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EXPLORING, SENSIBILITY AND WONDER
SCIENCE WITH YOUNG CHILDREN AND USING THE SENSES

Kees Both

When you understand all about the sun and all about the atmosphere and all about the rotation of the earth, you may still miss the radiance of the sunset. There is no substitution for the direct perception of the concrete achievement of a thing in its actuality. We want concrete fact with a high light thrown on what is relevant to its preciousness

Alfred North Whitehead

I know the answer, but what's the question?

Lazer Goldberg

What is it in the individual scientist's relation to nature that facilitates the kind of seeing that eventually leads to productive discourse? ...one must have the time to look, the patience to 'hear what the material has to say to you', the openess to 'let it come to you'.

Evelyn Fox Keller, about Barbara McClintock

Twenty-five years ago I was a firm believer in a process-approach to primary science. We were impressed of the rapidly growing amount of information the children were immersed in (especially by the influence of the TV) and by the rapidly expanding and changing sciences. A proverb we used frequently was: 'knowledge is like fish, it is rotting soon.' We also cited the wisdom of good old Heraklitos, who said: 'teaching is not filling a barrel, but lighting a fire'. It was not important *what* was learned, but *how* it was learnt. One had to learn how to learn and develop an attitude for life-long learning. Indeed many of the new science-curricula that were developed in the 1970's in the UK and the USA supported us in these convinctions. We, in the Netherlands and especially within the movement of the Jenaplan schools, were speaking about 'World Orientation'. By this concept we meant a style of teaching and learning about the environment and the world-at-large in which first-hand experiences, seeing and hearing and touching and smelling were basic and in which dialogues in the classroom about thoughts and feelings and the experiences of children, had a very central place. Developing independent learners and empowerment of children, especially social and otherwise disadvantaged children, were important goals. Here, primary science had (and still has!) much to offer.
Now, twenty-five years on, it must be said that there is a good deal of continuity between then and now. Despite changes in the political climate, in our country, we (the Jenaplanschools in the Netherlands) still believe in the values of developing independent learners, critical thinking, first hand-experiences with the environment and world orientation, especially with younger children. There are however important discontinuities too, for example, we had to acknowledge that

content, the *what* of teaching, really matters. Equally the kind of curriculum-framework that will be developed, if that will be a constraint or a support for teachers and children in their exploration of the world, is very important, especially if value the quality in stead of the quantity: 'less is more', as American say.

Continuity and Change: Towards a Creative Synthesis

In the Netherlands freedom in education - freedom for parents to choose a school for their children, freedom to start a school (under certain conditions) and freedom for schools to develop a specific profile - is part of a long tradition of living together with (mostly religious) minorities on a small piece of earth. Within a common framework of general guidelines (a kind of core curriculum) a great variety of schools developed. Among these were low-profile state schools and schools based on religion and/or a specific philosophy of education: Montessorischools, Daltonschools, Freinetschools, Steinerschools and (the biggest group among these) Jenaplanschools, all financed on the same basis by the state. All schools with a specific philosophy of education have their roots in the 1910's and 1920's, in the innovative movement of the New Education Fellowship (later World Education Fellowship) and the European part of it, that has been named the 'New European Movement for the Reconstruction of Education' (*'Neu-Europäische Erziehungsbewegung'*, Petersen, 1927). These movements had branches in many countries. Jenaplan schools orignated in Germany, Jena, where in 1923 Peter Petersen started an experimental school at the university. They were introduced to the Netherlands around 1960. Important features of these schools are: grouping children in age-heterogeneous 'family-groups' and the central place of 'world-orientation' (including 'science') in the curriculum (see about Jenaplan-education: Both, 1995a). Note that in 'world orientation' children are orienting themselves and schools help them in *their* orientation!

The Jenaplanschools did pioneering-work in the field of primary science in our country. They were influenced by curriculum-projects of the 1970's, such as Nuffield Junior Science and Science 5/13 from the UK, Elementary Science Study (ESS) from the USA and the African Primary Science Program.

In my opinion the Jenaplan movement in the Netherlands has shown that is is possible to look for a 'creative synthesis' between old and proven educational ideas, ideals and practices, and new developments in society, culture and educational research. There can be continuity on the basis of an open philosophy of education[1] and discontinuity and renewal (Both, 1996).

'We need to build our conception of the school upon a broad and deep foundation that will prove capable of bearing a superstructure of flexible patterns. We shall get nowhere by continually demolishing and starting afresh' (King, 1967).

Ask the Spiders Themselves

In autumn there are phenomena that you can hardly escape from if you are working with children from four to ten: the spiders and their webs that are to be found everywhere, coloured leaves, many fungi, fruits and seeds, the spicy smell of decaying organic material and soil, the days that become shorter and temperature that is falling. You can't escape them, because almost all children have some natural interest in these kind of things: observing; making some 'cloth' from gathering on a bent twig the loose-knitten webs of the young spiders, in the form of a tennis-racket; collecting fallen leaves, fruits and seeds and where possible eating them. Very little children (and adults), if any, see or hear something of bird-migration, despite the many times they have spoken and worked about it in school. Very few children (and adults) who have

1 The actual philosphy of education of the Dutch Jenaplanschools is expressed in twenty 'basic-principles'. See appendix 1. These are to be discussed and if needed revised every ten years.

collected acorns and beech-nuts and have heard about the development of fruits and seeds from flowers, have ever seen the oaks and beeches flowering.

With a group of children of eight to nine year old children I started a study on spiders, because of their interest and of the anxiety some of them expressed. I had seen many children active on this theme during playtime and asked them to express their feelings on spiders, what they already knew about them and what they wanted to ask about spiders. I showed them to formulate their questions in such a way that they were directed to the spiders themselves: 'spider, may I ask you ..... ?' This methodology I had learned from the African Primary Science Program: 'the asks the things themselves-principle' (Elstgeest, 1971; Duckworth, 1978). The children were trained to ask questions in this way and asked among others these questions:

- Why are there many more webs in autumn than in summer?
- How do you make your thread and how your web?
- What do you eat?
- Can you see well?
- How many eyes do you have? (this child had heard that a spider has many eyes)
- What kinds of spiders are there in our surroundings?
- Does a female-spider really eat the male after mating? (seen on TV);
- Are you a female or a male?
- What do you eat?
- What size of prey can you catch and eat?
- Are here 'black widows'? (a poisonous tropical species; the Netherlands does not have indigeneous spiders that are dangerous for humans)
- I do see your web, but don't see you, are you still there?
- Where do the threads of gossamer come from?
- Why is it that I am afraid of spiders and my friend is not?

Before the investigations began I asked the children to draw, individually, a spider that makes the wheel-webs in the schoolgarden (the diadem or garden spider) and almost all children drew a rather stereotype spider, with a simple cross on its back, shaped by two lines, I think because the name of this spider in Dutch is 'Cross-spider'. The drawings were displayed. After that children made plans for investigating spiders, in little groups, on the basis of the questions they had put. How could they be answered? Which questions can be answered by the spiders themselves and which by second-hand resources? Could questions be reformulated to get an answer from the spider herself? What do one need to answer them?
All children then had to make a new drawing of the garden spider, from observation, catching one and drawing it in the classroom or outside. This task led to discovering a surprising variety in the pattern of the spots the cross on the back is made of and to discussions about this variety, and about the parts of the spider's body and the number of legs. This led to better observation and to looking for new types of spiders and a nice exhibition of spider-drawings developed in the classroom
The observation of prey-rests in the webs led to the idea of simple food-chains, introduced by me: making little cards, connected like a chain, drawing and writing on it the two links observed and the hypothetical links before and after it. Many other observations and little experiments followed, such as: throwing little things into the web and seeing what would happen; blowing a white powder (flour) into the web to make it more visible, what had as an effect that the spider started to eat her own web and build a new one (discussing: why did she do that?); also interviewing children and adults about anxieties for spiders, etc. Equally important was also the patience children had to show in observing the spider at work or in trying to discover things

without disturbing it. I also introduced stories on spiders (about Arachne and Anansi), by telling and introducing reading materials, and we spoke about the anthropological background.
But how do you value this piece of practice as science education?
That depends of your view of the place of science in the primary school.

Why and What?
Why is science important for young children? The answer to this question depends on the kind of arguments for stimulating science in primary schools. David Hawkins once described three motivations for starting with science at an early age (Hawkins, 1984, p. 29-31):
(1) Creating a fertile ground for the development of future scientists, especially in relationship to economic competition, to 'refill the wells of available talent ... by earlier and wider and more effective science education'. I would call this 'education for science'. Hawkins calls this 'the narrow view';
(2) A wider view, concerned with preparing youngsters for eventual participation in the democratic discussion in a society heavy influenced by science and technology. Here it is important to prevent the development of a cultural proletariat. I would label this 'education in science'.
(3) A still wider view: the contribution of science education to the improvement of all education: education through science. Of course, this also has to make contributions to 'enlarging the pools of potential scientific talent and enhance the qualities of intelligent citizenship', but these goals then have their place in a concern for the education of children as persons.
Lilian Weber, dedicated early childhood-educator in the USA, expressed this in a nice way: 'what I had to come to from my own experience with children -- the enormous significance for children of the real world, emotionally and in making sense of what impacts on them and what changes around them -- could only reinforce my already-firm conviction that it is absurd to discuss **wether** there should or should not be primary science in the curriculum. As long as the child inquires there is no way to **eliminate** primary science ...... the child of course continues his making-sense of the world anyway, necessarily and inevitably."
(Weber, 1991)

Science is a human activity, a way of searching for meaning, searching for newness and for patterns in the natural world, for its own sake and for solving practical problems.
Putting it bluntly, science for young children must, in my opinion, concentrate on:
- Learning (better) to see and to hear and to smell and to taste; in the spider example the improvement of observation by drawing and comparing and discussion; other examples: hearing the voices within the choir of birds in spring or of the geese flying over in winter, seeing the colours in soap-bubbles, etc. Of course I know that observation does not exist without some theoretical framework, but nevertheless it is the beginning and the end of science with children.
- Learning to ask questions and devise simple ways to answer them.
- Infering, connecting bits and pieces of knowledge and formulating hypotheses, as contributions to concept formation and learning to think.
- Communication about observations and interpretations.
- Reflection (dialogue).
- Reporting: the reports of childrens' investigations can become a part of the reference library of the school, as a part of an ongoing movement, building on each other.
- Discovering that common things are fascinating if you are concentrating on them, dive into the material and act on them in new ways.
- Feeding curiosity and the sense of wonder about nature.

- Exploring diversity in phenomena, some simple relationships and change.
- Developing of independece in learning and contributing to a feeling of fate control, as far as possible (Rowe, 1983);
- Contributing to language-development and the learning of mathematics (Weber/Dyasi, 1985).
- Developing an attitude of alertness.
- Development a sense of objectivity or intersubjectivity: 'how do you know?'
- Development a concern with people, animals, plants, things, places; of respect and reverence for life; there are important links to environmental education and the arts (Margadant-van Arcken, 1990).

These are all basic educational aims for the primary years, to which science can make an important contribution.[2]

Between Question and Answer

I am well aware of the expression 'the children as scientists' and the discussion around it (Both, 1985a; Driver, 1983). Much depends here upon the definition of 'scientist'. If you are emphasizing science as a means in the education of children and as a human activity, you can see some analogy between children growing into the world and what scientists are doing (cf. Lilian Weber, 1991). In particular, in the primary years an emphasis on process skills is important and legitimate (Harlen, 1992; Hodson, 1985).

In general you cannot grow up with science without having some idea of the processes of doing science. We must have moderate expectations (Millar/Driver, 1987), but most important here is the question: I know the answer, but what's the question? (Goldberg, 1979). All knowledge is the result of people seeking answers to questions, wether on science, technology, the humanities, religion or another area of knowledge. Questions also play an important role in the development of children: explicit questions and questions implicit in the actions of children, their play and work. You can describe the interaction of children and the world around as a dialogue, an interplay of question and answer. The things around them are asking questions, inviting the child to see, to hear, to manipulate or sitting there and waiting for what will happen. The child is questioning the things around him or her by seeing and hearing and manipulating, etc. and science with young children develops between the questions and answers. Science can help the children in specific ways to find answers to their questions, especially if there is a community of inquiry: the children in the classroom and the teacher, a community in which they can feel safe enough to reach some objectivity as a standard, being challenged by feedback from others, with the question: 'how do you know'?

Researchers of early childhood development (Hodgkin, 1976), including ethologists as Niko Tinbergen (Tinbergen, 1975) have written about the curiosity in the environment children show at a very early age and they warn us not to underestimate the potential of young children. At the same time there is much 'learned helplesness', where, for example, children do not get adequate reactions to their questions. We can have a thorough belief in the powers of young children to build upon the information they receive.

Learning to See and Hear

I do not believe in an isolated training in seeing and hearing, there must be a meaningful context. In the past, educators like Herbart and Pestalozzi, and later a curriculum-project like 'Science, a Process Approach', were looking for teaching methods that were independent from the content

2 Some books on play in the primary years reflect the same philosophy of education, especially if exploratory play is connected with reflection: Moyles, 1989; Wassermann, 1990.

and finding and training in general learning skills. Training the sensory skills of children was an important part of it. Children must, however, understand as much as possible why they have to see and hear better, and also why they have to measure or classify or experiment. Research in the Netherlands revealed that in schools children often do so-called ‘experiments’ without knowing what they were doing, and without any context (Margadant-van Arcken/van Kempen, 1990). Training sessions with young children to improve seeing and hearing can be important (if needed), and often can be playful, but as much as possible these should be connected with a meaningful context. In one school, for exemple,. the children each year are doing excersises in handling binoculars and discriminating birdsong (from audiotapes or a CD) as a preparation for the annual bird census, mapping of territories of singing birds in a nearby park. You can't separate process from content in a rigid way.

Trust in your Senses

Children must first learn to trust and refine their senses but later on they learn that our senses can betray us and have their restrictions. Alas science education can also cause a premature and unnecessary mistrust in our own sensory perceptions. Fortunately I never found this in young children (there was not enough time to spoil them, I guess), but in older children in primary schools and in teachers I found it more than once. As a warning I will give it some attention, because teachers can do much harm in this area (Wagenschein, 1977).

Once I gave a workshop for teachers on questioning and investigation (inspired by Harlen and Elstgeest, 1992). The topic was 'water'. The participants had to fill a medicine beaker to the brim and to estimate how many drops they could add to it by a medicine dropper, writing down their estimation. Many discovered that they had underestimated the amount of drops that could be added by a ratio of 6-10. This activity caused a lot of arousement and wonder. Later on they had to write down perceptions (what had been seen) and questions that had been discovered. In the collection of the perceptions what they had seeb and the questions that had arisen. In the collection of perceptions and questions two teachers declared that they had seen 'cohesion'. I asked them what exactly they had seen, and it was very difficult for them to describe. Other teachers tried to express there experience of the mysterious forces inside the water that are pulling the water together in images like a 'skin' over the the surface of the water.

Elstgeest (1975), gives this example:

"I asked a student of mine (student-teacher), holding a round flask filled with water at arm's length, to look through it at the building on the other side of the road and to tell me precisely what he saw.

'It is an image', he answered'.

'No, tell me what you see'.

'It is refraction'.

'No, tell me what you actually see'.

'It is the angle of incidence', he persisted.

'No, I want to know what you see', I insisted.

'It is convex'.

'Oh come on, what does that house look like?'

'I see lateral inversion'.

I gave up."

An Heuristic Scheme

An heuristic scheme can help us in the planning of activities. This scheme has been used by Hawkins (1974) and others:

1. *Organizing an encounter of the children with the phenomena*
for example by:

- An observation-circle: a teaching method or 'form of encounter' in which the children all are observing the same (kind of) thing - an instrument, an animal, a leaf, etc.- and trying to communicate in a dialogue what they are perceiving. The other children try to see, etc. the same kind of thing; often questions are raised and little experiments can grow out of this intensive activity. The teacher should prepare this lesson, but at the same time cannot fully foresee what the children will discover[3].
- A ‘discovery-table’ in the classroom.
- Free exploration of the materials in groups ('messing about', Hawkins, 1974).
- Different forms of fieldwork.
- Children talking about their experiences and questions or showing something they have found (Paull and Paull, 1973).

2. Children asking questions about the phenomena, teachers, collecting these questions.
3. Discussing which questions can be answered immediate and which have to be researched. How can questions be formulated in a way that will get the information from the phenomena at hand? What questions deserve using second-hand resources?
4. Planning investigations by and with the children about selected questions.
5. Investigations undertaken by the children themselves.
6. Reporting to other children. Discussion, criticism
7. Lesson by the teacher to place the discoveries in a broader framework.

It is possible for teachers to ‘grow’ into this scheme during the primary years and teach the children to become more and more independent learners. The scheme can also serve as an important heuristic in the in-service education of teachers. It can be dealt with phase by phase first, in a workshop with connected theory and then trying it out in the classroom, sharing the experiences and training in some skills.
Learning to ask questions and searching for answers can also be excersised by working with sealed boxes ('mystery-boxes'), with something in them. The children have to find ways of trying to find out what is inside by manipulating, use of models, etc.

Questions: Going Back and Forth
Questions do have a key position in the heuristic method above. Often the questions of children must be reformulated in ‘action questions’ and teachers are trained to do this with children.
Wynne Harlen and Jos Elstgeest (Elstgeest, 1985; Elstgeest and Harlen, 1990) developed a simple scheme of questions, each connected with ways of answering them):

- ‘What’questions: What is it? What does it do? Have you seen (heard, etc.) that? etc.
- ‘How much?’questions
- ‘How different?’questions
- ‘What happens if?’questions
- ‘How could you?’questions
- ‘How?’questions: How does it come about? How does it work? How are .... related?
- ‘Why?’questions.

3 This way of working was first developed by the Belgian educator Ovide Décroly and was later rather popular in the Jenaplanschools in the Netherlands (Vreugdenhil, 1995).

It's an art for teachers to go back and forth in this scheme of questions. If, for example, children ask why the colours in soap-films are there (a very difficult question for children and many adults!), they can go back to questions like: what colours do you see? Are they always the same? Can you draw them? Do they change with time? Is it possible to make soap-bubbles without these colours? etc. Comparisons in time, space and conditions can lay a basis for the 'difficult answer', if it can be given. Teachers often stress 'why'-questions and children also want to know why, but if you can't find an exact answer, you can still discuss the question and discover interesting things.

The Book with the Empty Space

Years ago I bought a book on education; at home I skimmed through it and discovered a page without any text or illustration. I guessed it had to be a printing fault and called the bookshop. When someone at the other side of the line was comparing other copies of this book I read the page before the empty page and saw:

> 'Suppose all the syllabi and curricula and texbooks in the schools disappeared. Suppose all of the standardized tests ... were lost. in other words, suppose that the most common material imeding innovation in the school simply did not exist. Then suppose that you decided to turn this 'catastrophe' into an opportunity to increase the relevance of the schools. What would you do?
>
> We have a possibillity for you to consider: suppose that you decide to have the entire 'curriculum' consists of questions. These questions would have to be worth seeking answers to not only from your point of view but, more importantly, from the point of view of the students. In order to get still closer to reality, add the requirement that the questions must help the students to develop and internalize concepts that will help them to survive in the rapidly changing world of the present and future... What questions would you have on your list? Take a pencil and list your questions on the next page, which we have left blank for you'

(Postman/Weingartner, 1972).

I apologized to the bookseller and started thinking about this question about questions. If you take the children seriously as investigators, searching for meaning, you are touching a powerful source of motivation in children.

In the approach I described above, the questions of the children are taken seriously, and at the same time the children are not left alone with their questions, but empowered in seeking answers[4].

A Framework for World Orientation

Schemes questions, and going back and forth within schemes of questions, are important for teachers and staffs to give continuity to the work of children. The problem is that teachers experience a conflict between recognizing the importance for in-depth-work with the children and time-pressure. Teachers feel that 'less is more', that you have to restrict yourself in content, and for that reason they also are looking for overlaps in goals and content of primary science with less or more related areas. To help the schools in this work the Dutch Jenaplan-Association asked the National Institute for Currciculum Development to develop with and for the Jenaplanschools a new curriculum for world orientation, in which all aspects have their balanced place Both, 1995b). In addition, it had to meet the guidelines of the national curriculum.

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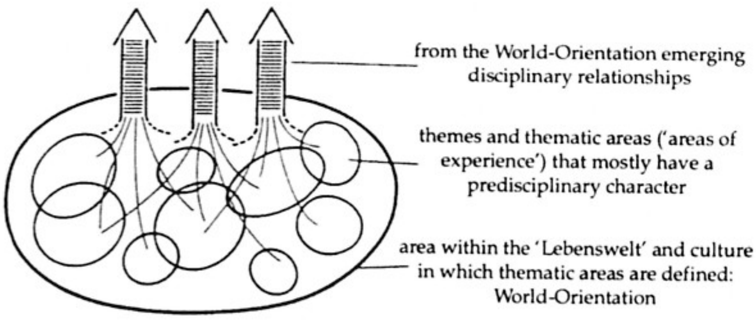
4 See the chapter on 'Encouraging and handling children's questions', in Harlen/Elstgeest (1992) for a discussion of this interplay between children questioning and teachers helping children to find instruments for finding answers to them. An important source on teaching and questioning is too: Dillon, 1988.

Seven areas of experience have been defines, that fulfil several criteria, among them:
- not separating nature and human society, but connecting them where possible;
- the possibillity of connecting predisciplinary goals, content and activities with the subjects later on; the latter have their roots within the 'areas of experience', as is visualized in figure 7.1.

In figure 7.2 below an overview is given of the areas of experience, with domains within each of them.



Source: adapted from: Köhnlein, 1985
Figure 7.1 World Orientation

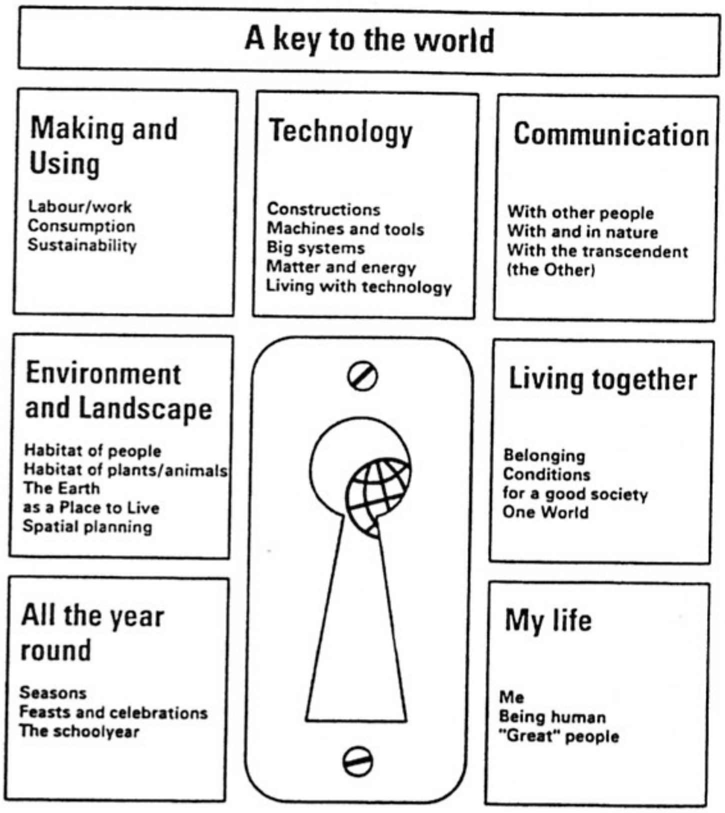


Figure 7.2 Goals and content in World Orientation Science

For each domain aims and learning-experiences have been described for the youngest, the middle and the oldest children of the primary range (in age-heterogeneous groups or 'family-groups') that give (an open) structure to the world orientation in the Jenaplanschools and that enables the schools to make world orientation ever more the heart of their curriculum I give some exeamples of the science goals and content in ‘Environment and Lanscape’.

ENVIRONMENT AND LANDSCAPE
The basis for this area of experience is the metaphor of the earth as a *home (oikos*), an ecological viewpoint. Important key concepts are: life, diversity, adaptation, behaviour (intra- and interspecific), 'worlds' of a certain organism (auto-ecologically seen), ecotope (or 'houses', e.g. a tree, a pond, a plot of grassland, etc., all with different inhabitants that relate to each other and to non-living things and factors; a synecological viewpoint), the food-chain, the progressive cycle of substances and decomposition and the biosphere (the earth as a home in space).
Important skills are: observation, drawing, describing of organisms, classifying plants and animals (to self-chosen and given criteria), using and making simple identification-keys, mapping and carrying out simple experiments about environmental conditions.
Important activities include:

- *For the youngest groups (4-6 year old*): caring for plants and knowing what they need, growing plants from seeds, study of one kind of 'minibeast' in its natural environment and also in some artificial environment within the classroom, visiting the same habitat regularly and looking for plants and animals and their behaviour; looking at the Sun and following it during the day and seeing where the Sun can throw more and less its light.
- *For the middle-groups (6-8/9 year old):* mapping a not too complicated small area and its inhabitants; collecting, observing, describing and classifying invertibrate animals; identifying plants and animals by using simple keys and reference-books; soil-studies, observing an (species of) animal in its natural environment and trying to learn as much about it as we can, adopting a piece of land and doing conservation work and monitoring the situation from year to year, detailed studies of the sun during the day ('daytime astronomy').
- *For the oldest primary groups (9-12 year old*): designing a simple identification key, mapping/visualizing a structural more complicated small area and its inhabitants and possible relationships with non-living components, studying the ‘world’ of one species of plant or animal (including the dispersion), aiming at the idea of adaptation; comparing some close related habitats (e.g. types of grassland) and their inhabitants; observing the colours, forms and behaviour of some animals and plants in the environment and trying to find some form-function-relationships; comparing this results with species far away; experiencing dimensions in space, by studying earth in space also by way of the materials of 'Powers of ten' (Morrison, 1982).

In the same way the science-content of 'Making and using', can be described, with a lot of physics ('kitchen physics') and chemistry (chemical changes in production processes) and the same for 'Technology' and the other areas of experience'.

Some Concluding Remarks
Nowadays some insights of tewnty-five years ago have now been reinforced in a new way, especially by developments in the cognitive sciences, such as metacognition, while. Others have been refuted. As a result of working in an open educational tradition, it is possible to find a creative synthesis of the old and the new, without having to make a complete new start and again and thereby destroying the old before making progress.

I think that in the broad view of science-education that I have tried to sketch, it is more important to develop in young children sensibility and sensitivity to the world, alertness and well- rooted knowledge, than 'covering' a broad spectrum. Consider the citation about Barbara McClintock at the beginning of this chapter: taking the time to look... to hear what the material has to say to you, the openness to let it come to you (Fox Keller, 1983). At this level there are still close connections between science and art. The ancient Greeks had a nice concept for the sensual experience that can be the common root of science and arts: *aisthesis* (Giel, 1994). It is the sensuous quality of the experience of both that makes sense. Later on in education there is more distance between arts and science, but also there we can look for connections and interactions. In ecology there are the writings of Annie Dillard, especially *Pilgrim at Tinker Creek* (1975) and in Aldo Leopold (1989) as important examples of such an *aisthesis.* It is possible to work with children in the same spirit. In areas such as pattern, size and scale in nature there is the example of 'D Arcy Thompson (*On growth and Form*. 1988) as a lasting source of inspiration (see here also Stevens, 1976; Wechsler, 1981 and the volumes in the *Science 5/13*-series about 'Structure and forces', James, 1972). In Germany, the 'grand old man' of science education, Martin Wagenschein, developed an approach to science education by (Socratic) dialogues with children. They were connected with hands-on activities, demonstrations (including 'discrepant events'), telling stories and diving into selected and potential fruitful examples (*'exemplarisches lehren und lernen'*; Wagenschein, 1965; 1977 1990 and 1992), as a contribution to teaching for quality, that is 'less is more'[5], in which there are connections between sensory, bodily, esthetical experiences and the emergence of objective, 'scientific' ways of thinking (Rumpf, 1990 and1993). Questions like 'How did people discover to make fire?' How can a ship, made of iron, float?' 'What is a good ball to play with?' are the starting-points for an intensive process of searching for answers (Thiel, 1987). In the question after 'the good ball' the teacher starts with a demonstration of dropping two balls and have the children watch and think. After that many activities develop: intense discussions about what happens if a ball bounces, discussions and experiments in small groups (formulating and testing hypotheses), reporting in a circle-discussion, proposals by the teacher for a more precise experiment, all ending with the story about the veterinary surgeon (Dunlop) who invented less or more by accident, but by analogy with the air-filled football and the the pneumatic tyre[6]

In all of this this the key word is: wonder, developing a sense of wonder (Weisskopf, 1979; Verhoeven, 1972).

Rachel Carson writes in her pedagogical book *The Sense of Wonder* (and I hope you can feel the wisdom behind her perhaps somewhat romanticized view of childhood):

> 'A child's world is fresh and new and beautiful, full of wonder and excitement. It is our misfortune that for most of us that clear-eyed vision, that true instinct for what is beautiful and awe-inspiring, is dimmed and even lost before we reach adulthood. If I had influence with the good fairy who is supposed to preside over the christening of all children, I should ask that her gift to each child in the wordld would be a sens of wonder so undestructible, that it would last trhoughout life, as an unfailing antodote against the boredom and disenchantment of later years, the sterile preoccupation with things that are artificial, the alienation from the sources of

5 The approach of Wagenschein and the people that are working in his spirit is to be characterized as: genetic-socratic-examplarery; 'genetic' because of the 'genesis' ('emergence') of the understanding of children and of the use, where possible, of historical examples. There are often some parallels (note: I am not speaking about some way of 'recapitulation-theory'!) between the development of scientific ideas in children and the history of science: e.g. children are sometimes thinking in 'aristotelean' ways.

6 I hope the Wagenschein-tradition can be discussed and tried in the English-speaking world too.

our strength.'

I think science with young children has the potential to make an important contribution to cultivating this sense of wonder.

References

- Both, K. (1985), *De natuur van natuuronderwijs en natuuronderwijs in de basisschool* (The nature of science and science in the primary school), Enschede: SLO, Institute for Curriculum Development
- Both, K. (ed.)(1995a), *Jenaplanschools in The Netherlands: a reader*, Hoevelaken: CPS
- Both, K. (1995b), *Weltorientierung Jenaplan: Einige Texte (World Orientation and Jenaplan),* Amersfoort: CPS
- Carson, R. (1987), *The Sense of Wonder*, New York: Harper and Row
- D' Arcy Thompson (1988), *On Growth and Form*, Abridged Edition, Cambridge: Cambridge University Press
- Dillard, A. (1975), *Pilgrim at Tinker Creek*, London: Picador
- Dillon, J.T. (1988), *Questioning and Teaching, A Manual of Practice*, London/Sydney: Croom Helm
- Driver, R. (1983), *The Pupil as Scientist?,* Milton Keynes: Open University Press
- Duckworth, E. (1978), *The African Primary Science Program: An Evaluation and Extented Thoughts*, Grand Forks (ND): University of North Dakota
- Elstgeest, J. (1971), Ask the Ant Lion: The Growth of an African Primary Science Unit, in: Richmond, P.E. (ed.)(1971), *New trends in Integrated Science Teaching*, Vol. 1, Paris: Unesco
- Elstgeest, J. (1975), New Science and Old Cultures, paper presented to the International Conference on Physics Education, University of Edinburgh, 29th July - 6th August, 1975 -Elstgeest, J. (1985), The Right Answer at the Right Time, in: Harlen, W. (ed*.), Primary Science: Taking the Plunge*, London: Heinemann
- Elstgeest,J./W. Harlen (1990), *Environmental Science in the Primary School*, London: Paul Chapman
- Fox Keller, E. (1983), *A Feeling for the Organism: The Life and Work of Barbara McClintock*, New York: Freeman
- Giel, K. (1994), Versuch über den schulpädagogischen Ort des Sachunterrichts, in: Lauterbach, R., a.o. (eds.)(1994), *Curriculum Sachunterricht*, Kiel: Institut für die Pädagogik der Naturwissenschaften/Gesellschaft für Didaktik des Sachunterrichts.
- Goldberg, L. (1979), I know the answer, but what's the question? in: *Science and Children*, Vol. 16, no. 5, p. 8-9
- Harlen, W. (1992), Research and the development of science in the primary school, in: *International Journal of Science Education*, Vol. 14, No. 5, 491-503
- Harlen, W./J. Elstgeest (1992), *UNESCO sourcebook for science in the primary school: A workshop approach to teacher education*, Paris: UNESCO
- Hawkins, D. (1974), Messing about in science, in: Hawkins, D. (1974), *The Informed Vision: Essays on Learning and Human Nature*, New York: Agathon
- Hawkins, D. (1983), Nature Closely Observed, in: *Daedalus,* Vol. 112, Number 2
- Hodgkin, R. (1976), *Born Curious*, London: John Wiley and Sons
- Hodson, D. (1985), Philosophy of science, science and science education, in: *Studies in Science Education,* Vol. 12, 25-57
- James, A. (1972), Science 5/13: *Structures and forces, Stages 1 and 2*, London: Macdonald Educational
- King, R. (1967), The Bridge of Jena, in: *The New Era*, Vol. 48, no. 3, March 1967, p. 38-43
- Köhnlein, W. (1985),Kindliches Denken und physikbezogener Sachunterricht, in: *Sachunterricht und Mathematik in der Primarstufe*, Vol. 13, No. 2, p. 73-78
- Leopold, A. (1989), *A Sand County Almanac and sketches here and there*, New York/London: Oxford University Press

- Margadant-van Arcken, M./M. van Kempen (1990), *Groen Verschiet, natuurbeleving en natuuronderwijs bij acht- tot twaalfjarige kinderen ('Green vista'),* The Hague: SDU
- Margadant-van Arcken, M. (1990), Nature Experience of 8-12-Year-Old Children, in: *Phenomenology and Pedagogy*, Vol. 8, p. 86-94
- Millar, R/R. Driver (1987), Beyond Processes, in: *School Science Review*, Vol. 14.
- Morrison, Ph. and Ph./C. and R. Eames (1982), *Powers of Ten: Dimensions in the Universe*, New York/Oxford: Freeman
- Moyles, J. (1989), *Just Playing? The Role and Status of Play in Early Childhood Education*, Milton Keynes/Philadelphia: Open University Press
- Paull, J. and D. (1973), *Yesterday I found* ....., Boulder: Mountainview Center of Environmental Education
- Petersen, P. (1927), *Die Neu-europäische Erziehungsbewegung*, Weimar: Böhlaus Nachfolger
- Rowe, M.B. (1983), Science and Fate Control: implications for the teaching of primary level science, in: Harlen, W. (ed.), *New trends in primary school science education*, Vol.1, Paris: UNESCO
- Rumpf, H. (1993), Erlebnis und Begriff, Verschiedene Weltzugänge im Umkreis von Piaget, Freud und Wagenschein, in: *Zeitschrift für Pädagogik*, Vol. 37, No. 3, p. 329-346
- Rumpf, H. (1990), Von der Stoffbeherrschung zur Weltaufmerksamkeit (From knowing content to alertness for the world), in: Mikelskis, H. (hrsg.)(1990), *Umweltbildung in Schleswig-Holstein,* Flensburg
- Stevens, P. (1976), *Patterns in Nature*, Harmondsworth: Penguin Books
- Thiel, S. (1987), Wie springt ein Ball? ('How does a ball bounce?'), in: *Die Grundschule*, Vol. 19, Nr. 1, p. 18-21
- Tinbergen, N. (1975), The Importance of Being Playful, in: *The Times Educational Supplement*, 10.1.75
- Verhoeven, C. (1972), *The Philosophy of Wonder*, New York: Macmillan
- Vreugdenhil, K. (1995), De observatiekring ('The observation-circle'), in: Boes, A. (1995), *Gesprekken in de kring ('Dialogue and circle-discussions'),* Hoevelaken: CPS
- Wagenschein, M. (1965), *Ursprüngliches Verstehen und exaktes Denken* ('Original Understanding and Exact Thinking'), Stuttgart: Klett, Band I.
- Wagenschein, M. (1977), Rettet die Phänomene! ('Save the Phenomena') in: Der Mathematische und Naturwissenschaftliche Unterricht, Vol. 30, Nr. 3.
- Wagenschein, M., a.o. (1990), *Kinder auf dem Wege zu Physik* ('Children on the road to physics'), Weinheim/Basel: Beltz
- Wagenschein, M. (1992), *Verstehen lehren* ('Teaching for Understanding'), Weinheim/Basel: Beltz

  Wassermann, S. (1990), *Serious Players in the Primary Classroom. Empowering Children Through Active Learning Experiences*, New York/London: Teachers College Press
- Weber, L./H. Dyasi (1985), Language Development and Observation of the Local Environment: first steps in providing primary-school science education for non-dominant groups, in: *Prospect,* Vol. XV, No. 4, p. 565-567.
- Weber, L. (1991), *Inquiry, Noticing, Joining With and Following After*, New York: Workshop Center City College
- Wechsler, J. (ed.)(1981), *On Aesthetics in Science*, Cambridge (MA): MIT Press
- Weil. S. (1987), *The Need for Roots. Prelude to a Declaration of Duties Towards Mankind*, London: Routledge and Kegan Paul
- Weisskopf, V.F (1979), *Science and Wonder, the natural world as man knows it,* Cambridge (MA): MIT Press

- Whitehead, A. N. (1957), *The Aims of Education*, London/New York: The Free Press