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An Argument for Reversing the Bases of Science Education - A Phenomenological Alternative to Cognitivism

Abstract

This paper is a phenomenological critique of some of the basic notions informing much of the research in and practice of science education (SE) today. It is suggested that the philosophical grounds of SE are in need of three “reversals of primacy”: the ontological primacy of the perceptual lifeworld must replace that of abstract scientific models; the epistemological primacy of attentive practice must replace that of conceptual cognition; and the pedagogical primacy of cultivating competencies must replace that of imparting ready-made knowledge. Four arguments for a phenomenological approach to SE are presented and some consequences for the training of science teachers are discussed; some of which are already being implemented at the science teacher education of the Norwegian University of Life Sciences.

INTRODUCTION

The current difficulties in science teaching have two major aspects: the inability of many or most students to achieve correct understandings of scientific concepts (Anderson & Helms, 2001), and many or most students' lack of interest in science subjects (Hannover & Kessel, 2004; Osborne, Driver & Simon, 1998; Svensson, 1996). The study by Hannover and Kessel (2004) shows that most students cannot match their own self-image with becoming a scientist or even with being good at science. A Swedish study by Svensson (1996) found that there is a large reserve of potentially able students for science and technology among working class girls. Many girls show the aptitude and ability but still do not choose science and technology subjects in their upper secondary education. Referring to studies showing the decrease of interest in physics and chemistry among secondary level students, Osborne et al. ask

...whether we teach too much science of the wrong kind for too long. [...] Before we ask more young people to dine at the restaurant of science should we not ask ourselves whether the menu we offer is both appropriate nourishment and appealing? (1998, p. 33)

Osborne et al. suggest that appropriate content for science education (SE) must be both *in* science and *about* science. Today the first dominates too much. Furthermore, students often regard science as too theoretical and too abstract. It is not experienced as integrated in children's and young peoples' lives (for an interesting example from higher education, see Beach, 1999). Can the roots of this alienated attitude be found in the philosophical understanding of SE as well as of science itself, prevalent among science teachers (and perhaps also among scientists)?

We propose that the answer to this question is yes. The purpose of this paper is to argue for a renewal of the philosophical understanding of SE, primarily. However, by implication, our arguments have some bearing also on the understanding of science as such. We do this by introducing a phenomenological perspective on science and showing its practical implications for SE. We try to show how this perspective in itself promotes a fruitful interchange between the theory and the practice of science teaching. What we mean by phenomenology will hopefully become clearer as we move along. However, a working definition may be that it is a basic philosophy of knowledge (epistemology) and being (ontology) in which 1) all possible human experience is considered equally significant for our understanding of the world; and 2) the subject – object relation is of an internal nature, i.e., subject and object must be seen as belonging together, as two aspects of one (non-dualistic) whole.

Our argument is based on three more or less radical “reversals of primacy”. We call them the ontological reversal, the epistemological reversal, and the pedagogical reversal (the first probably being the most radical, the last the least). The ontological reversal entails that the ontological primacy of the perceptual lifeworld must replace that of abstract scientific models. That is, scientific models must be recognised as reductive abstractions not explaining *everything* about a phenomenon, but only those aspects of it which we, for contingent historical reasons, have chosen to consider essential for our understanding of reality. Nor do they represent something *more real* than our human lifeworld. However, this does not in the least diminish their value or importance; it only puts them within a wider horizon of experience and understanding. Second, the epistemological reversal entails that the primacy of what we refer to as attentive practice must replace that of conceptual cognition. Sensing and perceiving in various forms of action related to studied phenomena must precede the formation of concepts and models about them. Finally, the pedagogical reversal means that the primacy of cultivating competencies must replace that of imparting ready-made knowledge. Knowledge as such is of little value if one is not able to put it into some kind of action; intellectual or manual.

We argue that the one-sided emphasis on abstract models and purely conceptual cognition are basic elements of a common educational stance (in practice as well as in research) which we call “cognitionism”. However, before we go into a theoretical critique of this stance in SE, we will recount the experience of a science teacher student who was exposed to the kind of science teacher education we have developed out of a phenomenological perspective:

Faced with a group of agricultural high school students and a three week block of mechanics, it struck me that this class just had finished a block of practical forestry, where huge masses and forces are at work and heavy bodies (trees) are falling [...] I met them Monday morning in the classroom. They seemed curious and attentive about their new teacher, and I asked them what they connected with the subject of Physics. The answer was some mumbling about forces, formulas and Newton. “*This*”, I said to the students, “is physics” – and I threw my coffee-

cup into the wall, smashing it into pieces. “What happened right now? Can you describe it?” Then we tried to describe it as precisely as possible. I told them that physics is about seeing the world through the glasses of the physicist and ask such questions. Then we went out again in the forest, with the glasses of a physicist, finding the forces at work when a tree, by different means – axe and gravity alone, chainsaw and levers or tearing it down with ropes and pulleys – is forced to falling. Taking these experiences from the forest as a point of departure, we were able to introduce the concepts of mass centre, momentum and purchase in a manner where everyone could relate their experienced meaning to the central concepts. This inductive approach to physics gave the subject a clear relevance for all the students. They participated attentively and engaged actively in the rest of the block. (Nordal, 2005a, p. 2)

In a later text, the same teacher student (Nordal, 2005b) also documents how, on the basis of the same process of action and activity, the students were able to transform the images and dynamics of their experiences to a corresponding dynamics of cognitive ability, i.e., to handle mathematical problem solving in mechanics.

THE ONTOLOGICAL REVERSAL AND LIFEWORLD ONTOLOGY

In his phenomenological critique of the historical development of Western science, Husserl (1970a) describes how scientific theories have lost their epistemological roots in the lived experience of our common human life world. According to Husserl, a *mathematisation of nature* took place in the natural sciences. It started with a “geometrisation” and was followed by an “algebraisation” of natural phenomena (Harvey, 1989). Thereby science moved two steps away from that foundation of meaning (*Sinnesfundament*), which is given to us in the immediate sense-perceptual experience of the world. (The German word *Sinn* can be translated as both “meaning” and “sense”, which gives Husserl’s *Sinnesfundament* and interesting twofold connotation.) Such mathematical transformations proved however (as we know) to be very successful. As a consequence, researchers became more and more interested in and occupied with them. Husserl calls this the “technisation” (*Technisierung*) of science. It constitutes a third step in the movement away from lifeworld experience. The progressive technisation involved a gradual “sedimentation of meaning”: the grounds of the original transformations in concrete, lived experience were *forgotten* and the level of what he calls “sedimented self-evidences” grew:

...this problem of forgetfulness is exacerbated by the fact that with each new generation’s inheritance of the new techniques – an inheritance that presupposes the process of transformation without explicitly recognizing them – another increment in the *Selbstverständlichkeit* [matter of course] of natural scientific achievement occurs as well. (Husserl, 1970a, p. 59)

The sedimentation of meaning makes the “higher objects” of science, such as mathematical formulas, take on a life of their own. They become cut off from the fluctuating experiences of everyday life and start to float above it. At the same time they are supposed to *explain* our everyday experiences. Being taken as explanations they are also ascribed an ontological status of truth and objectivity. According to Husserl the consequence is that abstract mathematical models are seen as more real than the concrete, lived experience in which they have their ultimate ground, and from which they have been abstracted. This is what Harvey (1989) calls *the ontological reversal*. It means that what actually is secondary, ontologically speaking, becomes primary. However, since scientific theories and models are often incorporated or re-assimilated into our everyday lifeworld, this reversal becomes more and more a part also of the “natural attitude”, i.e. of peoples’ general, unreflected and everyday notion of reality. In particular, it seems to be a prevalent, albeit unreflected, “figure of thought” among science teachers (Dahlin, 2003). As one of the science teacher students in Dahlin’s (2003) study expressed it: “If there is nothing behind phenomena, then there is nothing to investigate” (cf. *ibid.*, p. 84). Considering the context in which this was said, the most

probable interpretation is that if we do not assume that there is a real world “behind” our everyday sense experience, science has no purpose. The purpose of science is to reveal the reality which lies behind what we experience through our senses. Therefore, a scientific study of nature cannot pay too much attention to sense experience. It cannot stay or dwell upon the richness and variety of such experience. It must move on to what lies behind it, in the realm of mathematical algebraisations, i.e., the “real” world. As Galileo said, the language of nature is mathematics. Whatever other languages nature seems to speak to our senses – languages of colour, form, sound, smell and taste – exist only in subjective consciousness and is ultimately illusory (cf. Dahlin, 2001).

If this ontological reversal is a basic assumption among science teachers it has some serious educational consequences. It may even be one of the main reasons behind the flight from science witnessed today among young people. In many students it will produce a feeling of *alienation*, both to nature and to science. Why alienation to nature? Simply because of the claim, mostly implicit but sometimes perhaps explicit, that the nature we actually experience through our senses is not the *real* nature. And why alienation to science? Because science seems to substitute concrete lifeworld understanding by abstract models and mathematical formulas, and most people find such models strange and difficult. In order to place SE on firm feet, the ontological reversal described above has to be *reversed back*. It means giving *ontological* priority to the lifeworld of our common human experience, not to algebraic and other conceptual abstractions.

It may be argued that Husserl in the critique recounted above is not talking about all science but only about physics or, more specifically, mechanics. In mechanics the process of “geometrisation” can be clearly seen even in the basic levels of SE. Thus, Husserl’s argument may be relevant to basic mechanics teaching, but what about chemistry or biology? Especially in the latter, “geometrisation” hardly occurs at all. The basic levels of biology teaching consists mainly in classifying animals and plants and looking at their organ constitutions and physiological properties. However, “geometrisation” is only one step in the general process of “mathematisation”, and not a necessary one. Husserl may have thought primarily about physics or mechanics, but that is because physics was the first of the sciences to develop in a modern direction in the 17th century. Later on, “mathematisation”, i.e., the use mathematical models as representations of objective reality, became the ideal form of knowledge also in other scientific disciplines. On the upper secondary level of SE, mathematics is also used in chemistry. In biology it may not be so common, but here the more general process of *reductive abstraction* is all the more obvious, especially in that part of biology which merges with chemistry. In addition, there is a process of abstraction taking place in the transformation of biological research into school science; creating specific learning problems for students on the upper secondary level (Gericke, 2009).

It is actually the process of reductive abstraction that is the main target of our phenomenological critique of SE. In what we refer to as cognitionism reductive abstraction is a more general feature, of which “mathematisation” is a particular expression. But critique does not mean denial or rejection; it means the transformation of the traditional or “received” understanding of its object. Husserl did not want to abolish science or replace it with something else, but he wanted to change our understanding of its nature. Neither did he want to do away with conceptual abstractions; nothing can be understood or explained without concepts. Our argument is that the phenomenological understanding of the nature of science would make a positive contribution to SE in that the *nature* of scientific concepts or models, and the *process* of how we arrive at them, would be more focused on, displayed and illuminated.

The ontological re-reversal: the primacy of the lifeworld

Reductive abstractions in general and mathematical formulas in particular are typically purely cognitive and conceptual experiences. The ontological reversal puts such conceptual cognitions at the very centre of learning about nature. Hence, it promotes what Dewey (1997) calls intellectualism, or what we here choose to call cognitionism. Dewey identified and opposed intellectualism

as a major negative trend in Western philosophy. In intellectualism all *experience* is misunderstood as a form of *knowledge*. Thus, by intellectualism Dewey meant

...the theory that all experiencing is a mode of knowing, and that all subject-matter, all nature, is, in principle, to be reduced and transformed till it is defined in terms identical with the characteristics presented by refined objects of science as such. (Dewey, 1997, p. 21)

For Dewey, experience is always embodied and immediate, enjoyed or suffered, whereas knowledge is the mediated product of inquiry, such as the “refined objects of science”. But his critique of intellectualism is not intended as a denigration of science as such. It is the inherent reductionism that is his target. Intellectualism reduces the manifold forms of experience to a mere intellectual knowing, as well as the rich complexity of nature to what one single type of inquiry, namely science, can say about it.

Our notion of cognitionism draws heavily on what Dewey labelled intellectualism. By cognitionism we mean an educational stance in which conceptual cognition is taken as the necessary condition for all knowing and learning. It seems obvious that intellectualism and cognitionism on the one hand, and the ontological reversal on the other, are mutually supportive figures of thought. Their common denominator is the reduction of the richness, nuances and complexities of sense experience to “refined objects of science”, i.e., to theoretical concepts taken as referring to an underlying, non-perceptible “objective reality”. If this kind of thinking is part of science teachers’ “practical theories” of teaching (cf. Carlgren, Handal, & Vaage, 1994), the rich experience of natural phenomena that is a common part of children’s lifeworld is also reduced (Østergaard, 2006). That is, it tends to be neglected, devalued and forgotten in the teaching and learning about nature.

Another critique of intellectualism comes from the phenomenology of Merleau-Ponty (1992). Merleau-Ponty gave a new direction to the phenomenology of Husserl, continuing its dictum “to go back to the ‘things themselves’” (Husserl, 1970b, p. 168), i.e., things as experienced, but rejecting its inherent idealistic and transcendentalist tendencies, promoting instead a purely experiential and embodied point of view. Although Husserl is important in pointing out the ontological reversal described above, our phenomenological stance in this paper is basically that of Merleau-Ponty.

In Merleau-Ponty’s phenomenological analyses of perceiving and knowing, the conception of the relation between our conceptual systems and our sense experience is very different from that of cognitionism and the ontological reversal. His writings are extensive and complex, and we do not claim to expound the whole and true intent of his work. There is, however, one paragraph in one of his books (Merleau-Ponty, 1964), which we think captures the problem and suggests its solution in a particularly interesting way. It is when he defines the meaning of “the primacy of perception”, which is

...that the experience of perception is our presence at the moment when things, truths, values are constituted for us; that perception is a nascent *logos*; that it teaches us, outside all dogmatism, the true conditions of objectivity itself, that it summons us to the tasks of knowledge and action. (ibid., p. 25)

We note here that perception is “a nascent *logos*”. *Logos* is meaning, order, structure, and ultimately – knowledge. Perception is thus potential knowledge, or knowledge in the process of being born. It has not yet come into full consciousness. Thus, sense-perception is not yet fully developed knowledge, but it is nevertheless “pregnant” with meaning (a metaphor used by Merleau-Ponty himself). The kind of perception that Merleau-Ponty describes here could also be called *aesthetic*. Aesthetic perception is *holistic*, it is even *syn*-esthetic. It does not restrict itself to one sensory modality at a time. In aesthetic perception, we “see” what a thing sounds like if we strike it, or what it feels like if we touch it. These are examples of the inherent structures of this deeper level of awareness, which is perhaps better called *sensual* than perceptual. We sense before we perceive, and we perceive before we conceive.

When science teaching is based on cognitionism and the ontological reversal, it takes place on the grounds of what Martin (1974) calls “the spectating experience”. In this mode of experience aesthetic aspects of natural phenomena are lost, or relegated to the non-relevant background. Conceptual knowledge forms the framework within which the sensed and perceived thing is fitted. Martin contrasts this to the “participative” mode of experience, in which “ideas vivify the thing because *the thing initiates and controls every idea* [italics added]” (ibid., p. 93). The spectating experience rests upon the implicit assumption that our relation to things can only be of an external kind. We then use our ideas and concepts to bring order to the world *from without*. Order and meaning are imposed on phenomena by the thinking of human beings. According to this assumption the world in itself has no order and no meaning. This assumption is presumably at the bottom of a large portion of teaching and learning today, both in science and in other subjects. It makes for an aesthetically or sense-perceptually poor knowledge formation, because the qualities of sense experience are either disregarded, or only attended to as a passive material, to be structured and put in order by intellectual concepts.

An aesthetically rich mode of learning, on the other hand, is a learning that lets “the thing think” in us, as Martin (1974, p. 92) expresses it. “Only then will the depth dimension of our world come to presence explicitly in our experience” (ibid.). This kind of attentive learning, which Martin (1974) explains with reference to the phenomenology of Heidegger, has its roots in aesthetic perception. “The thing thinks” in the sense that *logos*, the meaning which thinking grasps in the thing, is not imposed from without, but born out of the sense-perceptual experience that the thing evokes in us, because this experience is itself “pregnant” with meaning. This mode of “thinking Being”, Martin claims, is not something extra, without educational or even philosophical significance; “it is the *ground* of all other modes, of all experiences” (ibid., p. 98). The problem is that this ground tends to be forgotten, neglected or suppressed. Therefore, it has to be re-awakened. This realisation leads us on to what we call the epistemological reversal.

THE EPISTEMOLOGICAL REVERSAL: THE PRIMACY OF ATTENTIVE PRACTICE

The re-reversal of the ontological reversal described by Husserl is the most basic of the three reversals we argue for in this paper. As far as we know, the ontological reversal and its consequences have not been extensively discussed in the literature on SE. The basic idea of what we call the epistemological reversal seems, however, to gain an increasing interest in the cognitive sciences (cf. Núñez & Freeman, 1999). One major source behind this development is Merleau-Ponty’s emphasis on consciousness as embodied and on the “lived body” as the ground of all experience. This has led to a greater emphasis on *action* as primary to cognition. In this interpretation, phenomenology provides a shift of focus from the cognitive understanding of the world to perceiving and acting *in* the world. For Merleau-Ponty, our primary relation to the world is a *doing*, not a knowing relationship. Our consciousness and our ability to think is based on our already being and acting in the world: “Consciousness is in the first place not a matter of ‘I think’ but of ‘I can’” (Merleau-Ponty, 1992, p. 137). Such a phenomenological study of coming to know something reveals that all perception and thinking encompass attentive practice (Hugo, 1995). All learning activities, ranging from mathematical to practical problem solving, are accompanied by such activity. Hence, having learnt to do or understand something entails having acquired the ability to attend to all the relevant aspects of the problem or the phenomenon dealt with.

Abercrombie’s (1960) study of medical students’ learning to perceive and judge in their professional field provides an interesting illustration of what we want to convey. Although Abercrombie does not base his study on phenomenology but on more conventional psychological theories of perception, his basic intent coincides with ours to a large extent. Abercrombie wanted his students to realise that they need continuous self-development in order to be able to assimilate all the information available within a particular field. There was a certain resistance to this message among the students. Nevertheless, the goal, according to Abercrombie,

...was to make it possible for the student to relinquish the security of thinking in well-defined, given channels and to find a new kind of stability based on the recognition and acceptance of ambiguity, uncertainty and open choice. (p. 141)

Being open to ambiguity and uncertainty is a basic aspect of attentive practice. It means being able to move one's perceptual attention in ways not predetermined by a fixed model or concept (but of course one has to be able to move one's attention according to a predefined and fixed pattern also). Not all students acquired this ability. Looking at X-ray plates, for instance, some of them came to premature conclusions about the diagnosis. As Abercrombie remarks, "a conclusion about 'meaning' had limited the perception of the observers, causing them to ignore information which did not fit the ordained pattern, the chosen schema" (p. 88). The students' attention was not able to move freely, but restricted itself according to the preset pattern of an abstract concept. (To ignore certain information as "not relevant" is the basic gesture of reductive abstraction.) Abercrombie's point of finding stability in spite of ambiguity is in complete agreement with Merleau-Ponty's phenomenological analysis of perception, revealing the basic ambiguity and the plurality of implicit meanings in our perceptual lifeworld experience. As Smith (2005) points out, indeterminacy, ambiguity and opacity are, according to Merleau-Ponty, the basic characteristics of our human being-in-the-world.

In the case of learning mechanics, for instance, the development of students' attentive practice is best done through the dynamics of experiential and bodily participation in physical activities and forces. This can be done in foresting and woodcutting, as in the story of Nordal (2005a & b). Describing the steps of attentive practice involved in the story, we see the students in the forest using their senses to experience the *real* interplay of the mechanical forces at work. The teacher's role in this phase is to direct the students' attention in order to focus on specific phenomena. Out of this activity the meaning of concepts like "mass centre" and "momentum" were actively constituted by the students themselves. In this way, the abstract concepts needed in order to understand Newtonian mechanics become loaded with personal and concrete perceptions as they grew out of an actively experienced situation. Our suggestion is that if students acquire abstract concepts in this way, they become less prone to the kind of limited perception and premature judgment described by Abercrombie above. This is because the concepts are not learnt by being *imposed* on experience, but by being *released* from the structures inherent in it (cf. Martin's (1974) distinction between the spectating and the participative mode of experience discussed above). We further suggest that such concepts, being rooted in lifeworld experience, can be more freely decontextualized and elaborated as specific elements in the understanding of general laws; subsequently transformed into the cognitive operational abilities of predictive mathematical calculations. We admit, however, that these suggestions have so far not been strictly verified empirically. We have previously noted the lack of empirical evaluations of phenomenological approaches to science teaching; see Østergaard, Dahlin and Hugo (2008).

The epistemological reversal described in this section implies the primacy of attentive practice embedded and embodied in concrete experience, as opposed to the (more or less "disembodied") cognition of abstract concepts. As a consequence, the concept of *action* in SE is extended to include the interplay between all aspects of embodied practice: sensing, feeling, perceiving and cognising.

THE PEDAGOGICAL REVERSAL: THE PRIMACY OF CULTIVATING COMPETENCY

The pedagogical reversal that we propose follows from the concept of attentive practice in SE described in the previous section. It entails a shift of focus from imparting or transmitting ready-made scientific knowledge to the cultivation of both teachers' and students' perceptive, cognitive and communicative abilities. This reversal is somewhat in accord with the recently emerging idea to change state school curriculum plans from content-based to competence-based (see for instance

Klieme, Avenarius, Blum, Döbrich, Gruber, Prenzel, et al., 2007). We say “somewhat” because it is an open question whether the competency we wish to cultivate in our phenomenological approach to SE will be the same as that emphasised in future competence-based national curricula (for a substantial critique of the idea of a competence-based curriculum, see Hopmann, 2007). The idea of a competence-based science curriculum may seem contradictory to the perspective of lifeworld phenomenology employed here. Nevertheless, there are fruitful attempts at least to *understand* competency from a phenomenological point of view; see for instance Dall’Alba and Sandberg (1996) and Little (2000).

The seeds of the abilities to be cultivated in SE can often be observed in young children. However, they seem to be easily discouraged and neglected by cognitive overloads in science teaching. A phenomenological approach to SE will try to keep students’ interest alive in all years of schooling (Østergaard, 2006). Taking a phenomenological perspective on natural phenomena as a basic stance in SE therefore implies a particular approach to curriculum design (Hugo, 2006). It means an increased emphasis on the aesthetic – sensual and feeling as well as imaginative – dimensions of phenomena even in subjects like physics and chemistry. It may be argued that physical phenomena in particular have very little to offer the senses and the feelings, therefore we need to move on to the conceptual abstractions in order to maintain interest in studying them. This may be relatively true, but we contend that this argument may be a consequence of the general “anaesthesia” of our culture (cf. Kamper & Wulf, 1984) and that there is more to experience than we first can appreciate. As for applying phenomenology to physics teaching, see Arons (1982); for chemistry, see Julius (1988).

As described above, in the phenomenological approach concepts grow out of holistic and sensory rich experiences of natural phenomena. An interesting illustration of this approach to research in natural science is provided by Hamilton’s (2000) biography of Michael Faraday. It describes how the creativity of this great scientist grew out of his aesthetic approach to experimentation, as well as his imagination, built on his cultivation of perceptual skills.

Cultivating competencies in science teacher education

The idea of reversing the ontological, epistemological and pedagogical foundations of SE is mirrored in the pre-service science teacher education at the Norwegian University of Life Sciences, where the second and third authors of this paper are teaching. The program is practice based, emphasising training of basic skills for becoming a science teacher. One such practical field is the training of abilities related to a phenomenological SE. In order to train these, it is crucial to start dealing with actual phenomena as early as possible. We expect of the pre-service science teachers that they go through a phenomenological learning process, so that they in their future teaching know how to offer similar learning processes to their students. In plenary sessions, a range of different themes are explored; for instance sound and tone, light and colour, sugar and starch. The result of an empirical study of these pre-service teachers exploring the phenomenon of sound has been reported by Østergaard and Dahlin (2009).

As a first introductory exercise to phenomenon-based SE, the pre-service teachers explore for about four hours a variety of different apples. The apple is chosen because it is an everyday phenomenon which most students (and children) regard as something common. It is a phenomenon which easily can be tasted, smelled, looked at and held in the hand. Out of these experiences grow a rich picture of “the apple”, and this picture is further connected to various themes in science as well as to other subjects (see Box 1).

After having worked in class with such common phenomena, exploring them aesthetically and discussing their relevance as starting points in teaching and learning processes, the pre-service teachers themselves are encouraged to seek and choose phenomena which could be used in their

“THE APPLE”

Through an exploration of the phenomenon, using all senses, the apple can be related to different subjects and themes in the school curriculum:

- **Biology:** botany, health themes etc.
- **Chemistry:** nutrition, organic acids etc
- **Physics:** density, weight etc.
- **Economy:** transport costs for imported apple compared to locally grown etc.
- **Horticulture:** how apples are grown, stored and consumed etc.
- **Art and mythology:** The apple in art expressions, myths, fairy tails and history (the Bible) etc.

Box 1: Exploring the phenomenon “apple” and relating it to the school curriculum.

own teaching. This exercise (see Box 2) is first worked with individually. After that, they compare and discuss their results in groups, and finally the more common challenges of such phenomena-based teaching are discussed in plenary.

Phenomenon exercise

On the basis of what you have learned in phenomenon-based science teaching, you shall:

- **Choose a phenomenon** which you think might be useful in class – or which simply interests you
- **Observe the phenomenon carefully**, and write down what you see, smell, taste, or hear after repeated observations
- **Reflect on possibilities** for using this phenomenon in a science class – or in other classes

The result of this individual exercise is presented in groups of students, ending in a discussion of the relevance for using such phenomena in science teaching.

Box 2: Teacher student exercise in phenomenological science education.

Such an exercise may be a fruitful start for the work of planning a lesson – or a series of lessons. The chosen phenomenon can either be a part of the lesson, working within one science subject, or it may connect different science subjects or even themes from other subjects, as is the case with the apple (see Box 1).

The approach described here entails more than what is usually implied by the common pedagogical advice to “start with concrete phenomena” and then move on to scientific concepts and models. An aesthetical exploration of the apple is more than an introduction to concepts of chemistry, botany etc. – it yields more than *not-yet*-conceptual knowledge. Aesthetically exploring the apple means revealing its characteristic expressions in taste, smell, touch and sight. These perceptual features have for hundreds of years guided our understanding and knowledge of apples. By an initial and prolonged resistance to hasty scientific reductions, phenomenon-based SE affirms that lifeworld phenomena are more than the sum of their scientific descriptions and explanations. It argues that an experience of a phenomenon is unique; it is a whole in itself. If this wholeness is reduced to causal explanations or conceptual denominations, essential features of experience are lost. Thus, explaining the apple in terms of basic components and causal laws will never do justice

to the apple as a lifeworld phenomenon. Doing justice to the apple implies allowing it to come to full expression in experience – *as well as* conceptualizing it in causal relations and reductive concepts. It is in this sense that the phenomenon can serve as an integrating point of multiple (aesthetical, cognitive, archetypal) dimensions.

Against this background we can define what we have coined as “a phenomenological teaching competency”. The abilities involved are complementary to and not replacing the more general abilities trained in teacher education. We see three basic aspects of a phenomenological teaching competency:

1. *The ability of phenomenological observation and reflection.* Through careful and precise observations – of both nature and students – natural and human phenomena are unfolded in sense-perceptual experience. This is in accordance with Husserl’s demand of letting phenomena “speak” on their own terms and as far as possible “parenthesising” what one already believes or knows about them. The ability to reflectively observe is important to cultivate in SE since pre-service science teachers tend to regard scientific knowledge as something “given” and often believe that their task is “only” to transmit this knowledge to the students. This kind of pre-understanding may hinder the phenomenon to experientially unfold itself in its sense-perceptual richness.

2. *The ability to communicate.* This implies an ability to actively listen both to the students and to the phenomenon explored; as well as the ability to express ones own experience in a living and colourful way. The teacher must be able to guide the students’ exploration of phenomena, to be sensitive to their ways of expressing their experience and to ask them the questions which can lead them on to new insights. This is in agreement with the German science teacher Martin Wagenschein’s call for Socratic dialogues in SE (cf. Wagenschein, 1968). It implies an open attitude towards seeing and promoting the students’ activity in exploring phenomena.

3. *The ability of curriculum design.* This comprises the abilities to choose a relevant and interesting phenomenon for teaching, decide ways to present the phenomenon and to guide the exploration, and to plan the amount of time needed for the students to develop the bridge from the phenomenon to the scientific concept(s) or model(s). It also means being able to choose phenomena of interest to the students and with great potentials for the discovery of central scientific concepts.

These three competencies all relate to sense-perceptual experience, attentive practice and lived actions. Points of departure for the learning process are real life situations and phenomena and not theoretical, context-free models or conceptual schemas, which are later “applied” to or “illustrated” by various everyday examples. The concepts of mass and force (from the story in the introduction) can be theoretically understood, but the weight of a huge timber log must be felt and measured in all its sense-perceptual richness. Scientific concepts are not forgotten or made peripheral; they are on the contrary embedded in and connected to a learning process which emerges out of an experienced lifeworld activity.

FOUR ARGUMENTS FOR A PHENOMENOLOGICAL APPROACH TO SCIENCE EDUCATION

The arguments presented in the previous sections does not entail a denial of the significance and value of mathematical and other abstract scientific models for explaining and predicting natural phenomena. However, from an ontological point of view such models must be taken as secondary and derived; they do *not* refer to a world that is “more real” than our immediate human lifeworld. Nevertheless, we can fully appreciate both their beauty and their usefulness in explaining, predicting and controlling natural phenomena; and their fruitfulness for technological developments are obvious. The ontological re-reversal implies, among other things, the importance of contextualising scientific models by relating them to the human interests driving the development of natural

science in past and present times, as well as to the history of their genesis and the controversies that preceded their acceptance. Such contextualisation reduces both their ontological and epistemological status as incontestable truths about a real world “behind” our experience, but they take nothing away from their significance and importance for our human endeavours.

In this section we give four further arguments for a phenomenological didactics of science teaching. Our first argument has more of an indirect character in that it argues that phenomenology has a more developed and differentiated philosophy of knowledge (and learning) than the approach to SE most commonly used today, namely constructivism. The other three arguments focus on the specific contributions of phenomenology to SE (cf. Dahlin, 2002, p. 189ff). As will be shown, these arguments are also closely related to the three reversals discussed above.

1. *The phenomenological approach is wider and deeper than the constructivist approach.* Constructivism is a designation for a variety of philosophical and epistemological stances (cf. Matthews, 1998). Educational constructivism stresses the individual creation of knowledge and construction of concepts (ibid., p. 3) and has decisively contributed to the shift of focus from teacher-based teaching to student-based learning. One branch of constructivism, socio-cultural learning, argues that knowledge construction is inextricably connected to its cultural context (Cobern & Aikenhead, 1998). This perspective also elaborates on the role of language and its importance for knowledge construction (Resnick, Säljö, Pontocorvo & Burge, 1997). According to Matthews (1998) constructivism has contributed to SE

...by alerting teachers to the function of prior learning and extant concepts in the process of learning new material, by stressing the importance of understanding as a goal of science instruction, by fostering pupil engagement in lessons, and other such progressive matters. (p. 7)

The importance of students’ pre-understanding, the goal of understanding and not merely passive assimilation, and the active engagement of students are all elements that constructivism have in common with the phenomenological approach we advocate here. However, constructivism still has a limited focus on cognition and the construction of conceptual knowledge. Phenomenology has a strong emphasis on the precognitive phase, including sensing and feeling as important initial grounds for the later, purely conceptual cognition. Phenomenology agrees that knowledge is actively produced by the learning individual and its holistic perspective acknowledges also the need to consider learning processes in their cultural contexts. However, phenomenology tries to balance the predominance of abstract conceptual explanations by connecting abstract knowledge to being and acting in the world as the ground for genuine understanding. It is our impression that this counterbalancing action is not an essential element in constructivist approaches; such approaches seem more concerned with the cognitive processes (individual or social) of constructing scientific concepts, models and laws. Thus, phenomenology is more open also to the aesthetic, ethical and moral dimensions of science; an aspect of SE which has recently gained renewed interest (cf. Corrigan, Dillon & Gunstone, 2007). Szybek (2002) provides an interesting example of how ethical questions belong to a phenomenological SE, and Blades (2006) presents a more general discussion.

2. *The argument about understanding the nature of science.* This argument is in accord with our quote from Osborne et al. (1998) in the introduction: there is a need for more teaching *about* science. To understand the *nature* of science – and not just basic scientific concepts and theories – has long been an overriding aim of SE. However, it has seldom been realised to any great extent. In order to see the nature of something, it is often necessary to contrast it with something similar in certain respects, but different in others. The importance of such experiences of *variation* for coming to understand something has been explicitly argued for by Marton and Booth (1997). Böhme (1980) makes a similar point concerning learning to understand the nature of science when he argues that Johann Wolfgang Goethe’s theory of colour ought to be included in

all science teaching at the upper secondary school level. Not many people know that the famous 18th century German poet also constructed a theory of colour based on principles very similar to those of phenomenology (Bortoft, 1996; Heinemann, 1934; Seamon & Zajonc, 1998). By including Goethe's theory of colour and contrasting it with that of Newton's, students may learn many things. They may become aware of the possibility of *another kind* of science than that which has become predominant today (again, see Böhme, 1980). They may realise that the interpretation of natural phenomena are just that, namely interpretations, not objectively "given" knowledge. They may also become acquainted with an interesting part of the history of science. Finally, Goethe's theory of colour is of particular interest in that it does *not* lead to the kind of ontological reversal inherent in Newton's optics (that colour is in *reality* "nothing but" electromagnetic waves of different frequencies). Goethe did not substitute immediately experienced phenomena by abstract theory, for him the phenomena themselves and the theory explaining them belonged together as one whole (Bortoft, 1996).

3. The argument of science and alienation. The modern human being's relationship to nature is somewhat divided (Meyer-Abich, 1995). On the one hand we have the scientific, technical and economical relations. In science, nature is represented as in itself without colour, without sound and without taste; these qualities being merely subjective appearances produced by the human senses. Technology and economical needs thereafter proceeds to transform nature into material or natural "resources" (cf. Heidegger, 1993), at the disposal of human needs and desires. On the other hand, we also have an aesthetic relation to nature. We cannot deny that nature's colours, forms and smells are sources of pleasure and beauty. We also use nature as a source of recreation. We then want to enjoy it in as pure and virginal state as possible. These two forms of relation do not harmonise very well. The beautiful sunset is, according to the interpretation of science, not really beautiful, and the recreational area of undisturbed nature may soon be destroyed by mining or other resource exploiting projects. We therefore create buffers between these two ways of relating to nature, so that we do not have to experience them both simultaneously. These buffers contribute to our modern more or less subconscious alienation to nature and non-human life forms.

The phenomenological approach takes all experience as real, at least in a primary sense of the term (Jackson, 1996). It never neglects sense experience, or puts it aside as merely subjective, but uses it as a starting point for systematic investigation, reflection and understanding. Cultivating the phenomenological approach to nature may therefore help us to overcome the basic split between subject and object, subjective consciousness and objective reality, which has become such a deep-rooted conviction in Western culture. It may subdue our drive to *control* nature and develop a more *cooperative* approach instead. This is again primarily related to the ontological reversal, since it means that our experiences of pleasure and beauty are not relegated to an unreal sphere of mere subjective appearances, but is taken as an essential aspect of reality.

4. The argument of personality formation. The French historian of philosophy, Pierre Hadot (1995), points out that Goethe's (phenomenological) thinking and that of antique philosophers shares a common theme, namely the emphasis on *living in the present moment*. This has nothing to do with a non-responsible forgetting of either the past or the future. To live in the present moment is part of an inner discipline which aims at developing and transforming our perceptual abilities. It is part of a transformation towards a more intensive experience of life, nature and the universe; a heightened feeling of life and a deeper feeling of communion with the whole of creation. This can be seen as a deeper motive behind phenomenological approaches to the study of nature. The continuously recurring, attentive observation of natural phenomena becomes a spiritual discipline which in time teaches us to live more intensely in the present, in a spirit similar to that of the antique philosophers. This is personality formation on a most fundamental, existential level.

However, if the natural scientist and the science educator neglect sense experience and trust only in technical instruments of measurement and registration, this possibility of personality formation

disappears. In present day science, there is a strong tendency in this direction (Bogen & Woodward, 1992; Dahlin, 2001). Goethe for his part was convinced that the human mind with all its senses was, or rather could develop into, the most refined instrument for the study of nature. In his scientific writings, Goethe (1981) wrote:

The human being in him/herself, as far as s/he uses her healthy senses, is the greatest and most precise physical apparatus there can be, and that is really the greatest harm of the new physics, that one has as it were separated the experiment from the human being and wants to know and prove Nature and what she can produce only through that which artificial instruments show and what is delimited by them. (p. 244; our translation)

Obviously, this argument of personality formation has to do with the cultivation of certain abilities, based on the attentive practice of “living in the present”. Hence, it is connected to both the epistemological and the pedagogical reversals described above: the ground of understanding is attentive action and the cultivation of perceptual abilities.

CONCLUSION

In his phenomenological approach to SE, Wagenschein claims that the main problem in science teaching is that it is too often planned “from the end”: starting with the basic concepts and the mathematical structures, the teacher is aiming at making these understandable to the students, using laboratory experiments as mere illustrations. Wagenschein has the opposite point of departure, using experienced lifeworld phenomena and experiments as gateways leading into the world of scientific knowledge. He even goes one step further, pointing at the value of letting scientific concepts be challenged by the encounter with phenomena of nature (Wagenschein, 1990).

One possible answer to this challenge is, in line with Husserl’s demand, to return to “the things themselves”. In this sense, phenomenology could be regarded as an attempt to restore the value of the direct lived-body-experience of things. This includes natural phenomena as well as students and their ways of understanding the world. Our main argument in this paper is that in order for SE to return to things themselves, we have to reverse some of our basic ontological, epistemological and pedagogical presuppositions. The phenomenology of Husserl and Merleau-Ponty (and also that of Goethe) has helped us to spot these suppositions and to reconstruct them.

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