Science as systems learning

Some reflections on the cognitive and communicational aspects of science[#]

Hugo Fjelsted Alrøe[*]

ABSTRACT: This paper undertakes a theoretical investigation of the 'learning' aspect of science as opposed to the 'knowledge' aspect. The practical background of the paper is in agricultural systems research – an area of science that can be characterised as 'systemic' because it is involved in the development of its own subject area, agriculture. And the practical purpose of the theoretical investigation is to contribute to a more adequate understanding of science in such areas, which can form a basis for developing and evaluating systemic research methods, and for determining appropriate criteria of scientific quality. Two main perspectives on science as a learning process are explored: research as the learning process of a cognitive system, and science as a social, communicational system. A simple model of a cognitive system is suggested, which integrates both semiotic and cybernetic aspects, as well as a model of self-reflective learning in research, which entails moving from an inside 'actor' stance to an outside 'observer' stance, and back. This leads to a view of scientific knowledge as inherently contextual and to the suggestion of reflexive objectivity and relevance as two related key criteria of good science.

KEYWORDS: Agriculture, cognition, communication, experiential, learning, research, science, self-reflective, systemic.

1 Introduction

A standard encyclopaedia definition of science is:

> Any system of knowledge that is concerned with the physical world and its phenomena and that entails unbiased observations and systematic experimentation. In general, a science involves a pursuit of knowledge covering general truths or the operations of fundamental laws. (Encyclopædia Britannica, 1999)

In the following, science is investigated not as a system of *knowledge* but as systems *learning*. The dynamic 'learning' aspects of science include observation, experimentation and communication, while the more static 'knowledge' aspects include models, theories, and other structures of meaning involved in scientific practice. The term 'systems learning' is meant to allow for at least two different perspectives on science as learning, which will be treated in this paper: science as a *cognitive system* involving observation and experimentation, and science as a *social, communicational system*, involving for instance peer criticism.

This approach to science is inspired by the tradition of philosophical pragmatism (see e.g. http://www.pragmatism.org): The primary aspect of science is learning or inquiry – there is no absolute scientific knowledge, only the cessation of doubt and settlement of opinion, in the words of Charles S. Peirce's 1877 essay "The fixation of belief" (Peirce,

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[*] Danish Research Centre for Organic Farming, P.O. Box 50, DK-8830 Tjele, Denmark
Phone: +45 8999 1679, Fax: +45 8999 1673. Further information at http://alroe.dk/hugo

1992: 109ff, online at http://www.door.net/arisbe). And there are better and worse ways of settling opinion – there are better and worse methods of inquiry and forms of logic, and these arise within the operation of inquiry and are disclosed by inquiry into inquiry (see also Dewey, 1991: 11ff, 108). The pragmatic view of science is connected to a critical attitude towards knowledge. Scientific knowledge is considered fallible in the sense that it is always open to further inquiry.

One of the purposes of focusing on the learning aspects of science is to develop a more general conception of science than the one given in the standard encyclopaedia definition of science, quoted above. From a broader view of science this definition establishes a false boundary between 'science', which concerns "general truths and fundamental laws" and which is therefore not contextual, and 'not science', which includes those areas of science where the contextuality of knowledge is a more fruitful concept than general truth. The area in question here is agricultural science. This paper has a practical background in research in organic agriculture and agricultural systems research (e.g. Sørensen and Kristensen, 1993; Bawden, 1992). Agriculture is characterised by an agricultural practice that involves both social and natural systems, and research in agricultural systems therefore faces the dual challenge of understanding complex agro-ecosystem interactions and handling the involvement of human actors, their practices and preferences. Agricultural systems research is inherently framed in a social context, and involves questions concerning different interests and discourses in society (Kristensen and Halberg, 1997). Organic agriculture, in particular, is based on explicit rules as well as broader formulated principles and goals for farming and manufacturing, which are connected to underlying values and perceptions of the relationship between human and nature (Woodward *et al.*, 1996; Alrøe and Kristensen, 2000a).

Agriculture is an area in rapid development - both in terms of technological development and in terms of the development of new production systems in response to problematic impacts of modern agriculture on nature, environment, human health, and animal welfare. And agricultural research plays an influential role in both these developments. Hence, agricultural science is a 'systemic' science, which influences its own subject area in important ways – for example in the development of new technology and new production systems, or in the evaluation and regulation of agricultural practice. That is to say, agricultural science is a science of complex, dynamic socio-ecological systems, which plays a part in the systems that it studies, and which can itself be studied as a social system and as a cognitive system. This paper addresses some of the philosophical challenges in understanding these systemic interactions of science.

In light of the involvement of agricultural systems research into its subject area, the conventional scientific criteria of quality are not fully adequate – there is a need to investigate a holistic or systemic research methodology and develop means for judging the quality of systemic research. This need has been particularly evident in research in organic farming (FØJO, 1998; Zanoli and Krell, 1999). In particular, the systemic research of agriculture cannot in general be 'unbiased', 'impartial', or 'objective' in the sense of being value-free (though it can, and must, include specific research activities that, given a larger context, are objective in the usual scientific sense). On the contrary,

values play an important role in agricultural research, and value inquiry is a specific task for research in organic agriculture (see e.g. Alrøe *et al.*, 2001; Alrøe and Kristensen, 2001). The practical purpose of this theoretical paper is to contribute to a more adequate understanding of science as a basis for developing and evaluating systemic research methods, and for determining appropriate criteria of scientific quality in areas such as agricultural systems research. But as a theoretical analysis of science it may be of broader interest, as well.

Looking at agricultural science as a social system there are at least four levels of systems[1] - the researcher, the research group, the scientific community, and the society. The different levels involve different aspects of scientific learning and the production and reproduction of different kinds of knowledge as elements of the system. The following is a tentative description of these levels. The level of the *researcher*[2] involves learning by experience and intuition, and the development and reproduction of inherent, experiential knowledge, bodily skills, etc., by way of personal study and practice. The level of the *research group* involves the learning of scientific methods, such as the ability to observe (e.g. the identification of plants or the diagnosis of diseases) and the ability and technology to make experiments, by way of some form of apprenticeship. The research group distinguishes itself from the scientific environment by way of communal skills, common research goals, and collegial loyalty. The level of the *scientific community* involves the learning of 'truths' - scientific or warranted knowledge - by way of peer criticism. The scientific community distinguishes itself from the social environment by impartiality and objectivity. The level of the *society* involves the learning of 'good' or relevant knowledge by way of discourse on the values, goals, and visions of society. Below, I will first (in section 2) investigate science as a cognitive system, a perspective that is primarily relevant at the level of the researcher and the research group. Later (in section 6) I will investigate science as a social, communicational system, a perspective that is primarily related to the level of the scientific community and the society.

2 Science as a cognitive system

In this section, science will be considered as a cognitive system. This perspective involves a naturalistic approach to scientific learning in line with John Dewey's "Logic: The Theory of Inquiry" (1991: 30ff), which presupposes an evolutionary and developmental continuity between different forms of cognition and learning. In such an approach, the cognitive and experiential processes of a living organism can be taken as a model of the cognition of science. This does not imply that there is no difference between less complex and more complex kinds of cognition - only that there are common features and that something can be gained from investigating these features.

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[1] In accordance with Luhmann (1995: 16ff), the difference between system and environment is taken as the systems theoretical point of departure, and levels of systems are not to be understood as structures of wholes and parts, but as structures of systems differentiation by way of further system/environment differences within the system. There is, however, a difficulty with fitting a cognitive system, such as the individual researcher into this framework of social systems.

[2] It may be more appropriate to speak of the *research unit* as the basic level of research, which includes the people and tools necessary to perform the research. The research unit is able to do research that no individual researcher can do on her own. In this sense individual researchers can be components in a larger, complex cognitive system, including other researchers and workers, measuring instruments, computers, etc. (see e.g. Giere, 2000; Knorr Cetina, 1999: 167-68).

And a key feature is that cognition involves the interaction of organism and environment (Dewey, 1980: 13, 22; see also Bateson, 1972: 451-60). Dewey speaks of experience prior to speaking of cognition, and the key aspect of his understanding of the experience of living creatures is that it is primarily about doing and interacting with the environment (Dewey, 1948: 84-87). Cognition cannot be understood independently of emotion and activity, and: "Knowledge is not something separate and self-sufficing, but is involved in the process by which life is sustained and evolved." (Dewey, 1948: 87).

In accordance with this point of departure - and ignoring the aspect of science as a communicational system until later - a basis for establishing a model of science as a cognitive system can be sought in the field of ethology, which studies the relation between cognition, motivation and behaviour in living organisms. Jacob von Uexküll's approach to animal behaviour (which is one of the roots of biosemiotics, see e.g. Hoffmeyer, 1997) seems to be the most fruitful basis for establishing a general model of a cognitive system (Uexküll, 1982a; see also Uexküll, 1982b; Emmeche, 1990; Brier, 1999a).

The main characteristic of Uexküll's approach is that he sees animals as subjects and takes the inner world of the animal as the primary (phenomenological) perspective:

> We no longer regard animals as mere machines, but as subjects whose essential activity consists of perceiving and acting. We thus unlock the gates that lead to other realms, for all that a subject perceives becomes his perceptual world and all that he does, his effector world. Perceptual and effector worlds together form a closed unit, the *Umwelt*. (Uexküll, 1957: 6)

'Umwelt' is Jakob von Uexküll's term for the subjective universe of each organism: "every action … that consists of perception and operation imprints its meaning on the meaningless object and thereby makes it into a subject-related meaning-carrier in the respective Umwelt" (Uexküll, 1982: 31). The system that Uexküll regards as the elementary unit of behaviour is the *functional circle* (figure 1), which connects the meaning carrier (the 'object') with the subject (Uexküll, 1982: 32).

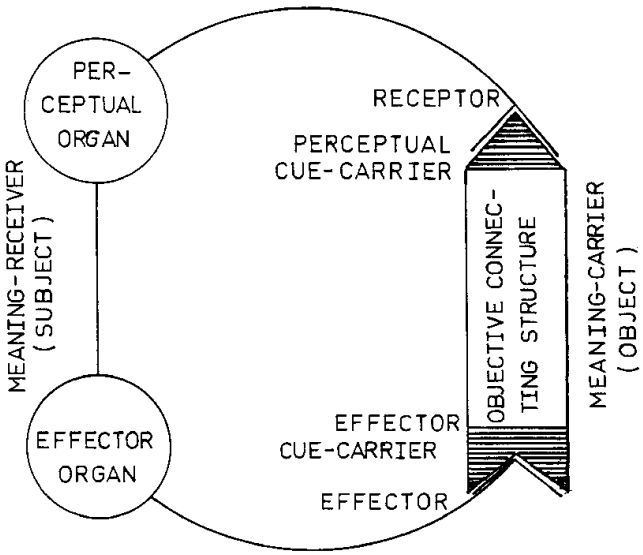

Figure 1: Jakob von Uexküll's functional circle of behaviour (Uexküll, 1982:32).

In line with Uexküll's description of the animal and its Umwelt, a simple model of a cognitive system is shown in figure 2. This model shares basic features with Uexküll's model, in particular the circle of *acting* and *perceiving*. In addition to that, the model shows the *Umwelt* as the phenomenological world of the cognitive system and the *representation* of the Umwelt, which is involved in the system's acting and perceiving. The representation entails a *reference* to the Umwelt, a non-causal, semiotic relation shown as a dotted arrow.[3]

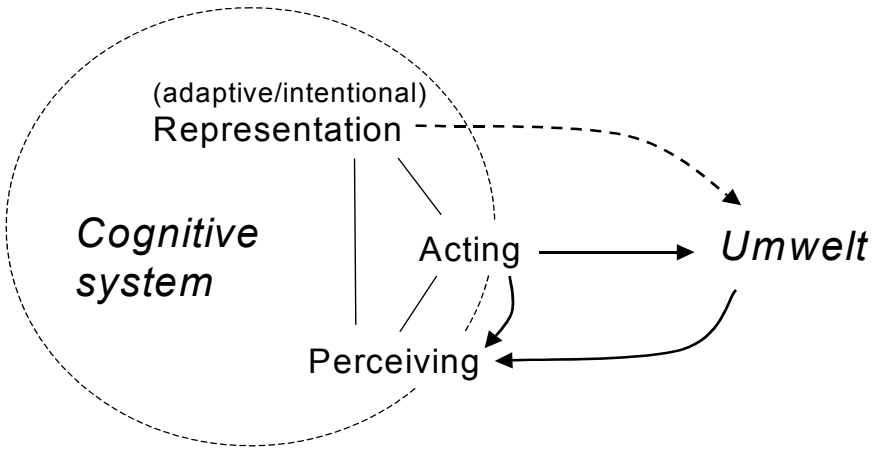

Figure 2: A simple model of a cognitive system. The dotted arrow indicates a semiotic reference, the solid arrows indicate causal processes, and the thin lines indicate a systemic connection or coordination of acting, perceiving and representation. Furthermore, the distinction between adaptive and intentional aspects of the reference to the Umwelt is indicated.

The reference to the Umwelt is also implied in Uexküll's model by his use of the concepts meaning-carrier and meaning-receiver, but in figure 2 this semiotic aspect is made more explicit.[4] This addition makes it possible to refer to the processes of adaptation and learning in the cognitive system as changes in the system's representation, and thus for drawing analogies to the learning processes of science. Uexküll himself rejected evolution and saw the adaptedness of organisms and their behaviour to their respective environments as a result of a pre-existing, pre-established harmony (a "Bauplan") (Brier, 1999a: 185).

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[3] In accordance with Peirce's concept of sign: "A sign, or *representamen*, is something which stands to somebody for something in some respect or capacity." (Peirce, 1955: 99) and, in a slightly different form: "A sign is a thing which serves to convey knowledge of some other thing, which it is said to *stand for* or *represent*. This thing is called the *object* of the sign; the idea in the mind that the sign excites, which is a mental sign of the same object, is called an *interpretant* of the sign." (Peirce, 1998: 13).

[4] See also Søren Brier (e.g. 1999b) for a suggestion of an integrative framework for the semiotic and cognitive/cybernetic approaches. Brier (1999a: 202, 205, 229) uses the term 'signification sphere' for the biosemiotic understanding of the individual Umwelts of animals and he mentions that this relates to what Maturana and Varela, from another theoretical standpoint, calls the 'cognitive domain'.

No internal system processes are shown in figure 2, and the causal processes transgressing the system boundary, which are shown as solid arrows, are discriminated as either acting or perceiving. Perception may be directed towards the immediate acts, or towards more mediate effects of actions or independent dynamics of the Umwelt, as indicated by the two arrows of perception. The first arrow indicates that perception is the only means for the system to "check what it is actually doing". Acting and perceiving are, however, not entirely separate processes in the cognitive system – looking is an act – and this organic connection is illustrated by the thin line between acting and perceiving in the figure. Furthermore, the reflex arc of stimulus and response is not only a causal sequence but also a 'coordination', as Dewey called it: In a psychological sense, "sensory stimulus and motor response are always inside a coordination and have their significance solely from the part played in maintaining or reconstituting the coordination" (Dewey, 1896: 360; see also Bateson, 1972: 292).

The use of the term 'representation' does not imply that the acting is controlled by way of some sort of map or depiction of the world, only that the acting and perceiving of the system to some degree refer to patterns outside the system (see also Maturana and Varela, 1987: 131ff). While the representation is connected to acting and perceiving within the system (as a 'coordination', indicated in figure 2 with thin lines), it is only indirectly related to the Umwelt through action and perception processes that transgress the system boundary – the reference to the Umwelt entailed in 'representation' is dependent on the structures of actions and perceptions. And the other way round, perception involves the representation and action aspects as well. The cognitive system is 'operationally closed', with a term from Maturana and Varela (1987: 156ff) - the system's structure determines the possible cognitive interactions with the environment. Instead of a depiction, the representation in the model is better construed as patterns of *habits*, [5] where 'habit' is understood in Charles Sanders Peirce's sense, corresponding to Aristotle's use of 'hexis', as a disposition: the tendency and ability to do something under certain conditions (Peirce, 1992: 131; Ransdell, 1999). And even though the 'representation' may be no more than habits of action and perception, including representation explicitly is a way of making the model applicable to the processes of learning and adaptation. This view is in accordance with Dewey, who describes the learning of organisms as habit-formation (Dewey, 1958: 279-81; Dewey, 1991: 38-39). The representation can, as a habit, thus be seen as entailing expectations - the representation is a construction of an Umwelt in a semiotic sense, but this construction may be disappointed, in which case change (adaptation or learning) can take place, if the system has the capacity to change.

Seeing the cognitive system's reference to its Umwelt as tendencies and expectations brings us close to the use of the terms anticipation and motivation in ethology. Søren

[5] The relations between representation and acting and perceiving in the cognitive system may thus be more like a hierarchy of habits, where the flexibility of behaviour can be seen as based on the constraining of a habit by a habit on a higher level (Lorenz, 1976: 123-33). This is mimiced in the subsumption architecture of modern robotics, where robot reaction involves higher levels of behaviour taking control over – subsuming – lower levels behaviour (see e.g. Brooks, 1991). These patterns of behaviour refer to the Umwelt of the system, but they cannot be considered a depiction of the world - they are deeply embedded in the actual 'experience' of the cognitive system.

Brier argues for the necessity of including motivation in a theory of cognition (1999a: 91, 205, 227-31), supported by quotes from Ellis & Newton:

> We are suggesting that the 'felt' aspect of experiencing is tied in with the fact that organisms are emotionally motivated to 'look for' elements of the environment that are significant with respect to the organism's motivational purposes; that the organism 'anticipates' experience in terms of motivational categories which preselect for attention; and that the emotions that guide this anticipation and selection process are a major contributor to the conscious feeling of 'what the consciousness of such-and-such an object is like'. (Ellis and Newton, 1998: 431)

Ellis & Newton further state that both "emotion and representation must be present for phenomenal experiencing to occur" (Ellis and Newton, 1998: 435). These considerations on the role of motivation in behaviour suggest that there are two aspects of the semiotic reference to the Umwelt (indicated in figure 2): the 'adaptive' or 'learning' aspect of representation, which refers to past experiences, and the 'emotive' or 'intentional'[6] aspect, which refers to future experiences. Implicit in the concept of learning is the idea that the system changes in a way that could be otherwise. Thus, the outcomes of learning processes is incorporated in the system, and this contingent aspect of the systems reference to its Umwelt is the backward-looking, adaptive aspect of the 'representation' in figure 2. The forward-looking, intentional aspect is related to that which in other contexts is called *values*. In other words, since the representation of the Umwelt does not refer to 'independent objects in the world' but to aspects of the organism-in-its-environment, the representation is inherently value-laden. The reference is mediated by actions and experiences and is therefore of necessity connected to emotions and intentions. Another way of putting it is that the representation entails meaning or significance for the organism[7].

We may, however, even use the model of the cognitive system in figure 2 to describe a simple mechanical cybernetic system such as a thermostat. The action aspect in the thermostat is the switch turning the boiler on and off; the perception aspect is the thermostatic coil, being open towards certain changes in the environment; and the representation aspect is implicit in the way the coil is directed towards changes in temperature, and in the way the boiler effects the temperature in the environment. The Umwelt (phenomenological world) of the thermostat is quite narrow, only including the temperature of the air around the coil. The point of this example is to show that the 'phenomenological stance' is just that - a particular approach to the observed system, which takes the point of view of the observed system as a subject. Both the objective and phenomenological stances are possible stances in research, but when researching cognitive systems the objective stance will prove inadequate. Further down, I will discuss the second order observation of observing systems in more detail, in order to reveal what we can gain from looking at science as a cognitive system. But first I will look briefly at different kinds of learning in living organisms, as a means to closer

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[6] 'Intentional' is used in nearly the same sense as 'representational' in philosophy – that something is directed at or referring to something. The meaning here is more related to the everyday meaning of 'intent'.

[7] Taking both aspects of representation into account, the concept of 'representation' becomes closely related to Niklas Luhmann's concept of *meaning* (Luhmann, 1995: 60-62): "The phenomenon of meaning appears as a surplus of references to other possibilities of experience and action." (Luhmann, 1995: 60). But see also the discussion in section 6.

determine the potential and the limits of the analogy between cognition in organisms and in research.

3 Types of learning in organisms

Obviously 'organisms' are very diverse systems, ranging from bacteria and trees to humans, where we may find different kinds of learning. Gregory Bateson distinguishes different logical types (or levels) of learning in his "The logical categories of learning and communication" (Bateson, 1972: 279-308): Zero learning is characterised by specificity of response, which is not subject to correction. Learning I is change in specificity of response by correction of errors of choice within a set of alternatives. Learning II is change in the process of learning I, such as a corrective change in the *set* of alternatives from which choice is made or a change in how the sequence of experience is punctuated. Learning III is change in the process of learning II, such as a corrective change in the *system of sets* of alternatives from which choice is made. Bateson stressed, however, that the theory of logical types is only applicable, in a formal way, to 'digital communication' - that is, communication by means of distinctions - and that it is doubtful how far it can be applied to 'analogue communication', where there is no distinction and hence no negation (Bateson, 1972: 372f, 291, 54f). Bateson mentions gestures and the tone of voice as examples of analogue communication. This distinction seems to correspond to Peirce's distinction between iconic and symbolic signs (disregarding indices), and it seems important in comparison with Luhmann's theory of communication, which is based on distinctions (corresponding to 'digital communication'). See further in the next section.

Bateson uses examples from biological systems and here we need to distinguish two kinds of processes: ontogenetic or organismic processes, where the relevant change is called learning; and phylogenetic or evolutionary processes, where adaptation is the change analogous to learning. Thus Bateson says that learning IV, the change in the process of learning III, "probably does not occur in any adult living organism on this earth. Evolutionary process has, however, created organisms whose ontogeny brings them to Level III. The combination of phylogenesis with ontogenesis, in fact, achieves Level IV." (Bateson, 1972: 293).

4 Observing systems

Gregory Bateson defines information, or the basic unit of information in communicational and mental processes, as "a difference which makes a difference" (e.g. Bateson, 1972: 453). And in Niklas Luhmann's terminology, observation means nothing more than handling distinctions - making a difference in this context involves an observing system. Luhmann, following George Spencer Brown, defines 'observation' as *indication by means of a distinction* (Luhmann, 1998: 167ff; Luhmann, 1989: 144). In terms of the simple model of cognition in figure 2, observation involves both representation and action besides perception. An indication can be seen as a simplest kind of reference to the environment - a reference to this as distinct from that - by means of a distinction entailed in the action and perception process, in the form of for example the sense apparatus, attention, or conceptualisation. In accordance with the necessary relationship between the different aspects of cognition, Bateson pictures perception, representation and action in a circular cybernetic process, where the

transform of a difference travels in circuit (Bateson, 1972: 458f). In more complex learning processes the three aspects gain a more independent existence, as in the models, experiments and observations of research - and this seeming independence makes the acknowledgement of their relationship all the more important.

Investigating the process of observation as part of cognition, we shall look at Niklas Luhmann's formulation of a theory of cognition from a systems theoretical approach, in the tradition of constructivism, see for example his "Erkenntnis als Konstruktion" (Luhmann, 1998). In the tradition of cognitive idealism, the cognitive problem of the unity in the difference between cognition and the real object starts with the question: how is cognition possible, *even though* it has no of itself independent access to outside reality? Or: how can a subject know anything outside itself, when any such cognition cannot take place independently of the subjects cognition? The radical constructivist approach, on the other hand, starts with the empirical statement: cognition is only possible *because* it has no access to realities outside itself - because it is operationally closed (Luhmann, 1998: 164). The *subject theory* of cognition has never addressed this question, Luhmann says, because it has always wrestled with the paradoxical quest of inferring the relation of others to the world by way of introspection. Therefore it must presume a common world, or at least a commonly observed world. In a constructivist approach, we are able to ask the contrary question of subject theory: how is the *disconnection* (Abkopplung) of the cognitive system possible (Luhmann, 1998: 165-66). An *object theory* of cognition, on the other hand, also fails to address this question, because the reduction of the description of cognition to processes within the object leaves out the problem of disconnection.

The question of disconnection is approached by replacing the fundamental distinction between subject and object with a distinction between 'system' and 'environment'. This approach maintains the classical cognitive problems connected with subject-object theories, by making a distinction in cognition where one side of the distinction re-enters the other,[8] but it also transgresses the classical problems by revising both subject and object theories. The question of disconnection is asked as a question of differentiation and operational closure of systems and the premise of a common world is replaced by a theory of observation of observing systems (Luhmann, 1998: 164ff). Operational closure of systems is possible by way of the system producing and reproducing its own operations, thereby maintaining a distinction between system and environment. This is what Humberto Maturana and Francisco Varela calls *autopoiesis* in their answer to the questions "what is life?" and "what is cognition?", using the concept in a description of organisms as cognitive systems. They consider first of all unicellular organisms as autopoietic systems. The neural system and metacellular organisms (e.g. multicellular organisms and colonies) are operationally closed systems, and meta-cellular organisms are considered second order autopoietic systems (meaning no more than that they consist of cells), while they leave the question open as to whether meta-cellular organisms are (proper) autopoietic systems (Maturana and Varela, 1987: 96-98, 156ff).

[8] The world as the unity of system and environment can only be a concept within the system, and thus the difference between system and environment re-enters the system. Likewise, the world as the unity of subject and object can only be a concept within the subject, and thus the difference between subject and object re-enters the subject. See also Luhmann (1998: 178).

Luhmann extends the concept of autopoiesis to other kinds of systems - he distinguishes between organisms, psychic, and social autopoietic systems.

Although Luhmann uses autopoiesis theory as one point of departure for his general systems theory, he does not adopt the conception of cognition originally connected with the theory. Maturana and Varela characterise cognition as *effective action*, an action that allows a living being to sustain its existence in a certain environment, as it reproduces its world - no more, no less (Maturana and Varela, 1987: 44-45).[9] Luhmann (1998: 167) presupposes a concept of cognition as observation based on distinctions and indications, and this allows him to extend the concept of autopoiesis beyond autopoietic living beings. But is also entails an approach quite different from the original autopoiesis theory. Maturana and Varela's concept of operational closure of a system's organisation (which is not quite clear from the sources I have) entails that the identity of the system is specified in a network of dynamic processes, the effects of which do not leave the network (Maturana and Varela, 1987: 98, 157). Luhmann's concept of closure allows for the disconnection of the cognitive system and thus for cognition, as discussed above. He asks: "How is closure possible? Probably only by this, that a system produces its own operations and reproduces them in its network of recursive progresses and regresses. The process itself creates the difference between system and environment."[10] (Luhmann, 1998: 167). That is, closure presupposes autopoiesis. And "the concept of autopoiesis can be extended to the social domain only when the elements of social systems are conceived as communicational acts (events) and not as persons, roles, subjects, individuals, etc." (John Bednarz's introduction in Luhmann, 1989: xi).

Taking this approach, Luhmann may be neglecting an important aspect of social systems, having to do with Gregory Bateson's 'analogue communication' (above), since Luhmann's entire system is based on observations and, fundamentally, distinctions. It is important to keep this in mind, when drawing general conclusions from the insights of autopoietic theories of cognition. Where Maturana and Varela takes the position that all cognition is effective action and Luhmann only recognises observation as indication by means of a distinction, I shall leave the question open as to whether there is more to cognition than either one of these positions.

Luhmann's theory of cognition does, however, have a series of important implications. First and foremost, that all observation is dependent on distinction, and that the recognition of the environment therefore is dependent on the distinctions applied in observation. The distinction with which a cognitive system observes, is its "blind spot" or latent structure, because this distinction cannot be distinguished in the observation - if it were, it would be distinguished by means of another distinction, with its own blind spot. Any observation presumes and produces a splitting of unmarked space (Luhmann, 1998: 168f).

[9] Maturana and Varela's conception of cognition is also presented as an aphorism: "All doing is knowing and all knowing is doing." (Maturana and Varela, 1987: 43).
[10] Translated from the Danish edition.

5 Self-reference and self-reflection

The basic distinction in Luhmann's autopoietic systems theory is between system and environment, between self and not-self, and this distinction is established by the system's self-reference. The distinction between system and environment, in turn, gives rise to two types of reference in autopoietic systems: self-reference and other-reference (Luhmann, 1989: 22f), in contrast to allopoietic systems such as a thermostat, which do not by necessity have self-reference. Thus, if the model in figure 2 is taken as a model of an autopoietic system, there should be two semiotic arrows from the representation, indicating a reference both to the Umwelt and to the system itself.

Luhmann distinguishes between three types of self-reference in autopoietic systems: basal self-reference, processual self-reference and reflection (Luhmann, 1995: 443-44). *Basal self-reference* is the minimal form of self-reference, without which the autopoietic reproduction would not be possible. This self-reference is that of an element in the system. *Processual self-reference*[11] is the self-reference of a process, such as communication about communication or thinking about thinking. "The basic form of processual reflexivity is always the selection of selection. Therefore reflexivity can emerge only on the basis of a self-selective structure of processes that intensifies the selection of selection" (Luhmann, 1995: 450). In comparison with Bateson's logical types of learning, reflexivity would correspond to learning I as opposed to the zero learning behaviour (cognition of cognition) - or to learning II as opposed to learning I (learning of learning). Luhmann's processual self-reference does not distinguish between these two types of processes,[12] but Luhmann does hint at the connection to learning and adaptation:

> Reflexive processes can be used as processes that change structure, and their development imposes itself if a great need for controlled structural change exists. Of course, a counterinstance can be included in a process only in accordance with its own type of event. When this is possible, the process acquires a greater degree of freedom, a greater range of application, and a better capacity to adapt. (Luhmann, 1995: 452)

Reflection (I will use the term 'self-reflection' for clarity) is the self-reference of the system (as distinguished from the environment). Where the first two types of self-reference refer to elements and processes, self-reflection refers to the whole system by way of the distinction between system and environment. In Bateson's terms, self-reflection would require the process of learning III[13]. Bateson calls the habits acquired in Learning II for "the premises of what might be called character", and links this to the concept of self:

> If I stop at the level of Learning II, "I" am the aggregate of those characteristics which I call my "character". "I" am my habits of acting in context and shaping and perceiving the contexts in which I act. Selfhood is a product or aggregate of Learning II. To the degree that a man achieves Learning III, and learns to perceive an act in terms of the contexts of

[11] Luhmann also uses the term 'reflexivity' for this type of self-reference, but I find that term more prone to misunderstanding.

[12] It seems like Luhmann is not aware of the difference - he states that: "in learning something one learns to learn as well." (Luhmann, 1995: 463).

[13] Bateson's types of learning are *logical types* and there is therefore no necessary connection between Bateson's learning III and self-reflective cognition - in an evolutionary perspective learning III becomes learning IV, as mentioned in section 3. I shall disregard this here.

> contexts, his "self" will take on a sort of irrelevance. The concept of "self" will no longer function as a nodal argument in the punctuation of experience. (Bateson, 1972: 304)

The latter sentence means that the self/not self distinction will itself become subject to learning, and no longer be a given distinction in the categories implied in our model of the world.[14] Selfhood or individual character being a result of the habits acquired through learning II, the change of these habits, the change of self implied in learning III, seems at least to some degree to correlate with the concept of self-reflection.

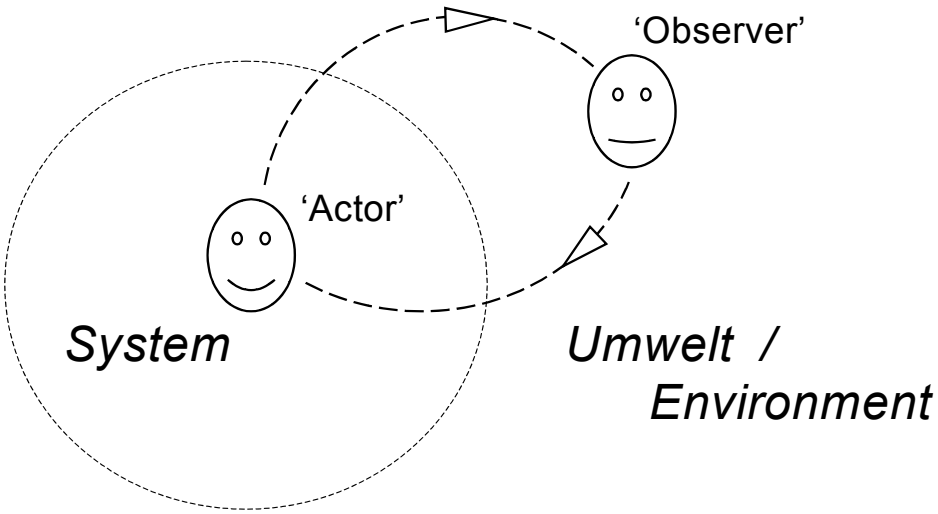
Where processual self-reference allows for a dynamic identity and, hence, for learning in the sense that the system acquires new habits, self-reflection allows for the representation of oneself as another - that is, for self-awareness or self-consciousness - and thus for a transformation or shift of identity. It can be argued that the historical emergence of self-reflection in cognitive systems presumes the recognition of the other as oneself - that is, seeing oneself as another presumes seeing the other as oneself, recognising the other as in some sense the same as oneself (the obvious example, found in both humans and some 'higher' animals, is of course the recognition of oneself in a mirror). Self-reflection thus forms an important foundation for ethics.

Self-reflection presumes not only that the system can represent contexts of contexts in its Umwelt, as in learning II, but also that it can represent itself as a system with an Umwelt. Luhmann speaks of *rationality* when the unity of the difference between system and environment is reflected, that is, when the system reflects the connectedness of system and environment. But rationality can never be definitive, because no system can step out of itself or encompass the environment, which is always more complex than the system (Thyssen, 1992: 43). In Uexküll's phenomenological perspective, a more complex organism has a more complex Umwelt - the complexity of the Umwelt is conditioned on the complexity of the system. Luhmann's distinction between system and environment has a different stance - in his perspective, the environment is always more complex than the system (e.g. Luhmann, 1995: 182). In this perspective the development of the complexity of the system can be discussed in relation to the complexity of the environment, and it is possible to speak of the systems indifference to its environment (or ignorance of the environment). I consider the different meanings involved in Luhmann's use of 'environment' and Uexküll's use of 'Umwelt' to be conditional upon the different stances involved.

We can picture self-reflective learning as a circular cognitive process including the representation of oneself as another (figure 3). The process begins with the viewpoint of the 'actor' - the first order viewpoint of a cognitive system (with the capacity for self-reflection) - then it moves to a second order viewpoint, where the 'observer' views the system from without. And the knowledge learned from this outside point of view can take effect upon returning to the first order viewpoint of the system. From without, from the viewpoint of the 'observer', both the system and its 'actor'-Umwelt is seen as part of the observer's Umwelt - the observer looks at himself as another. In this observer

[14] See also Bateson's ideas on eco-mental systems, an expanded concept of mind, and the expansion of self (Bateson 1972: 461-63). For a discussion of the expansion of self as a basis for a systemic environmental ethics, see Alrøe and Kristensen (2000b).

perspective it is possible to make a distinction between the Umwelt of the system, corresponding to the actors phenomenological stance, and the environment of the system (in Luhmann's sense), corresponding to the distinction between system and environment from the stance of an ideal observer. In a learning perspective, the



cognitive system can expand its Umwelt through such self-reflective cycles. In the observation of other cognitive systems, the observer stance can include a representation of the phenomenological stance of the other, such as for example Jakob von Uexküll's descriptions of the phenomenological worlds of different animals and humans (Uexküll, 1982: 29ff). And, off course, there is also an observer stance implied in making a model of a cognitive system such as that in figure 2.

Figure 3: The self-reflective circle of learning, moving from an inside 'actor' viewpoint to an outside 'observer' viewpoint, and back.

Luhmann uses the same terms (actor and observer) in connection with a discussion of the two perspectives of second order cybernetics: first and second order observation:

> Sociopsychological investigations of attribution have come to similar conclusions entirely independent of this biologicocybernetic research tradition. Here, research proceeds under the title of causal attribution. The actor's mode of attribution (first order observation) is distinguished from that of the observer's (second order observation). While the actor finds the bases for action primarily in the situation itself, the observer sees the actor-in-the-situation, looks for differences in the interpretation of the situation by different actors and makes attributions primarily in terms of the personal characteristics of the actor. (Luhmann, 1989: 25)

However, in a logical sense the system cannot represent itself as a whole. The system has no privileged view of itself:

> That a system can observe itself, and maybe even describe itself, gives it no privileged access to a special insight. That self, which observes itself, has as noted above its blind spot: it cannot lean on other's observation, but is one with its own observation. And it cannot lean

> on its own observation, because an observation cannot observe itself in the moment it observes, anymore than you can run from your own shadow. (Translated from Thyssen, 1992: 46f)

And this perspective has obvious implications for science. Luhmann states it like this:

> In all these cases the beginning has to be - and this constitutes the innovation vis-à-vis the naïve faith in science - the fact that second-order observation together with its theoretical apparatus is possible only as a performance of structured autopoiesis, i.e., it is not 'objectively better' knowledge but only a different knowledge that takes itself for better. … Even science would not be able to understand why with its 'better knowledge' it often finds no resonance within society because what it comes to know - its 'better knowledge' - would have no value at all as reality in the environment of other systems or is at best a scientific theory for them. Not much is gained, therefore, by following an ontological theory of reality (which corresponds to a first order observation of the environment) because this theory is not in a position to grasp the problem as such. We have to choose a second order cybernetics as the point of departure. We have to see that what cannot be seen cannot be seen. Only then can we discover why it is so difficult for our society to react to the exposure to ecological dangers despite, and even because of, its numerous function systems. (Luhmann, 1989: 25-26)

Acknowledging the different stances in the self-reflective circle of research allows for an increased awareness of the *limits* of the Umwelt of research - or, in other words, an increased awareness of ignorance and the cognitive structures on which knowledge and ignorance depends. The case of development and use of environmental indicators is an obvious example, where the choice of indicator determines the kind of 'sense-apparatus' employed in the observations and, hence, the kind of knowledge that can be gained. The 'blind spot' entailed in this choice can only be remedied by new kinds of observation involving different measurements and indicators. Furthermore, the use of these indicators as indicators depends on the environmental values and goals connected with them.

6 Science as a social, communicational system

In speaking of self-reflection as the cognition of oneself as another, we have approached the second aspect of science, science as a social, communicational system. According to Luhmann's theory of social systems, organisms, psychic systems and social systems are all autopoietic systems, each in their own way (Kneer and Nassehi, 1997: 63). Psychic systems are systems of thought, while social systems are systems of communication - their elements are communications that are produced and reproduced in the communicative systems. Individual human beings are, in this perspective, not one system, but consists of several independent autopoietic systems, such as the organic system, the neural system and the psychic system, which are self-referentially closed to each other. One psychic system is closed to another - we have no insight in the minds of others, no telepathic abilities[15]. And psychic and social systems are closed to each other, communication is an independent and self-propelled process – humans do not communicate and psychic systems do not communicate with each other, according to Luhmann (Kneer and Nassehi, 1997: 69ff). The two systems operate as closed systems

[15] Luhmann's point is that we can only communicate precisely because of this disconnection, because we have no telepathic abilities.

under completely separate operative (autopoietic) and structural conditions (Luhmann, 1998: 180).

According to Luhmann, communication is an independent emergent level, like the psychic system is an emergent level beyond the neural system. But this does not imply that the psychic system can exist without the neural system or that communicative processes can exist without psychic systems. Luhmann uses 'interpenetration' as a term for the relation between systems that are environments for each other and, in particular, for the relationship between human beings and social systems (Luhmann, 1995: 213ff).[16] He speaks of the co-evolution of psychic systems (or persons) and social systems and states that "persons cannot emerge and continue to exist without social systems, nor can social systems without persons" (Luhmann, 1995: 59).

While Luhmann is very explicit about the relation between psychic and social systems, he is, as far as I have read, less clear on the relation with the organic system. And this makes his theory problematic in the present context, due to my naturalistic point of departure. Luhmann criticises John Dewey's approach to meaning, which is indicated in this quote: "Meaning is not indeed a psychic existence; it is primarily a property of behavior" (Dewey 1958: 179), and he states that "the attribution of meaning to behavior, which gives itself meaning only in reference to something else" is incorrect (Luhmann, 1995: 512, note 2). Instead of following the connection of meaning with behaviour, Luhmann says (somewhat vaguely!) that "it is better to avoid references to anything specific, since they always exclude something, and to introduce the concept of meaning as a concept 'devoid of difference' and intending itself along with." (Luhmann, 1995: 59-60), in the sense that: "meaning always refers to meaning and never reaches out of itself for something else" (Luhmann, 1995: 62). Luhmann does not offer a definition of this key concept, but he does give a "phenomenological description", saying that "meaning equips an actual experience or action with redundant possibilities." (Luhmann, 1995: 60). I do not in his phenomenological description find anything opposed to an integrative view of experience and meaning - Luhmann's sharp separation of the psychic and organic systems seems instead to follow from his application of autopoiesis theory (perhaps he has been seduced to go too far by the beauty of this theory), or from the deeper structures and motivations of his philosophy.

Taking meaning as connected to experience and action is in line with ideas concerning the importance of the embodiment of human cognition (e.g. Brier, 1999a: 222ff), and new trends in the theory of learning involving a 'constructionist' approach[17]. This view is illustrated by the connection between representation, action, and perception in the model of cognition in figure 2. Reyes and Zarama (1998) take a similar approach to learning, at least with respect to the connection between learning, embodiment, and action. They distinguish between knowledge, knowing, understanding, and learning:

> While *knowledge* is seen as an assessment made by an observer about our competence in a particular domain of action according to some criteria, *knowing* is related to our capacity for

[16] Luhmann has later used 'structural coupling' as a term for the interdependence between autopoietic systems at different (emergent) levels, and according to Kneer and Nassehi this is different from Maturana's use of structural coupling as a term for the structural correspondence between two or more systems (Kneer and Nassehi, 1997: 64ff, 74f).

[17] See for example the MIT Epistemology and Learning Group [http://el.www.media.mit.edu/groups/el/]

> making distinctions in that domain of action and *understanding* relates to the grounding and embedding of the distinctions in a particular history and tradition. In this approach, *learning* is a process by which we embody these distinctions in our actions. (Reyes and Zarama, 1998: 32)

They state that "the meaning of a distinction is in the actions it allows us to take", and that "what we do does not refer to the object itself but to the way we relate to it" (Reyes and Zarama, 1998: 31), and this is in accordance with my view. However, Reyes and Zarama ground their approach, including action, knowing, and learning, on the capacity to make distinctions, and the drawing of distinctions in their model of learning is based on reflection and language. In this respect their model is less general than the one presented in this paper – probably reflecting their focus on the problematics of teaching. Reijo Miettinen (2000) discusses the concept of experiential learning in a recent article, criticising David Kolb's model of learning on the basis of a study of his sources, which include John Dewey's conception of experience and reflective thought and action. His critique of Kolb's four stage model of experiential learning as a general model of learning can be seen as a relevant critique, in this respect, of Reyes and Zarama's (somewhat similar) four stage model as well.

With respect to communication, the view of cognition as connected to experience and action implies that the communicative act *is* indeed dependent on the intentionality entailed in the system's 'representation'. In Luhmann's somewhat peculiar formulation, psychic, and only psychic (! - not organic), systems are participatory in communication, and they can only irritate or tickle communication, not instruct it (Kneer and Nassehi, 1997: 74).[18] I acknowledge that actual communication is dependent upon the other participants in communication and not 'instructive', but I disagree on the exclusion of individual intentionality in communication. Luhmann himself may have moved in this direction in his last works, criticising his own description of the elements of the psychic system as thoughts and pointing instead at Husserl's "intentional acts" as a possible candidate for the elements of the psyche (Kneer and Nassehi, 1997: 64).

In a learning perspective there is, of course, the possibility of correcting the communicational process in accordance with the intentions of the individual. This is a key aspect of dialogue. So even though any individual communicative act is non-instructive in itself and the actual communication (as opposed to the intended) is dependent on the meaning context of the receiver, this is not so in a longer developmental perspective. In the continued dialogue or interaction, the constraints on intentional communication can be somewhat remedied by structural coupling (in Maturana and Varela's sense). Take for example the development of warning signals in evolution or, closer to science, the development of deep common understanding through prolonged dialogue and interaction in a small group of people.

In terms of science as a communicational system it is, however, important to consider Luhmann's perspective and acknowledge the constraints on communication. Though the lesson is not to ignore intentionality, but to emphasise it. Acknowledging the importance of intentions and values in the learning of scientific systems leads to the

[18] Luhmann focuses on the relation between *consciousness* and (social) communication (e.g. Luhmann, 1989: 29), and not on experience and cognition in an organismic sense - it seems important to keep this focus in mind when evaluating his conclusions.

need to reflect on the influence of the intentional aspects and include them in the scientific communication - quite contrary to the effect of pursuing the ideal of a value-free science.

The above considerations lead to a new perspective on scientific communication as a learning process. Luhmann considers science as a functional subsystem (among other subsystems) of a differentiated society, which structures its communication through the binary code of logic: the difference between true and false (Luhmann, 1989: 76f, 36f). He states that: "The code of scientific truth and falsity is directed specifically toward a communicative processing of experience, i.e. of selections that are not attributed to the communicators themselves[, and] … towards the *acquisition* of new scientific knowledge." (Luhmann, 1989: 77-78). However, this seems only to capture the communicational aspect of science that has to do with peer criticism – the cognitive aspect of science as experiential learning is left out. The self-reflective learning process of science (figure 3) illuminates the importance of the involved, phenomenological stance as a necessary ground for the observational stance. In this perspective it becomes clear that 'truth' is dependent on the cognitive context, including the values and intentions involved, and a contextual view of knowledge is therefore seen as a prerequisite for genuine peer criticism.

As generally recognised in light of today's specialised sciences, peer criticism is only in principle open to the scientific community in general. In practice peer criticism is to some degree conditional upon the special knowledge that is restricted to disciplines or sub-disciplines in science. However, if the scientific communication is to be even in principle open, it has to include sufficient context to be unambiguous. And, insofar as the intentionality and values of scientific inquiry are found to be important contextual aspects of the knowledge production of science, these aspects have also to be included in the scientific communication in order to achieve a genuine criticism. Research in organic farming, for instance, presupposes the understanding and employment, at least to some extent, of the values and goals of the organic movement. In this perspective the structure and organisation of science is of interest, including the presence of 'subcultures' in science and society, such as for example the organic farming movement, which distinguish themselves from their environment in terms of worldview, values, and discourse. Some research groups are connected to a specific subculture and in this sense they are already 'involved' in their subject area in contrast with 'outside' researchers. An example illustrating this difference can be found in the organisation of research in organic agriculture: In some countries (such as Switzerland) organic research is primarily found in separate research institutions closely connected to the organic movement, while the organic research in other countries (such as Denmark) is carried out by researchers on 'conventional' research institutions.

7 Conclusions and suggestions

There are two important aspects of scientific learning – cognition and communication – which have been discussed in this paper. Science is often seen as a communicational community, which is based on the ideal of objectivity and the practice of peer criticism.

But agricultural science and similar 'systemic' sciences[19] influence their own subject area in the course of learning about it, and therefore the intentional aspects of the learning process are of obvious importance here. This is in conflict with the ideal of objectivity, which construes science as value-free. More fundamental than objectivity, however, is the criterion that science should be *public*, first of all in the sense of being open to critique, but also in the sense that the scientific learning process expresses a common goal. And the criterion of openness to critique applies equally well to systemic sciences.

In this paper the model of a cognitive system in figure 2 is taken as a point of departure for the understanding of scientific learning at the level of the researcher or the research unit. The adaptive aspect of representation can be identified with scientific theories or models and the intentional aspect with the underlying interests and values of scientific inquiry. Acting and perceiving can be correlated with experimentation and observation - experimentation with an emphasis on the action part and observation with an emphasis on the perception part. This model then suggests that these three elements of scientific learning are intimately connected, in the sense that scientific theories and scientific observation depend on the possibilities and impossibilities of practical research activities; that action, experimentation and observation depends on the theories and models available as well as on the values and goals of the research unit; and that theories and possibilities of action are dependent upon the available modes of observations. An example of this is the interdependence of theories, computer models, and machinery used in high energy physics (see e.g. Pickering 1995). The 'knowing' of high energy physics cannot be separated from the learning of high energy physics. But according to the suggested models of cognition and learning, this is a general characteristic of research.

When science is a part of the world that it studies, the criterion of objectivity becomes problematic as a general scientific ideal. The experiential approach to cognition suggests the importance of the cognitive context in scientific learning and knowledge. Any research project involves some necessary (but not necessarily explicit) choices on which interests and values to take as a ground for research. And the openness towards genuine critique is conditional upon the reflection and communication of this value-laden ground. In this perspective, any research project that insists on being value-free is less objective than the project that presents the values entailed in the research. This does not eliminate the criterion of objectivity, but transforms it into a criterion of *reflexive objectivity*, which involves taking an observational, detached stance and at the same time acknowledging, investigating, and exposing the involved stance and the related interests, values, and goals, which the observational stance presumes as a necessary cognitive context of the 'objective' observations.[20]

Instead of seeing science as a distinct communicational system that is only concerned with truth and falsity, these considerations suggest a view of science as the learning process of society. In this view, the criterion of *relevance* is an important criterion of

[19] Other systemic sciences are for instance health sciences, environmental sciences and engineering sciences as well as, of course, the social sciences and some of the human sciences, including, apropos, the sociology and philosophy of science.

[20] The role of values in science is further investigated in Alrøe and Kristensen (2000c).

good research. However, modern society consists of many different groups or 'subcultures', with different interests and values, and there is no single common goal of society, which science can relate to. In this perspective the dependence of scientific knowledge on the cognitive context, and the connections between research activities and different groups, interests, and discourses of society, become issues that science has to reflect upon. As it turns out, the criterion of relevance is conditional upon the analysis and communication of the value-laden context of research, which is promoted by the criterion of reflexive objectivity. And on this basis some aspects of scientific quality can be outlined:

- research should investigate and explicitly describe its own point of departure, the viewpoint and values entailed in the research project, in order to facilitate the use and critique by different users and researchers with different values and perspectives
- and conversely, research should engage in the problems to be investigated, and work explicitly with the goals and values involved in its subject area
- research should describe the choices made, the delimitations and constraints involved, and the areas of ignorance uncovered in the particular project, as a necessary context of the positive results produced.

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