Curiosity satisfaction	Learning environment organized around self-motivation and problem-based learning
Fulfilment of obligation	Clearly defined goals and unambiguous instructions
Need to feel socially included	Learning environment organized around cooperation

On the basis of the different motivations for learning at school, the learning environment is varied and structured in a flexible manner in order to give consideration to the needs of each child (Charles 2000). The cognitive development, which is expressed during the learning process, is accompanied by emotional sensitivity. West and Pine (1983) designate four possible emotional aspects:

- children experience a feeling of strength when they grow increasingly competent
- children recognize how seemingly complex states of affair become simpler, and how they become more straightforward and transparent.
- children develop aesthetic sensitivity for the beauty, harmony, and logical coherence of the subject they are learning about.
- children feel of sense of well-being and feel that their personal integrity has been strengthened

Teachers can be said to have taken into consideration the close links between cognition and emotion (Csikszentmihalyi, 1985) when they pay attention to the following during the learning process:

- that the children direct their attention to a limited, clearly outlined field of activity (→knowledge of the goals of learning).
- that the children can carry out a variety of possible actions in the framework of the clearly outlined field of activity (→ possibilities for independence and cooperation).
- that the instructions are coherent and unambiguous and are, in turn, accompanied with clear and unambiguous feedback (→ knowledge of the criteria of learning).
- That they let each child know that they have mastered the task when the child has done his utmost, asked for help with problems, and worked with the other children (→ strengthening the feeling of self-worth).
- that they have eliminated all sources of disruption (→selective und polarising awareness).

Sustainable Learning and Conceptual Knowledge

Owing to our daily interactions with our surrounding environment, we all have a comprehensive conceptual knowledge, so-called everyday concepts, which, insofar as they provide means of orientation for our actions, prove their worth in our everyday life. Within the everyday world, the natural sciences and humanities form relatively independent fields, influenced by culture, and formed in and through historical processes (Berger, Luckmann 1991), fields which, among other things, are characterized both by their particular activities, patterns of speech and concepts, and by their tendencies to generalize and to form ideas and symbols (Singer 2003). Learning at school is oriented by the shift from the conceptualizations used in everyday life to those found in scientific and scholarly understanding. This poses a problem, namely that the conceptualizations in our everyday world and the conceptualizations in scientific and scholarly fields are decidedly different from each other but, at the same time, reciprocally influence each other (table 2).

Table 2: Features of everyday conceptions and scientific conceptions (Wygotski 1987, 2002)

Everyday Conceptions	**Scientific Conceptions**
• spontaneous conceptions • high level of personal significance • mostly attached to local, specific events and situations, and isolated from other conceptions. • largely learned through *induction* • scientific concepts gradually find their way into everyday conceptions (from general to specific: downwards)	• are general, abstract, and idealized • linked to other general conceptions • principally learned through deduction • their comprehension depends on everyday conceptions • everyday conceptions form the foundation on which scientific ideas can gradually develop. (from specific to general: upwards)

The question is whether teaching can bring about sustainable learning. Sustainable learning is manifested through understanding. To understand something means to be able to reflect on the subject at hand in distinctly different ways, to explain it, to determine its meaning, to illustrate it using examples, to relate it in a meaningful way to other states of affair—in particular to those found in everyday life—and, if necessary, to vary it. Understanding is not the same thing as knowing, but knowledge does provide a basis for understanding. Understanding is also manifested in a certain competence in applying scientific concepts. It is thus indispensable to acquire general, comprehensive concepts of knowledge and skill, in order to be able to act effectively and meaningfully in a complex world and in new situations.

The more general a concept is, the greater its field of application will be, and, likewise, the more robust its sustainability is. There are general strategies for developing such knowledge of concepts: systematically forming analogies, searching for the greatest number of various examples, realizing similarities and differences, examining hard cases, illustrating and modelling while, at the same time, developing concepts, presenting in the context of different systems, carrying out thought experiments, and, last but not least, reflecting on objects, events, occurrences, and learning itself. From a cognitive-psychological perspective, the qualitative, conceptual aspects of the subject matter should be conveyed relatively early in the educational process and distinguished from everyday conceptions before they are placed in relation to quantitative-numerical subject matter (Spada, Lay 2000).

Natural scientific learning—a form of enculturation

Natural scientific learning takes place in the framework of a third-person perspective and is aimed at gaining knowledge of non-semantic objects and phenomena which are open to objectification (movement, force, reproduction, combustion, etc.). One of the goals of scientific education is the learning and acquisition of abstract, general concepts. Already by the time they enter school, children have instinctively acquired ideas about animate and inanimate nature through their own independent experience ("instinctive knowledge") or through the media ("non-expert knowledge") (Claxton 1993). At school children become familiar with scientifically based concepts about animate and inanimate nature, concepts that make it possible for them to acquire comprehensive and overarching cognitive and practical orientations. As we have already seen, there is a significant reciprocal relation between the children's everyday concepts and scientific concepts, despite the fundamental differences between such concepts. Scientific learning can thus be explained as a shift in concepts (Carey 1985). How can children be introduced to these new concepts? A debasement of everyday concepts does not contribute to the enhancement of scientific concepts (Hodson 1998), for these have proved their worth in everyday life to such a degree that, at least initially, there is no reason to question or replace these concepts. It is not a rare occurrence that scientific explanations are learned and acquired only in a formal manner and laid on top of everyday explanations, simply to be retrieved during the relatively limited context of the school lesson. In pedagogical literature, it has been hotly discussed whether one should opt for a "hard" shift in which everyday conceptions are completely replaced by scientific conceptions or a "soft" shift in which scientific concepts are allowed to exist alongside everyday concepts, allowing them to be activated and used in a manner appropriate to the particular situation (Duit 1997).

The findings of our own research on scientific learning during the initial education phase have given us the opportunity to critically examine whether a true, that is to say, sustainable parallel existence between logically different concepts is feasible or whether such a parallel existence would constitute a rather temporary situation. We assume that scientifically based concepts, if properly understood, successively replace everyday concepts. These shifts are long-term in nature and take place at various speeds. Although such shifts are relatively constant, stagnations and sudden progress also occur, during which we witness not only significant qualitative improvements but also a qualitative breaking down of knowledge, skills or personal identity. Developmental processes frequently have a hierarchically structured starting point from which future developments proceed in a web-like pattern (Toth 2006). But when everyday concepts prove in the end to be highly resistant, no real understanding in the scientific field can take place.

Moreover, it seems to us that the German translation of "conceptual change" as "*Konzeptwechsel*" does not suitably describe the development of mental models because the German word denotes a single phase, namely one in which a concept is completely replaced by another. During our analysis of the pupil's results, we noticed that after completing the teaching unit, very few children had undergone a complete change in their explanatory concepts, although many children (but not all) had somewhat changed their understanding of the subject matter. Thus we would not term the development of the children's conceptions as a conceptual replacement (*Konzeptwechsel*) but as a gradual conceptual change (*Konzeptveränderung*). A replacement of concepts (*Konzeptwechsel*) does indeed describe a part of conceptual change. This term can be used to describe a completed conceptual change. Conceptual changes occur in a variety of forms. So far the following patterns have been identified:

- *Conceptual construction:* there are no initial conceptions which can be used as links for new information.
- *Conceptual persistence:* no changes in the initial conceptions take place.
- *Conceptual addition:* pre-existing conceptions are enhanced by new conceptions. Both concepts can exist together in a parallel manner.
- *conceptual change*: pre-existing conceptions are fully replaced by other conceptions
- *Conceptual breakdown*: pre-existing conceptions are rejected but no new conceptions are built up.

We assume, that beside these 5 different categories of conceptual change there exists another one which we would describe with the term of *conceptual modification* In this case the pre-existing conceptions are changed within the pre-existing frame of reference.

When we start from the presupposition that scientific learning is reflected in a change in mental concepts, we still have to address the question of how these changes can be optimally achieved in and through school-based learning.

At present, scientific learning is primary organized on the basis of an inductive method, in which the children's investigative and explorative activities provide the starting point. The children are meant to arrive at scientific realizations with the aid of their pre-existing experiences. But it is difficult to increase and improve the children's natural scientific knowledge through the application of an inductive method. Such a course of action cannot deliver valid results for the mere fact that there are no "pure" observations. Observations are always interpreted on the basis of previous knowledge, beliefs, expectations, and experiences, meaning that they are always theory dependent—even when these theories are everyday theories. Observations need an incentive, a focus of attention, and a goal. At the same time, they are influenced by language and the terminology available to and used by the children. For this reason, scientific learning must be organized on the basis of a deductive method. Without the knowledge of the correct terminology, the children neither observe nor express their observations correctly. But when they are taught relevant specialist terms (theories), they "see" that matter "dissolves" rather than, as had previously been the case, "seeing" matter "disappear". Children acquire new concepts not through observation but rather through the application of concepts that furnish their observations with meaning (Hodson 1998).

Scientific learning can thus be seen as enculturation, as a familiarization with a new culture. During this process, the teacher takes on a decisive function. He must be, in the truest sense of the word, "encultured", which means that he has mastered the scientific method and the subject matter at hand, and can teach both to the children. At first, the teacher determines which conceptions the children already possess about the scientific phenomena they are to learn about. Then the teacher and the children work out and clarify the meaning, goals and criteria of the teaching unit. The children are guided to a new or higher conceptual understanding through social interaction and the communication accompanying it. These are manifested and expressed in the initial leadership role of the teacher, in the proper support for each child, and in the children's increasing independent participation in the learning process. The decisive instrument of the children's enculturation is social cooperation, not only between a knowledgeable teacher and the young learners but also between children who have already internalized the lesson material and those who are still in the process of learning it. In the course of the learning process, as their knowledge and understanding grow, the children start to work in an increasingly independent manner (Hodson 1998).

The children are systematically sensitized to the scientific problems present in the world around them. They make their own connections between their experiences and natural occurrences. The children and the teacher develop and nurture a culture of inquiry and discussion. The teacher avoids "closed" questions, that is, questions for which there is only a single answer. This manner of posing questions hinders the development of the thinking process because it leads the children to concentrate solely on finding the answer they believe the teacher expects. In particular younger children adopt their teacher's manner of posing questions, arriving at answers, and developing arguments.

Moving beyond a merely superficial level of viewing the world, the teacher makes individual phenomena comprehensible to the children in a manner appropriate to their understanding. At the same time, he places the phenomena in a larger context of relations, thus enabling the children's first attempt to form theories (supposition, hypothesis, trial and error, modelling, and experimentation). He introduces the children to the scientific working method and organizes its systematic application.

The teacher formulates everyday practical and scientific explanations predominately in the children's own language. At the same time, he introduces certain terms that the children need in order to understand the lesson material and to communicate about it with others. The teacher complements and enhances every illustration with specialist terms or explanations that the children can understand. The children have varied opportunities to contemplation, observation, and testing. Step by step, they learn to read and reproduce the tables, drawings, and diagrams. During all of their activities, they always receive feedback from their teacher and fellow students on their progress.

Didactic elements of the Rostock Model

The Rostock Model is especially suited to planning teaching units in science-based classes, overarching teaching units and project based learning. Although it was developed for primary school education, it also lends itself to planning secondary and high school teaching units, and can be applied to adult learning.

The following *elements* characterize the main themes of the Rostock Model in terms of its content.

- Discussion of the meaning of what is being taught
- Establishment of generative themes
- Formulation of collective goals
- Construction of concrete evaluative criteria
- Knowing the presupposition of learning
- Integration of independent learning and instruction
- Development of a culture of inquiry and communication
- Accompanying the learning process with self assessment and feedback
- Stimulating of self-reflexion of the own learning
- Strengthening the self-respect of each child

Discussion of the meaning of what is being taught

A fundamental didactic idea informing this model is the active integration of learners in the clear and understandable organization of the learning process. At the beginning of every new teaching unit, the teacher and the children discuss the meaning of the educational topics dealt with in the unit: "why should we learn this?" and "for what reason is it important?"

Children (and adults) often ask about the meaning or use of what they are learning (Schneider 2003b, p.22). They do a "costs-benefits evaluation", as it were. For the most part, they pay attention to and learn only those things they feel are meaningful. For this reason, topics must be chosen that the children can recognize in their own lives. For younger children, it is particularly important to investigate natural phenomena present in their immediate environment. They need cognitive challenges that they can master. In this process, we must include "appropriate investigations" that have clear goals that work and which, as a whole, support and foster the development of mental concepts.

The children must have a clear idea about the reasons for learning what they are learning. The meaning of the subject matter should be discussed in the framework of a pupil-to-pupil conversation. In this process, the integration of the concrete subject matter in an overarching context plays a significant supportive role. This procedure also appeals to how the human brain works. The brain has expectations about incoming information and compares the pieces of information it receives from the environment on the basis of these expectations. When the learner's attentiveness is heightened by "pre-stimuli", their learning processes can be intensified and improved (Spitzer 2004). The children's ability to learn is positively influenced when the meaning of the unit is formulated in a language they can understand, and when they are constantly reminded of its meaning (for instance, by writing it down on the blackboard). During the learning process, there should be constant reference to the meaning of what is being learned.

Establishing the generative theme

It is essential to acquire cognitive and practical concepts in order to act in a complex world and in new situations.

Central ideas of a content of learning are called **generative themes**, if the serve as a basis for further secondary and/or overarching thoughts. Generative themes support the transferable and interdisciplinary character of the skills and understanding being developed by the children.

Themes are generative when they

- are significant for one or more subjects
- are interesting for the pupil and the teacher
- are accessible for the pupil, i.e. when many sources are available, when they allow

Planning a generative theme

1. Brainstorming: What is important about the given conditions? What does teacher and their students' interest?
2. Creating a network of ideas.
3. Where do we find the greatest concentration of information in the network of ideas?
4. Select one of points of the greatest concentration and setting as the generative theme (Blythe 1998)

numerous strategies and activities, when they make connections between personal experience and the theme at hand
- offer the opportunity for diverse connections, i.e. when they link dissimilar and complex phenomena and can be formulated in open questions (Blythe 1999).

Generative themes vary depending on the pupil's age, social and cultural background, personal interests, and intellectual experience. However they lose their productive force when they are too strictly planned from a didactic point of view. This means that they are dependent on an open form of instruction.

"Generative topics are issues, themes, concepts, ideas; and so on those provide enough depth, significance, connections, and variety of perspective to support student's development of powerful understandings." (Blythe 1998, S. 25)

A generative theme should be understood as a motif which can be found throughout the teaching unit (and can thus be compared to a motif in a piece of music). It constantly refers back to the central idea of the unit and opens the central idea to new perspectives in terms of its content. Such a theme presents itself in oppositions and contradictions; it must allow for many perspectives that cannot be seen as either "right" or "wrong" and which permit the students to formulate their own opinions. For this reason, generative themes are closely connected to concept-based and strategic knowledge

Exemplary Generative Themes:
- progress
- development
- contradiction
- quality
- element
- transformation
- maintenance
- life and death
- ….

One must give oneself enough time to identify a generative theme. Together with the children, a teacher can decide on a generative theme for the teaching content by using "mind mapping" (Blythe 1999). In a brainstorming session, all the thoughts and considerations for the teaching content are drawn up in the form of a net. The "junctions" generated through this process reveal possible generative themes. This implies that each subject matter can have a number of generative themes, of which one has to be chosen. (Blythe 1999)

Formulating common goals of learning

To a great degree, expectations stimulated the interest in and attention given to a topic. But this is not the whole story. In a fundamental way, learning is a process of selection and interpretation, guided by expectations and strongly influenced by previous knowledge (*Vorwissen*).

In order to tie in to expectations, to stimulate them and to maintain them over the course of the learning process, one needs to do more than organize a motivational phase at the beginning of the teaching unit. Here it proves to be far more effective when the goals of learning are instrumentally deployed above and beyond the perspective of the teacher.

Traditionally, the teacher, while preparing a new teaching unit, determines the educational goals in relation to the knowledge to be learned, the skills to be trained, and the attitudes to be developed (teacher perspective). What is new is that the teacher now formulates these goals in two forms: once, as a open question (what should be clarified: to what degree is event x similar to event y, or how do they differ?), and once, as a conclusion (what will the pupils know, recognize, learn, be able to do, etc.: the children will understand/ learn about the characteristics….)

In order to use the children’s expectations as a tool in the learning process, this manner of determining the goals of learning is not sufficient for an optimal teaching and learning process. Moreover, we start from the presupposition that the learning process is more successful when the children:

- are clear about the goals and tasks involved in the learning process
- can make decisions and can control their own learning processes.

From the very beginning, pupils need a continual (and therefore always visible) orientation about the goals of the teaching unit. Clear goals are, as it were, docking stations for expectations. The learning goals of a unit must therefore be determined from the pupil’s perspective. After the teacher has explained the meaning of the new topic to the children, she discusses the desired learning goals with them: "What should we know and be able to do?" The learning goals should above all be formulated concretely and in a language understandable to the children (child perspective), and the learning goals should be present in the class for all to see in order that they can be used as a constant means of orientation. They will be referred to throughout the learning process.

Developing concrete learning criteria

In order to be used in a manner that fosters learning, assessments and feedback need to be oriented to criteria. The learning goals are the starting point for the determination of learning criteria. At the very beginning of the teaching unit, the teacher is asked to determine the criteria whereby the accomplishments and performance of the pupils will be judged: "What must a pupil at level x know or be able to do?" A precise characterization of the performance level permits the determination of the current level of development of a particular pupil and the determination of the zone of future development. The teacher can thus organize a well mapped-out and purposeful support with the use of instructions and appropriate learning tasks. As we all know, the process of realization and its accompanying emotions are joined when during the organization of the learning process the teacher takes clear that the children’s attention is focused on a limited, clearly defined field of action and when the instruction given to the children are coherent and clear, and tied to unambiguous and clear feedback.

Just like the learning goals, at the beginning of a new unit the learning criteria ought to be formulated not only from the teacher’s perspective (means of analysis and assessment) but also from the pupil’s perspective. Throughout the whole learning process, the children should be familiar with both the goals and the criteria on the basis of which they and the teacher can recognize whether and to what degree the goals have been met. It is strongly recommended that the learning criteria for the pupils (pupil perspective) are developed by the teacher and the pupils together, and set down in the language of the children: "How can I recognize what I already know?" "What tasks can I not yet accomplish or only partly accomplish" "Where do I need help?"

Learning criteria developed from the pupil’s perspective give the children the possibility to think about their progress critically and to evaluate themselves. The criteria are presented in the classroom in a way that they are always visible or they can be given to the pupils in the form of a list.

Investigating the learner's preconceptions

When planning their lessons, many teachers are not oriented by the children's ideas and conceptions. In addition, they do not possess the necessary knowledge to realize that the children's ideas and conceptions are characterized by their conceptual nature, relative stability and potential faultiness. (Heer-Dörr 2005, p. 169 f.) When at the beginning of the lesson teachers do indeed activate the children's everyday experiences, they do so primarily as a means to motivate the children to participate in conversation. But only when the children engage in discursive investigation of their experiences do they become an important factor in the learning process. It is a decisive question whether the children's ideas and conceptions can be didactically mobilized within the context of a lesson.

One possible starting point can be introducing a brainstorming session into an association phase. The children's thoughts, ideas, and terminology are first recorded. In a second step, the children are asked to organize them in a meaningful way. In this stage, *concept mapping* can play an important role. Concept mapping is a tool used to determine and investigate an individual's declarative knowledge as applied in a specific field. It makes it possible for the teacher to determine a child's present state of knowledge and how this knowledge charges over a specific period of time (Novak 1998). The child's level of understanding can be determined by how he uses and organizes terms. The question thus is, what terms are the children familiar with and how can they be joined predicatively.

Alongside concept mapping, pupil-to-pupil conversations can be employed to investigate the children's preconceptions. This method lends itself particularly to the discursive investigation of a problem, and it supports the child's reflexive understanding of the problem at hand. The ideas and conceptions pupils possess can be investigated and comprehended by interpreting the pictorial representations (*the pupils' drawings*) produced by the children. Conclusions about a child's explicit knowledge can be drawn through an analysis of which terms a child uses (or does not use) and of how he applies them. While concept mapping, pupil-to-pupil conversation, and pupils' drawings can easily be employed and applied in the analysis of preconceptions, the *determination of knowledge hierarchies* using the *knowledge space theory* (KST) proves far more problematic and time-consuming. This being said, insights into the hierarchical structure of the previous knowledge that serve as the starting point for the learning process can greatly contribute to the optimization of the teaching and learning processes (Toth 2006).

Connecting instruction to independent activity

Learning is a complex process based on a variety of different mechanisms. In every case, learning is tied to the learner's independent activity. This independent activity is carried out both in physical and mental actions. It is thus essential that the children are given a good deal of room for practical-physical actions, and also receive ample opportunity to reflect on their practical-physical actions.

At the same time, the human brain is programmed to absorb and process the greatest possible amount of information from other humans. Children are dependent on the information gathered by previous generations that adults offer them. They receive more and better information from adults than they themselves could possibly collect (Gopnik 2000). When at certain points in the children's learning processes, teachers offer summarizing, explanatory, and informative instructions, they lastingly support and foster our intellectual achievements in structuring reality. The transmission of information takes on a great importance in learning processes that introduce children into a particular reality or culture (e.g. the sciences) and that are consequently organized on a deductive basis. Learning through instruction and learning through independent activity should not be seen as competing procedures but rather as procedures that maintain a dialectical and complementary relation. Both procedures initiate and support mental constructions and reconstructions.

Developing communicative culture of discussion and inquiry

In developing communicative culture of discussion, the teacher familiarizes the children to the *culture of reflection* and stimulates them to engage in *discursive investigation* of the subject matter being taught. What is important here is developing a form of communication dominated by the pupils themselves and initiating *pupil-to-pupil conversations* with the following features: the participants have the same rights, every opinion enriches the discussion, freedom of thought is guaranteed, and thought experiments are welcome.

Characteristics of pupil-to-pupil conversation

- The teacher is a (reserved) moderator.
- There is no lecturing, rather the greatest possible distance from school-based instruction.
- Creation of free, open, and equal discussion.
- There is time to reflect, follow up, associate, analogize and ask questions.
- Quick answers are not the goal, rather the possibility to overcome previous personal limits.
- Everyone has the chance to listen, give reasons for their opinions, to tolerate those of others, to express criticism, to accept criticism and to draw on the ideas of others.
- There is no pedagogic over-planning or isolation, rather intermittent application of the method (Schneider 2000 p. 68ff.).

The children learn that not being able to understand something at first and the questions that result from this state are natural and important elements in the learning process. When one has difficulties understanding and has to exert oneself, this means that one has reached a new stage in learning. At this point it is important that the children are able to articulate their problems and ask for help.

We start from the presupposition that the children's *questions* and assumptions, together with their ability to solve specific tasks with the aid of instructions, signal a sensitized willingness and readiness to learn. Children's questions never arise by pure chance, even if it might appear this way to adults. Reform pedagogy in particular regards children's questions as an overflowing source of learning. "At the moment when the child asks a question, he is without a doubt interested in the topic and his mind is ready to acquire knowledge" (Otto 1965, p. 11).

According to the Rostock Model, discursive understanding of the problematic should be found at the beginning of each complex teaching unit, one which, among other things, discusses the meaning of the teaching units and leads to the formulation of learning goals and criteria from the perspective of the pupils. During the learning process the teacher repeatedly stimulates reflective thought about the progress and problems of the learning process and, by doing so, a subjective awareness. Every teaching unit is to be concluded with an intensive phase of reflection. It is thus essential to develop communicative culture of discussion and questioning from the beginning of the very first class onwards in order that the children are able to engage in a discursive exchange of thoughts and to actively integrate them into the learning process.

Self assessment and feedback accompanying the learning process

Simply to place an assessment at the end of the lesson is to waste the inherent learning potential contained within assessments and feedback.

Therefore during the whole learning process the children should

- learn to use mistakes as a chance to learn
- know the goals and criteria of learning and to repeatedly refer back to them
- receive regular feedback on the state of their learning process(from the teacher and fellow pupils, as well as through self inspection)
- obtain continuous opportunity to think critically
- have the chance speak about their feelings as they learn
- have the opportunity to qualify their work

From the beginning to the end of a lesson the children are given the chance to express their current understanding. The learning processes are structured in a manner that allows the children to make connections to similar events they have experienced in their everyday life. They are repeatedly stimulated to use their own words to explain events and to speculate about what would have happened under other conditions. The learning process is monitored not so much by having the children take tests (which, of course, cannot be totally excluded) but rather by letting the children express their understanding in the form of individual and creative presentations such as posters, collages, small exhibitions, oral presentations, essay-like texts, and the documentation of a project or the creation of a portfolio.

> A **portfolio** is a goal directed collection of various documents accompanying the learning process which the pupil compiles about a particular topic (samples of texts, concept maps, drawings, multiple choice tests, collages, poems, corrections, photos with written reflections) and which reveal his successes at learning, the gaps in his knowledge, and metacognitive abilities (Häcker 2002)

An ongoing assessment of the children’s performance and abilities must help the children recognize both what they have learned and how they can creatively apply what they have learned to solve problems and to form new realizations. In order to test whether the pupil has understood the lesson’s problem and content, he should be encouraged to express his thoughts in at least two different ways. Children need an appropriate degree of personal control and independence which the teacher grants them as their abilities improve. In this process, a crucial role is played by the goals and criteria of learning formulated from the pupil’s perspective.

Reflecting on learning

All cognitive learning processes involving the knowledge of physical objects should be tied to metacognitive learning, that is to say, to learning about learning. Corresponding reflections support the reciprocal relation between the learning process and the results of learning. To this end, children can write a journal or compile a portfolio. Practical tasks involving solving problems that the children can relate to their everyday life provide information about the transferability of the knowledge they have acquired. The acquisition of transferable knowledge provides an essential building block for metacognitive competences (Revákné Markóczi 2006).

Every teaching unit should be concluded with a comprehensive phase of reflection. The children are asked to assess, with the aid of the learning criteria, whether they have reached the learning goals:

- What do I know about the topic?
- Do I understand the topic as I would like to?
- What additional questions do I have?
- Which tasks are too difficult for me, which ones did I really like?
- ……

Along with these questions, which refer primarily to the learning material, other questions are posed about the children's' emotional state of mind during the learning process:

- How did you feel when you
    - could not solve a task?
    - had difficulties with a task?
    - had to ask for help?
    - received help?
- What atmosphere in the class help you learn?
- …

The teacher inspires this exchange of though by posing stimulating questions such as the following:

- What did you find difficult with this topic?
- Can you use what you have learned to explain phenomenon x or y?
- Did you have the chance to organize something?
- Do you feel recognized by the group and was your contribution appreciated?
- ……

Strengthening each child's sense of self-worth

Every measure should be taken to strengthen the self-worth of each child. Self-worth is to be understood as a psychological construct expressing the positive or negative emotional self assessment of the individual (Damon 1989). It is based on emotional, situational and field-specific experiences structured within an intra or inter-individual context of comparisons and generalized over a sustained period of time and in terms of specific social fields, and becomes a fundamental and underlying feeling for the person (Haußer 1995).

Positive self-worth is one of our central needs; accordingly, it has a determining influence on our behaviour. When analysing feelings of self-worth in terms of their relation to means of assessment, we can determine three distinct categories: self confidence, trust and self confidence (Schneider 2003b, S. 42ff.). *Self confidence* provides information about subjective feelings concerning our abilities and character traits. It develops within a relational field structured by two poles: confidence and uncertainty. Both the general atmosphere of the classroom and the manner in which performance and ability are acknowledged influence the children's self confidence. Thus throughout the learning process individual progress should always be the yardstick for assessment. The performances and abilities of individual children ought not to be compared with another. Mistakes are not to be seen as a lack of ability but as a potential for learning.

Trust expresses our need for security. The individual directs his attention to another person from whom he expects this need to be fulfilled. At school, this other person is, to a large degree, the teacher. An essential precondition for developing relations of trust is the mutual respect for the physical and mental integrity of the personality. Trust shows the need for personal ties, support and orientation.

In contrast, the category *self confidence* refers to the individual's assessment of his own abilities and the corresponding appreciation of his particular skills and willingness to act. The manner in which the individual reflects on his own behaviour and actions in relation to those of others leads to a basic underlying feeling that, in distancing the individual ego from that of others, ascribes the ego a particular value, which, in turn, leads to a self determined willingness to act. This can express itself in, for example, an entitlement to carry out plans, self-assertion, value judgements, and dissociation. The consistent integration of the children in the planning of the learning process strengthens their sense of self-worth, and a positive sense of self-worth is a learning factor, the importance of which should not be underestimated.

Model for planning a teaching unit

Teaching Unit: "......................"		
Generative Topic:		
Knowledge and Understanding	#1. .... #2. .... #3.	Central Terms
Skills	The children develop the ability to • .... •	
Attitudes to be developed	The children develop the need to • .... •	
Learning Activities		Evaluations and Feedback Fostering Learning
Learning Phase	Content	
Intro-duction		
Explo-ration		
Sum-mary		
Ref-lection		

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