Authors' Response: A Perspectivist View on the Perspectivist View of Interdisciplinary Science

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> Upshot • In our response we focus on five questions that point to important common themes in the commentaries: why start in wicked problems, what kind of system is a scientific perspective, what is the nature of second-order research processes, what does this mean for understanding interdisciplinary work, and how may polyocular research help make real-world decisions.

Introduction

« 1 » The commentaries on our target article are very diverse in their standpoint and focus. This diversity illustrates a main point in the article: perspectives determine what observers can and cannot observe (§17), and that goes as much for the reading of a scholarly article, particularly in an interdisciplinary context. Some are critical, some corroborate and elaborate on the ideas in the target article; but despite the diversity, there are some common themes running through the commentaries. We will focus on those in our reply, trying to reinforce some of the key points in our article, and hopefully make them clearer.

« 2 » The target article takes a perspectivist view of interdisciplinary research. Rick Szostak (§13) joins us in "urging a specific understanding of 'interdisciplinarity' centred on an appreciation of the importance of disciplinary perspective." Werner Callebaut (§4) agrees fully with our perspectivist grounding, and we agree with him that perspectivism is "needed everywhere" as a basic epistemological tenet. We do not, any more than Callebaut (§6), want to enter into a complex discussion here about whether our approach is "realist" and in what way, but we agree with him that "perspectivism is as much realism as you can get" (paraphrasing Ronald Giere, see §74). And we can answer Callebaut's question about what we mean by constructivism, by saying that we see perspectivism as most closely connected to radical constructivism (as we state in the article, §9), and not, e.g., the social constructivism that Callebaut mentions.

« 3 » As always in (radical) constructivist approaches, we cannot, and should not, avoid turning perspectivism on itself; we need to take a perspectivist approach to the perspectivist view of science. When in our reply we refer to different perspectives on what we are doing, this is therefore not an attempt to evade giving a straight answer, but an attempt to explain reflectively our (perspectivist) approach by including multiple different perspectives on the topic of interdisciplinary research.

« 4 » The themes we address in the following represent the full span of our approach, from the starting point in wicked problems and what kind of system a scientific perspective is, to the nature of second-order research processes, what this means for how interdisciplinary work is understood, and how polyocular research may help make real-world decisions.

Why take wicked problems as a starting point?

« 5 » Steve Fuller and Callebaut are critical of our starting point in wicked problems, whereas Michael Hoffmann and Robert Drury King agree with this starting point while being critical of other aspects. Fuller (§3) states that according to our article a wicked problem enjoys an autonomous existence, independent of whether it threatens anyone or is registered by any scientific discipline. This is far from our understanding of a wicked problem and from how it is described in greater detail by Hoffmann (§1). Fuller (§7) suggests a revised understanding of "wickedness," with reference to Louis Pasteur. However, we find that Pasteur is an example of a technical problem and a technical solution, rather than a wicked problem. The issue is not that wicked problems are independent of any particular framing, as Fuller puts it, but that "there is no definitive formulation of a wicked problem" because "every specification of the problem is a specification of the direction in which a treatment is considered," as Hoffmann (§1) states, with a quote from Horst Rittel & Melvin Webber (1973: 161). "To find the problem is thus the same thing as finding the solution; the problem can't be defined until the solution has been found," Rittel & Webber write. Yet, paradoxically, the solution cannot even be sought before some formulation of the problem has been made, and this paradox adds to the wickedness of wicked problems.

« 6 » We agree with Fuller's (§§5f) deviant standpoint on interdisciplinarity that "it is not merely that the normal disciplinarian knows more and more about less and less but that her very narrowness of vision distorts what she purports to see" (Fuller 2010: 53). But we do not agree with his ensuing argument that:

> "It follows that the deviant tends to treat the very presence of different disciplines as prima facie pathological, rather like neuroses, which Freud treated as mere coping mechanisms for a reality we cannot fully manage in its entirety." (ibid)

We see scientific specializations as an inevitable consequence of the quest for new insights. The problem is not specialization and differentiation in science as such, but how we can handle the ensuing increase of complexity. And we see Fuller's (2010) account of different deviant interdisciplinarities as examples of new allegedly integrating scientific perspectives that are merely specialized in another way than the disciplines they react against. His example of general systems theory as "the most ambitious form of deviant interdisciplinarity in recent times" (ibid: 60) brings this point home.

What kind of (autopoietic) system is a scientific perspective?

« 7 » Systems theory is sometimes posed as a paradigm for interdisciplinary science, but there are a range of very different systems perspectives that lead to very different understandings of the system in question and its environment (see, e.g., Noe & Alrøe 2003, Alrøe & Noe 2012). The commentaries illustrate this. Fuller (§8), on one hand, is concerned with "open systems," which are dubbed open systems in contradiction to the closed systems of classical science, focusing on whole-part relations and referring to Ludwig von Bertalanffy. King (and we), on the other hand, is concerned with operationally closed systems, focusing on self-organisation, autopoiesis and system-environment relations, which provide an entirely different take on system bound-

ary, and referring to the systems theories of Humberto Maturana & Francisco Varela and Niklas Luhmann. Perhaps this difference is why Fuller (§1) thinks the concept of "system" remains unclear in our article, despite our very clear references to the system theories we build on, and why he perceives polyocular vision as an ad hoc construction despite our efforts to substantiate and elaborate the polyocular framework.

« 8 » However, we agree with Fuller's point that network theories are a counter-image to system theories (§9). We think this juxtaposition is even more acute with regard to actor-network theory and self-organising systems (see, e.g., Noe & Alrøe 2006, 2012), and we take this as an example of the need for multiple perspectives to understand complex research objects more fully. Fuller further emphasizes that the images of the sciences as either systems or networks also play a role in the position of science in society (§10): "The more that science agrees to the network-based self-understanding, the greater science's struggle to define its own epistemic distinctiveness (aka system boundary) in society." We think this is a good point and an example of how scientific perspectives are intertwined with perspectives in society at large.

« 9 » King (§1) states that it is an intriguing philosophical claim that "a perspective, scientific or – presumably – otherwise, is an autopoietic system." It is indeed an intriguing idea that perspectives in general are autopoietic, but in the article we only pose the more modest claim that a *scientific perspective*, such as a discipline, is an autopoietic system. King (§3) continues by asking what concept of autopoietic system we refer to in this claim. This is a very relevant question, to which we have a simple and a not so simple answer. The simple answer is that in making this claim we consider scientific perspectives as social systems, and that, e.g., the differentiation of science into specialized disciplines supports this understanding of science (§17 and §12). This idea of disciplinary perspectives is supported by Szostak (§2), who states that it is central to the discourse in the Association for Interdisciplinary Studies and provides examples of the key elements of such scientific perspectives that are largely in accordance with ours.

« 10 » The not so simple but more adequate answer aims at developing the pluralistic approach to scientific perspectives that we indicated in our target article (§10) and that spurred King's question. Even if we agree to regard a scientific perspective as a self-organizing and in some sense autopoietic system, there are, as King (§3 and elsewhere) points out, at least two different understandings of autopoietic systems, originating in Maturana & Varela and in Luhmann. Maturana & Varela focus on organisms or living, cognitive systems, which reproduce their own constituent parts such as proteins, nucleic acids, organelles, etc. Luhmann focuses on social, communicative systems, systems that consists of communication, and which reproduce their own communication elements, processes and structures. We have discussed this difference, and related questions such as different concepts of observation, elsewhere in some detail (Alrøe & Noe 2012, 2014), as noted in footnotes 5 and 6.

« 11 » Overall, we employ a Luhmannian social systems approach to radicalize the existing perspectivist, cognitive approach to science (§10). Luhmann's theory of autopoietic, communicative social systems forms the basis for the polyocular framework that we suggest. In reply to King, we acknowledge the issue is more complex than that. But since we are dealing with scientific perspectives as social systems, Maturana & Varela's account of autopoietic systems is inadequate, and therefore we rely on the theory of social systems, which Luhmann and others have elaborated in great detail. That said, social systems theory is not the only perspective on science; elements of the systems theory of Maturana & Varela (and other perspectives) are needed to gain a better systems theoretical understanding of scientific perspectives.

« 12 » A scientific perspective, for instance a specialised discipline such as soil physics, can be observed as a purely communicative social system or as a more material, cognitive system analogous to an organism or a living system. As a communicative social system, it establishes and reproduces its own specialised scientific concepts, semantics, archetypical examples, argumentative logics, hypotheses, diagrams, models, theories, etc. In analogy with a living system, the scientific perspective reproduces key constituent elements of the system as a cognitive system, such as specialised researchers, observation instruments and methods, experimental facilities, research platforms, indicator systems, etc. This is often done through structural couplings with other systems and other scientific perspectives. A very prominent example is that of the very large high-tech instruments for experiments and observation established by high-energy physics in CERN and elsewhere. The scientific perspective also establishes and reproduces the organisational structures that support communication in the form of conferences, journals, peer review systems, educations, email discussion lists, web pages, etc. The key point is that scientific perspectives are operationally closed (cf. King §12); it is the perspective itself that determines what is, and what is not, needed and accepted, through a continuing process.

What is the nature of second-order polyocular research processes?

« 13 » How do we employ multiple perspectives? Here we approach the heart of the target article, the second-order polyocular research process, and a large part of the questions in the commentaries. For example, King (§2) asks: "How can polyocular research observe/not observe?" and (§6) "what it is that synthesizes first-order observations into something adequately polyocular?" We have several different, but equally important, answers to these and related questions.

« 14 » One key to understanding the idea of polyocular research is that there is no hope of a holistic perspective. The paradox of scientific expertise is that the growth of science leads to a fragmentation of science and scientific knowledge (Alrøe & Noe 2011). This is a consequence of the functional differentiation of science illuminated by social systems theory, which shows how differentiated social systems become independent and closed to each other. Practical experiences from interdisciplinary work support this closure and lack of insight between different perspectives, as indicated in the target article (§4) and backed up by Hoffmann (§§1–3), Szostak (§2), and Callebaut (§4); the latter two also fully agree on the prevalence of hegemony and lack of respect between the involved disciplines.

« 15 » So how can independent and mutually closed perspectives cooperate on observing some complex phenomena or wicked problem? Our answer is "second-order observation." This is not carried out by first-order perspectives, because these are all specialized in observing different aspects of the world and not each other (economics, for instance, can only observe the observations of biology in economic terms, such as valuation). Nor are we thinking of what might be called second-order science in the form of sociology of science, history of science, philosophy of science, etc. These perspectives have science as their research object, whereas the second-order observation of polyocular research has the same research object as the first-order perspectives involved. Disciplines do not "spontaneously generate their own second-order visions when encountering domains of reality currently outside their remit" as Fuller (§6) suggests. Unlike reflexive processes in general, polyocular second-order observation requires a very deliberately planned framework. But given the right conditions, polyocular perspectives are indeed self-organising and autopoietic, they are not determined from without.

« 16 » There is a reason for using the term "polyocular" to designate this second-order observation process, and not something more colloquial such as "multi-perspectival" (cf. Hoffmann §3). The analogy to binocular vision is deep, because it incorporates the idea of looking at something through multiple "oculars" without seeing directly what each ocular is seeing. The polyocular research process is not just a second-order process, it is a first-, second- and zeroth-order observation process (cf. Figure 2); it is observing a complex dynamic object that cannot be "observed as it is," but only through the observation of different perspectives' observations of it.

« 17 » The first- and second-order processes of polyocular research are separate, very different, and mutually dependent. There cannot be a second-order polyocular perspective without first-order perspectives. And first-order perspectives cannot proclaim to observe complex phenomena without a second-order, polyocular observation process that establishes that these different perspectives are even observing the same dynamical object, let alone gathering a multidimensional understanding of it.

« 18 » The gathering of aspects of this dynamical research object by a polyocular, second-order observation of the observations – or insights cf. Szostak (§4) – of a range of different first-order perspectives is thus not like the synthesis of observations that can be made within a single perspective. The second-order process must observe and communicate these first-order observations together with their perspectival context, just as binocular vision must operate with the distance between the two oculars and the matching of the two images to infer depth.

« 19 » Callebaut (§§8–10) objects to a "levels view" of science based on a naturalistic account of science. This objection is directed against our second-order approach, but we actually agree with Callebaut in this. We do not consider second-order science of interdisciplinarity to be based on a transcendental theory of knowledge (*sensu* Luhmann, quoted in Callebaut §10). And we agree with Callebaut (§9) that: "As a matter of principle, any naturalistic/scientific account of science must be reflexive, for otherwise one would 'get out of the system'." It is important to maintain that polyocular research is a research process like other research processes; it is part of science as a self-corrective activity (Callebaut §8) or a common learning process (Alrøe 2000), just like any other kind of research proper. We think of this in terms of the systems theoretical insight that such self-correction and learning is inherently a systems internal process due to the operational closure of scientific perspectives as autopoietic systems.

« 20 » Somewhat in the same vein, Hoffmann (§§5f) asks why the second-order science of interdisciplinary research is supposed to be a "science." Second-order polyocular research must always be concrete; it is a research process that is done in connection with a selection of (first-order) scientific perspectives. It is thus not a general institution or research community, to answer Hoffmann's (§5) questions; it is an approach to interdisciplinary research. We do not speak of polyocular research as "*a* science," but as "second-order science," that is, as a form of science that consists not only of first-order scientific observation, but of first-, second- and zeroth-order observation processes. The reason we speak not only of second-order research processes, but of second-order science, is that we (in line with the special issue that this article is part of) consider the development of methods for carrying out second-order processes in science – and the concomitant criteria for whether such methods are better or worse science – a very important development of science as such; equal in importance to the differentiation and fragmentation of science that motivates such second-order science.

« 21 » As an aside, Callebaut (§11) suggests sticking to "multi-perspectival" and avoiding the term "polyocular" because it "perpetuates the persistent bias toward vision in our scientific and philosophical understanding of human perception." However, since "perspective" comes from the Latin verb for "to see through" or "look closely" (*perspectiva ars* was the "science of optics"), we are not better off using "perspective" rather than "ocular" in this regard. Instead, we suggest emphasizing the evolution of these concepts to cover not only other forms of human perception than vision, but also other forms of the much broader variety of scientific observation, which are evidently much broader, just as we use, for example, "see" and "insight" in a broader sense than that of vision.

What does this mean for understanding interdisciplinary work?

« 22 » Turning from the theoretical to the more applied side of polyocular research as a framework for interdisciplinary work, we are happy to learn of the recent publication by O'Rourke et al. (2014), which, Szostak (§9) reports, is similar to our approach in addressing perspectival barriers to cross-disciplinary communication. We have not been able to read this publication yet, but according to Szostak, the findings from the Toolbox project seem to corroborate our own findings from projects where we have tried out multi-perspectival and polyocular methods.

« 23 » In the commentaries we received several questions concerning who is doing the second-order observing. Callebaut (§7) asks: "who are to be the polyocular problem solvers," and suggests that these should be first and foremost the researchers them-

selves and other involved stakeholders. King (§§12f) asks: "Who or what does the synthesis of the multiple first-order observations," and speculates that "some human agent or languaging capacity" may be needed. Here we must emphasize the distinction between a scientific perspective as an autopoietic, communicative social systems and the scientists, researchers, and other stakeholders that may play a part in that system. Strictly speaking, from a social systems perspective, humans are not part of scientific perspectives (be they first-order or second-order), but belong to the environment of the social system. That said, we agree with Callebaut that the researchers and others involved in the first-order perspectives can take part in the second-order observation process. Researchers can to some degree participate in more than one scientific perspective, and interact (communicate) with other specialized perspectives, depending on their degree of interactional expertise (insights into other perspectives, see §61). But interactional expertise does not in itself constitute second-order science (to answer the question in Hofmann §6), though interactional expertise can help researchers partake in the second-order processes of polyocular research. We also think there are benefits from the same researchers partaking in both first- and second-order polyocular research processes, in terms of avoiding new alienations, as Callebaut (§7) suggests, and in terms of bringing insights from first-order perspectives into the polyocular communication. But there is definitely also room for other kinds of researchers to take part in polyocular research, such as the body of interdisciplinary scholars suggested by Szostak (§12), who work symbiotically with disciplinary specialists but have quite different skills and attitudes.

« 24 » Fuller (§10) suggests that the state must intervene in the case of cross-disciplinary conflicts "as a fair arbiter of these contesting second-order perspectival claims." But this does not at all enter into our suggestion of a polyocular framework for interdisciplinary research. Fuller focuses on the political conditions and incentives to encourage or – in the case of the state – "force otherwise wayward disciplines to work together to address free-standing social problems" (§5). We focus on the conditions for interdisciplinarity within science: the paradoxical co-occurrence of, on the one hand, ubiquitous and continuing calls for interdisciplinarity to compensate for disciplinary specialization in the face of complex problems and, on the other hand, a general lack of recognition of the value of interdisciplinary work and lack of incentive structures that encourage interdisciplinary work.

« 25 » Focusing on how interdisciplinary research may work, Hoffmann (§10) states that "the crucial question is obviously […] how a shared, coordinated, or integrated perspective can be achieved." We disagree, because this question throws "integrated" together with "shared" and "coordinated," and we see those as very different. In the target article (we write with reference to Alrøe & Noe 2011):

> "The differentiation and specialization of science and expertise results in what we call perspectival knowledge asymmetries: different scientific perspectives see complex matters differently, and these differences cannot, and should not, be merged." (§12)

Hoffmann (§11) writes in response to this: "If this is indeed true, why should we engage in any polyocular research project? If first-order perspectives can never be merged, how should we ever be able to cope with wicked problems?" In a similar vein, Szostak (§10) states the "there seems very little about what I would see as the critical step of integration," pointing to Repko (2012) for "the value of finding some common ground: a concept or conceptual map or even a theory that all might potentially accept" (§10).

« 26 » This question about the need for integration is, we believe, a key point, and a point that many seem reluctant to accept. We will therefore try to explicate it in a little more detail here. We think that different scientific perspectives can in general be coordinated and that synchronization is a particular aim in polyocular research; we think that a shared problem is a precondition for polyocular research; and we think that shared research in form of polyocular contextual communication is crucial to polyocular research (§§59–65). But we think that the idea of finding common concepts and theories across very different scientific perspectives as a ground for interdisciplinarity is misguided. We are of course aware that integration or merging of first-order scientific perspectives takes place, mostly in the form of related perspectives spurring a new intermediate perspective (e.g., molecular biology) or in relation to the development of new technologies, and that it may well be a political goal, such as the "converging technologies" agendas that Fuller (§4) refers to. Our point is that such integrations remain first-order, that they therefore, in contrast to the aim of integration, contribute to further differentiation of science, and that they therefore cannot solve the problem of solving wicked problems.

« 27 » As Szostak (§8) notes, we think the Kuhnian incommensurability between consecutive paradigms corresponds to problems in integrating and communicating across perspectives in interdisciplinary work (§75). But we find a deeper perspectival source of such incommensurability than language barriers, residing in the different observational apparatuses and forms of interaction provided by them. In the case of such incommensurability, when the difference is not between rationality and non-rationality, but between completely different conceptions of rationality, levelling out the disagreement by transforming it into a continua, as suggested by Szostak (§11) will be a disservice to the effort to achieve a better understanding. In the same way, holistic and hegemonic interdisciplinarity tend to hide incommensurability, whereas we want to make it visible. The contextualised observation and communication that we see as essential for polyocular research does not remove the barriers of communication between scientific perspectives, but transcends them (in line with Niels Bohr's recommendations in quantum physics, see §§22 and 63).

« 28 » Unlike what Hoffmann (§3) states, we find our approach to be very far from the "model of planning as an argumentative process in the course of which an image of the problem and of the solution emerges gradually among the participants, as a product of incessant judgment, subjected to critical argument" suggested by Rittel & Webber (1973: 162), which Hoffmann (§10) has developed as an approach to "solving wicked problems by integrating a multitude of perspectives in practice." We do not wish to claim that first-order interdisciplinarity

never works, but we also note that Hoffmann works with an approach to understanding ill-structured problems in applied ethics education, which does not directly involve scientific perspectives, whereas our article is directed at actual interdisciplinary research.

« 29 » It is important to stress, however, that the existence, and relative importance, of interactional expertise (§61), local integrations in science, and the "interfield theories" that Callebaut (§4) refers to, does not contradict our claim that scientific perspectives cannot, and should not, *in general* be merged, and that the solution to wicked problems therefore relies on polyocular research processes.

How may polyocular research help make real-world decisions?

« 30 » Szostak (§10) finds our remark that "any deliberate approach to instigate change and transformation must take place through an established perspective" (§66) rather cryptic. However, this follows directly from a perspectivist understanding of science. The scientific repertoire of interaction with the world is perspectival: physics, ecology, economy, sociology, and psychology all have different ways of interacting with the world in their research, and therefore their means of addressing a problem are different and they point to different forms of interventions to solve a problem. There is no escaping this; all research-based solutions are subject to these conditions, the different ways to instigate change are connected to different scientific perspectives. Therefore the process of establishing a shared solution is a separate, difficult task in polyocular research, based on the multidimensional understanding that has been established (§§66f). And these perspectival conditions for how to instigate change are also crucial to understanding complex societal tasks such as the regulation of agroecosystems (Noe & Alrøe 2014b).

« 31 » Szostak (§8) writes that though we, the authors, are thoroughly "perspectival," we argue that one can "gain an 'unambiguous' description of a 'complex phenomenon' by looking at this from multiple perspectives (§22)." But this is a misunderstanding; what we advocate is "taking a *complex phenomenon* to mean a phenomenon where multiple perspectives are needed to give an unambiguous description of the phenomenon." The term "unambiguous description" is from Niels Bohr (see §22), meaning a description that does not contradict itself because it includes the observational context, and not some form of objective description in a classical sense.

« 32 » In relation to this, Callebaut (§5) states that a first priority of scientific perspectivism should be the elaboration of a *grammar of perspectives*, telling us how scientific perspectives can (and cannot) be meaningfully combined; a grammar to which we, the authors of the target article, have not begun to contribute. This aim is certainly important, and we do in fact suggest at least one element of such a grammar in the target article (§76); namely a typology of the forms of complementarity between scientific perspectives and their relation to the general conditions for observation. Based on such a typology, we write,

> "an analysis can be made of what role complementarity plays in cross-disciplinary research, how scientific disagreements may be connected to the complementarity of scientific perspectives, and what this means for the options to produce unambiguous descriptions of complex phenomena through second-order science." (ibid)

« 33 » Finally, Hoffmann (§11) somewhat challengingly asks how the polyocular framework "could help make good decisions when facing wicked problems." He elaborates:

> "We can talk forever about the multitude of perspectives that come into play when we want to build a highway […] But at the end of the day there needs to be a decision: should it be built or not?" (ibid)

« 34 » We agree with Szostak (§8) that "there is no value in interdisciplinarity unless it allows understandings that are in some way superior," and that we therefore need to answer Hoffmann's question. However, Szostak (§8) continues that "we cannot speak of scientific progress unless we can understand each other well enough to recognize progress collectively." And in this lies the seed to a reply. Hoffmann's question is posed in a frame that goes beyond the frame of research. The decision to build or not build the highway is a political decision, not a scientific one. The role of science is to provide the best possible basis for the political decision. And here we think polyocular research is better, because the alternatives are worse: advice from a range of disparate and blindly disagreeing experts, advice based on interdisciplinary research biased by the hegemony of a single discipline, self-proclaimed "holistic" advice that is blind to what this particular perspective is not able to observe, etc. There is a need for interdisciplinarity to address wicked problems, and the polyocular framework is, we believe, a way towards better interdisciplinary research.

Conclusion

« 35 » There is a large and continuing increase in complexity in society. Science is itself part of this complexity increase through the involvement of science in the development of new technologies and new ways of looking at the world. But science is also a means for society to handle the (wicked) problems that the growing complexity gives rise to. Second-order science, as we see it, is a different way to handle complexity. Instead of trying to reduce complexity in the form of new universal approaches that rely on the continuing growth in computing power, the polyocular approach aims to work with concrete problematics in the form of new arenas for handling observations: arenas that are based on second-order observation of the insights of first-order scientific perspectives. Polyocular research is thus an example of a new form of science, a second-order science that incorporates both first-order and second-order research processes.

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Combined References

Alrøe H. F. (2000) Science as systems learning: Some reflections on the cognitive and communicational aspects of science. Cybernetics and Human Knowing 7(4): 57–78.

Alrøe H. F. & Kristensen E. S. (2002) Towards a systemic research methodology in agriculture: Rethinking the role of values in science. Agriculture and Human Values 19(1): 3–23.

Alrøe H. F. & Noe E. (2008) What makes organic agriculture move – protest, meaning or market? A polyocular approach to the dynamics and governance of organic agriculture. International Journal of Agricultural Resources, Governance and Ecology 7(1/2): 5–22.

Alrøe H. F. & Noe E. (2011) The paradox of scientific expertise: A perspectivist approach to knowledge asymmetries. Fachsprache – International Journal of Specialized Communication Vol. XXXIV, 3–4/2011: 152–167.

Alrøe H. F. & Noe E. (2012) Observing environments. Constructivist Foundations 8(1): 39–62. Available at http://www.univie.ac.at/constructivism/journal/8/1/039.alroe

Alrøe H. F. & Noe E. (2014) Communication, autopoiesis and semiosis. Open Peer Commentary on "Social autopoiesis?" by Hugo Urrestarazu. Constructivist Foundations 9(2): 183–185. Online at http://www.univie.ac.at/constructivism/journal/9/2/183.alroe

Andersen E. S. (1991) Techno-economic paradigms as typical interfaces between producers and users. Journal of Evolutionary Economics 1(2): 119–144.

Andersen N. Å. (2003) Discursive analytical strategies: Understanding Foucault, Koselleck, Laclau, Luhmann. Policy Press, Bristol.

Andersen N. Å. (2008) Partnerships: Machines of possibility. Policy Press, Bristol.

Anderson R. L. (1998) Truth and objectivity in perspectivism. Synthese 115: 1–32.

Atlan H. (1986) A tort et à raison. Intercritique de la science et du mythe. Seuil, Paris.

Barwich A.-S. (2014) A sense so rare: Measuring olfactory experiences and making a case for a process perspective on sensory perception. Biological Theory 9(3): 258–268.

Bateson G. (1979) Mind and nature. A necessary unity. E. P. Dutton, New York.

Bohr N. (1985) Kundskabens enhed. In: Naturbeskrivelse og menneskelig erkendelse. Udvalgte artikler og foredrag fra årene 1927–1962. Rhodos, Copenhagen: 19–39. Danish original published in 1957. English translation: Bohr N. (1955) Science and the unity of knowledge. In: Bohr N., The unity of knowledge, Doubleday & Co., New York: 47–62.

Bracken L. J. & Oughton E. A. (2006) What do you mean? The importance of language in developing interdisciplinary research. Transactions of the Institute of British Geographers 31: 371–382

Börner K., Contractor N., Falk-Krzesinski H. J., Fiore S. M., Hall K. L., Keyton J. & Uzzi B. (2010) A multi-level systems perspective for the science of team science. Science Translational Medicine 2(49): 1–5.

Callebaut W. (2003) Lorenz's philosophical naturalism in the mirror of contemporary science studies. Ludus Vitalis 11(20): 27–55.

Callebaut W. (2007) Simon's silent revolution. Biological Theory 2(1): 76–87.

Callebaut W. (2010) The dialectics of dis/unity in the Evolutionary Synthesis and its extensions. In: Pigliucci P. & Müller G. B. (eds.) Evolution: The extended synthesis. MIT Press, Cambridge MA: 443–481.

Callebaut W. (2012) Scientific perspectivism: A philosopher of science's response to the challenge of big data biology. Studies in History and Philosophy of Biological and Biomedical Sciences 43(1): 69–80.

Caporael L., Griesemer J. R. & Wimsatt W. C. (eds.) (2013) Developing scaffolds in evolution, culture, and cognition. MIT Press, Cambridge MA.

Cartwright N. D. (1999) The dappled world: A study of the boundaries of science. Cambridge University Press, Cambridge.

Chen X. (1997) Thomas Kuhn's latest notion of incommensurability. Journal for General Philosophy of Science 28: 257–273.

Clark A. (2008) Supersizing the mind. Oxford University Press, Oxford.

Collins H. (2004) Interactional expertise as a third kind of knowledge. Phenomenology and the Cognitive Sciences 3: 125–143.

Collins H. (2010) Tacit and explicit knowledge. Chicago University Press, Chicago.

Collins H., Evans R. & Gorman M. (2007) Trading zones and interactional expertise. Studies in History and Philosophy of Science Part A, 38(4): 657–666.

Darden L. & Maull N. (1977) Interfield theories. Philosophy of Science 44(1): 43–64.

Dawkins R. (1982) The extended phenotype. Oxford University Press, Oxford.

Favrholdt D. (ed.) (1999) Niels Bohr – Collected works. Volume 10: Complementarity beyond physics (1928–1962). Elsevier, Amsterdam.

Foerster H. von (1981) Observing systems. Intersystems, Seaside CA.

Foerster H. von (2003) Understanding understanding. Essays on cybernetics and cognition. Springer, New York.

Folse H. J. (1985) The philosophy of Niels Bohr: The framework of complementarity. Elsevier Science Publishers, Amsterdam.

Fraassen B. C. van (2008) Scientific representation: Paradoxes of perspective. Oxford University Press, Oxford.

Fuller S. (1988) Social epistemology. Indiana University Press, Bloomington.

Fuller S. (1993) Philosophy of science and its discontents. Second edition. Guilford, New York. Originally published in 1989.

Fuller S. (2010) Deviant interdisciplinarity. In: Frodeman R., Klein J. T. & Mitcham C. (eds.) Oxford handbook of interdisciplinarity. Oxford University Press, Oxford: 50–64.

Fuller S. (2011) Humanity 2.0: What it means to be human past, present and future. Palgrave, London.

Funtowicz S. O. & Ravetz J. R. (1990) Uncertainty and quality in science for policy. Dordrecht, Kluwer.

Galison P. (1997) Images and logic: A material culture of micro-physics. University of Chicago Press, Chicago.

Giere R. N. (1988) Explaining science: A cognitive approach. University of Chicago Press, Chicago.

Giere R. N. (1999) Science without laws. University of Chicago Press, Chicago.

Giere R. N. (2006a) Scientific perspectivism. University of Chicago Press, Chicago.

Giere R. N. (2006b) Perspectival pluralism. In: Kellert. S. H., Longino H. E. & Waters C. K. (eds.) Scientific pluralism. University of Minnesota Press, Minneapolis: 26–41.

Griesemer J. (2002) Development, culture, and the units of inheritance. Philosophy of Science 67: S348–S368.

Hales S. D. & Welshon R. (2000) Nietzche's perspectivism. University of Illinois Press, Chicago.

Hardwick C. S. & Cook J. (eds.) (1977) Semiotic and significs: The correspondence between Charles S. Peirce and Victoria Lady Welby. Indiana University Press, Bloomington.

Harrison S., Massey D. & Richards K. (2008) Conversations across the divide. Geoforum 39(2): 549–551.

Hoffmann M. H. G. & Borenstein J. (2014). Understanding ill-structured engineering ethics problems through a collaborative learning and argument visualization approach. Science and Engineering Ethics 20(1): 261–276.

Holbrook J. B. (2013) What is interdisciplinary communication? Reflections on the very idea of disciplinary integration. Synthese 190(11): 1865–1879.

Hull D. L. (2000) The professionalization of science studies: Cutting some slack. Biology and Philosophy 15(1): 61–91.

Kellert S. H. (2006) Disciplinary pluralism for science studies. In: Kellert. S. H., Longino H. E. & Waters C. K. (eds.) Scientific pluralism. University of Minnesota Press, Minneapolis: 215–230.

Kitcher P. (1998) A plea for science studies. In: Koertge N. (ed.) A house built on sand: Exposing postmodern myths about science. Oxford University Press, New York: 22–56.

Klein J. T. (1996) Crossing boundaries: Knowledge, disciplinarities, and interdisciplinarities. University of Virginia Press, Charlottesville, VA.

Klein J. T. (2004) Interdisciplinarity and complexity: An evolving relationship. E:CO 6(1–2): 2–10.

Klein J. T. (2010) A taxonomy of interdisciplinarity. In: Frodeman R. (ed.) The Oxford handbook of interdisciplinarity. Oxford University Press, Oxford: 15–30.

Koskinen K. (2013) Knowledge production in organizations. Springer, New York.

Krishnan A. (2009) What are academic disciplines? Some observations on the disciplinarity vs. interdisciplinarity debate. National Centre for Research Methods Working Paper Series 03/09. Available at http://eprints.ncrm.ac.uk/783

Kuhn T. S. (1996) The structure of scientific revolutions. Third edition. The University of Chicago Press, Chicago. Originally published in 1962.

Kuhn T. S. (2000) The road since structure. The University of Chicago Press, Chicago.

Ladyman J., Lambert J. & Wiesner K. (2013) What is a complex system? European Journal for Philosophy of Science 3(1): 33–67.

Lakatos I. (1978) The methodology of scientific research programmes. Volume 1: Philosophical papers. Cambridge University Press, Cambridge UK.

Latour B. (1988) The pasteurization of France. Harvard University Press, Cambridge MA.

Levinson S. C. & Majid A. (2014) Differential ineffability and the senses. Mind & Language 29(4): 407–427.

Lipsey R. & Lancaster K. (1956) The general theory of second best. Review of Economic Studies 24(1): 11–32.

Longino H. E. (2006) Theoretical pluralism and the scientific study of behavior. In: Kellert. S. H., Longino H. E. & Waters C. K. (eds.) Scientific pluralism. University of Minnesota Press, Minneapolis: 102–131.

Luhmann N. (1989) Ecological communication. Polity Press, Cambridge, UK.

Luhmann N. (1990) Die Wissenschaft der Gesellschaft. Suhrkamp, Frankfurt am Main.

Luhmann N. (1992) The concept of society. Thesis Eleven 31: 67–80.

Luhmann N. (1995) Social systems. Stanford University Press, Stanford. German original published in 1985.

Luhmann N. (2000) Art as a Social System. Stanford University Press, Stanford.

Læssøe J., Ljungdalh A., Alrøe H. F., Noe E., Christensen T., Dubgaard A., Olsen S. B., Kærgård N. & Kastberg P. (2014) Three perspectives on motivation and multi criteria assessment of organic food systems. Ecology and Society 19(3): 7.

Maruyama M. (1974) Paradigmatology and its application to cross-disciplinary cross-professional and cross-cultural communication. Dialectica 28: 135–196.

Maruyama M. (2004) Peripheral vision – polyocular vision or subunderstanding. Organization Studies 25: 467–80.

Maturana H. R. (2014) Understanding social systems? Constructivist Foundations 9(2): 187–188. Available at http://www.univie.ac.at/constructivism/journal/9/2/187.maturana

Maturana H. R. & Varela F. J. (1980) Autopoiesis and cognition. The realization of the living. Reidel, Dordrecht.

Maturana H. R. & Varela F. J. (1987) The tree of knowledge: The biological roots of human understanding. Shambhala, Boston.

Mesarovic M. D. & Sreenath S. N. (2006) Beyond the flat earth perspective in systems biology. Biological Theory 1(1): 33–34.

Miller T. R., Baird T. D., Littlefield C. M., Kofinas G., Chapin F. III & Redman C. L. (2008) Epistemological pluralism: reorganizing interdisciplinary research. Ecology and Society 13(2): 46.

Mingers J. (2004) Can social systems be autopoietic? Bhaskar's and Giddens' social theories. Journal for the Theory of Social Behavior 34(4): 403–426.

Mitchell S. D. (2009) Unsimple truths: Science, complexity, and policy. University of Chicago Press, Chicago.

Moran J. (2010) Interdisciplinarity. Second Edition. Routledge, Oxon UK.

Müller H. F. J. (2007) Epistemology returns to its roots. Constructivist Foundations 2(2–3): 72–80. Available at http://www.univie.ac.at/constructivism/journal/2/2-3/072.muller

Müller K. H. (2014) Mapping a new and post-disciplinary research frontier – Science and cybernetics at the second-order level. In: Müller K. H., The new science of cybernetics. Volume 4. In press.

Noe E. & Alrøe H. F. (2003) Farm enterprises as self-organizing systems: A new transdisciplinary framework for studying farm enterprises? International Journal of Sociology of Agriculture and Food 11(1): 3–14.

Noe E. & Alrøe H. F. (2006) Combining Luhmann and Actor-Network Theory to see farm enterprises as self-organizing systems. Cybernetics and Human Knowing 13(1): 34–48.

Noe E. & Alrøe H. F. (2012) Observing farming systems: Insights from social systems theory. In: Darnhofer I., Gibbon D. & Dedieu B. (eds.) Farming systems research into the 21st century: The new dynamic. Springer, Dordrecht: 387–403.

Noe E. & Alrøe H. F. (2014a) Sustainable agriculture issues explained by differentiation and structural coupling using social systems analysis. Agronomy for Sustainable Development. Online first.

Noe E. & Alrøe H. F. (2014b) Agroecology and Social Sciences – Regulation of agroecosystems. In: Monteduro M., Buongiorno P., di Benedetto S. & Isoni A. (eds.) Law and Agroecology: A Transdisciplinary Dialogue. Springer. In press.

Noe E., Alrøe H. F. & Langvad A. M. S. (2008) A polyocular framework for research on multifunctional farming and rural development. Sociologia Ruralis 48(1): 1–15.

Norton B. G. (2012) The ways of wickedness. Analyzing messiness with messy tools. Journal of Agricultural and Environmental Ethics 25: 447–465.

Nöth W. (2011) Some neglected semiotic premises of some radically constructivist conclusions. Constructivist Foundations 7(2): 12–14. Available at http://www.univie.ac.at/constructivism/journal/7/2/12.noeth

Ortega y Gasset J. (1961) The modern theme. Edited by James Cleugh. Harper & Row, New York. Spanish original published in 1923.

O'Rourke M., Crowley S., Eigenbrode S. D. & Wulfhorst J. D. (eds.) (2014) Enhancing communication and collaboration in interdisciplinary research. Sage, Thousand Oaks CA.

Palmer C. L. (2001) Work at the boundaries of science: Information and the interdisciplinary research process. Kluwer Academic Publishers, Dordrecht.

Palmquist S. (1993) Kant's system of perspectives: An architectonic interpretation of the critical philosophy. University Press of America, Lanham MD.

Peirce C. S. (1998) Excerpts from letters to Lady Welby. In: The essential Peirce Volume 2. Indiana University Press, Bloomington: 477–491.

Pennington D. D. (2008) Cross-disciplinary collaboration and learning. Ecology and Society 13(2): 8.

Repko A. F. (2012) Interdisciplinary research: Process and theory. Second edition. Sage, Thousand Oaks CA.

Riegler A. (2001) Towards a radical constructivist understanding of science. Foundations of Science 6: 1–30. Available at http://www.univie.ac.at/constructivism/riegler/20

Riegler A. (2005) Inclusive worldviews: Interdisciplinary research from a radical constructivist perspective. In: Aerts D., D'Hooghe B. & Note N. (eds.) Worldviews, science and us: Redemarcating knowledge and its social and ethical implications. World Scientific, Singapore. Available at http://www.univie.ac.at/constructivism/riegler/34

Riegler A. & Scholl A. (2012) Luhmann and the sociological turn in constructivism. Constructivist Foundations 8(1): 1–4. Available at http://www.univie.ac.at/constructivism/journal/8/1/001.riegler

Rittel H. W. J. & Webber M. M. (1973) Dilemmas in a general theory of planning. Policy Sciences 4: 155–169.

Rudolph L. (ed.) (2013) Qualitative mathematics for the social sciences. Routledge, London.

Schaeffer W. (ed.) (1984) Finalization in science. Kluwer, Dordrecht.

Scholl A. (2012) Between realism and constructivism? Luhmann's ambivalent epistemological standpoint. Constructivist Foundations 8(1): 5–12. Available at http://www.univie.ac.at/constructivism/journal/8/1/005.scholl

Sebeok T. (2001) Biosemiotics: Its roots, proliferation and prospects. Semiotica 134(1/4): 61–78.

Shapere D. (1984) Reason and the search for knowledge. D. Reidel, Dordrecht.

Simon H. (1977) Sciences of the artificial. Second edition. MIT Press, Cambridge MA. Originally published in 1969.

Star S. L. & Griesemer J. R. (1989) Institutional ecology, "translations" and boundary objects: Amateurs and professionals in Berkeley's Museum of Vertebrate Zoology, 1907–39. Social Studies of Science 19: 387–420.

Stichweh R. (1992) The sociology of scientific disciplines: On the genesis and stability of the disciplinary structure of modern science. Science in Context 5: 3–15.

Stokes D. (1997) Pasteur's quadrant – Basic science and technological innovation. Brookings Institution Press, Washington DC.

Strijbos S. (2010) Systems thinking. In: Frodeman R., Klein J. T. & Mitcham C. (eds.) Oxford handbook of interdisciplinarity. Oxford University Press, Oxford: 453–469.

Suppes P. (1978) The plurality of science. PSA: Proceedings of the Biennial Meeting of the Philosophy of Science Association 1978(2): 3–16.

Szostak R. (2007) Modernism, postmodernism, and interdisciplinarity. Issues in Integrative Studies 26: 32–83.

Thorsøe M. H., Alrøe H. F. & Noe E. (2014) Observing the observers – uncovering the role of values in research assessments of organic food systems. Ecology and Society 19(2): 46.

Uexküll J. von (1982) The theory of meaning. Semiotica 42(1): 25–79. German original: Uexküll J. von (1940) Bedeutungslehre. J. A. Barth, Leipzig.

van Fraassen B. C. (2008) Scientific representation: Paradoxes of perspective. Oxford University Press, Oxford.

Varela F. J., Thompson E. & Rosch E. (1991) The embodied mind: Cognitive science and human experience. MIT Press, Cambridge MA.

Weingart P. (2010) A short history of knowledge formations. In: Frodeman R. (ed.) The Oxford handbook of interdisciplinarity. Oxford University Press, Oxford: 3–14.

Wimsatt W. C. (2007) Re-engineering philosophy for limited beings: Piecewise approximations to reality. Harvard University Press, Cambridge MA.