Quasi-objects and actors in the web of belief.
Formation of a national nuclear waste management system: the case of Finland

Paper by Ismo Kantola and Marianne Silvan-Lempinen*, presented in ISA RC23 meeting, Gothenburg July 16th 2010*

** Department of Social Research / Sociology, University of Turku, Finland. Communication toIismo Kantola <ikantola [at] utu.fi>*

Introduction

The purpose of the paper is to discuss sociological ways of articulation that would best make sense of an apparent as well as significant cognitive dissonance at the core of a massive technology project: nuclear waste management.

We will first sketch the outlook of the dissonance that we have observed. The empirical data is of two kinds: the almost infinitely malleable public opinion on the one hand and the stubborn facts of the behaviour of radionuclides, bentonite, statistics, bedrock, and the like on the other.

We will then take up various ways of sociologically modelling similar phenomena. In fact, the problematique of cognitive dissonance in communication over differentiating areas of scientific-technological know-how has been known since the classics of sociology.

Finally, we will discuss the role and responsibility of a sociologist witnessing apparently incontrollable expansions of irrationality at the core of the technological basis of our modern world.

Beginning of the dissonance

Nuclear energy producers in Finland want to expand their production. The Finnish authority of nuclear radiation safety, STUK, has found the nuclear waste management Safety Case - which is a *sine qua non of* licencing any new utilities - incomplete thus far and in a way that opens up the discussion about the nature of problems of communication within a multidisciplinary body of scientific expertise (STUK 2010). There are practical difficulties in demonstrating the safety of the proposed disposal system. The system can be divided in subsystems that evolve simultaneously and interact with each other. The interactions make the analyses extremely complex and difficult, and Posiva, the company in charge of the final disposal of the waste, has to work hard to give satisfactory descriptions of them. The STUK has pointed this out in its response (STUK, 2008) to the report describing Posivas's view of the expected evolution of the repository (Posiva, 2006):

"The most substantial weakness of the report is that when each process is scrutinised the other components are assumed to behave ideally and alternative, but very probable chains of events are ignored."

Assessing the behavior of the spent fuel is a complicated task and can be done only in limited exactness (Anttila 2005). Yet plenty of reliable characteristics can be presented. The most significant sources of radiation are C-14 (carbon 14), Cs-137 (cesium), Sr-90 (strontium), and Pu-241 (plutonium). In the course of time the picture changes quite much except that C-14 remains the most active source of radiation. (see: Anttila 2005, 158, 299.) When the burnup of the fuel is increased the picture changes quite much. (cf. Anttila 2005, 216, 301.)

Preparing the Safety Case is a multidisciplinary research project hosting specialists from several fields of science. To name a few of the specialties, the following list can be provided: geology, hydro-geology (ground water flows), geochemistry (chemistry of ground water etc), radio chemistry (chemistry of radioactive releases), geo- and rock engineering (building the undeground repository), chemistry and physics (materials science), mathematics and computer science (numerical simulations), biology (microbial activity in the near field of the waste canisters and analysis of effects on biosphere).

In 2001 unresolved issues deserving inspection and research effort within the nuclear waste management programme were questions of reprocessing, transmutation and long term storage; principles of safety and radiation protection, retrievability of the final disposal, breaking into the final disposal premises, environmental impact assessment, monitoring the final disposal premises; cost estimates of nuclear waste management, safety accounts of nuclear waste transport and decommissioning nuclear utilities; improving preparedness for long term safety assessment, finding means of targeting limited investments in safety assessment optimally; reducing uncertainty in the subsystems of safety, developing and testing new tools and methods for nuclear waste management. (Rasilainen 2001.)

Objects of concern were the uncertainty of the behavior the bedrock of final disposal premises and the combination of effects of phenomena of several domains of activity and the corresponding fields of expertise. Development of methods of the analysis of uncertainty was hoped for. The choice of scenarios was admitted to be of importance in communication to the outsiders (the concept of 'outsider' was not specified). Scenarios were appreciated as a means of reflecting ways of exposure to radiation. In 2001, making a drilled well was the most common case of assessing intrusion to the final disposal premises.

The effects of the chemical conditions of the final disposal premises on the canisters containing the spent fuel were of concern in 2001. Developing barriers to possible releases of radionuclides from the canisters of spent fuel were on the agenda at that time. A central barrier, the proposed filling material of the final disposal premises, bentonite, was of concern with regard to its thermal hydro mechanical behavior which was still unknown. Microbes and colloides were there waiting for the leakages of radionuclides through the bentonite coat. The effects of an ice age were of concern, too.

Deforming of chrystallized forms of the bedrock was of concern. Integrating the results of modelling and geochemical interpretation of ground water flows into an internally consistent total interpretation of the research site was on still the agenda. Paleo hydro geological research was appreciated.

Assessing the future dispersion of radionuclides in the bedrock was stated as a central task in the development of the a safe national nuclear waste programme. Designing and developing methods for it was singled out in several places of the research programme of the National Nuclear Waste Programme (KYT) in 2001.

Several of the problems have been solved during the past decade. New problems, however, have emerged - problems that were not anticipated in 2001.

The so called fifth reactor which is presently under construction will apply increased burnup of the fuel. The fact has not been much publicly discussed although it poses remarkable new problems to be solved for the Safety Case. New research topics in preparing the Safety Case since 2006 are the following ones. New types of reactors complicate possible reactions of the spent fuel because of the higer enrichment levels. New possibilities for canister corrosion have emerged.

Maybe the biggest new topic is erosion of the buffer material and the tunnel filling. It is extremely important that there are no flow paths for the ground water from the canisters towards the biosphere. Erosion can create these. Mineralogical alteration processes of bentonite (the filling material) seem to be more complicated than previously thought. The buffer can freeze during glaciation. This possibility and the changes it causes were not previously taken into account.

In addition to these, there are other (maybe) less significant topics.

Ways of understanding distortions of scientific communication

Since different parts of the system are analysed by experts of different fields, multidisciplinary communication poses additional difficulties in description of the interactions. Multidisciplinarity entails the problem of overcoming inherent incommensurability between participant disciplines. Public relations in turn are burdened by the management task of a double picture of science (cf. (Fuller 2000)).

Not all problems of communication within science can be tracked down to the phenomenon of incommensurability between fields of science. In practice, however, incommensurability of concepts and whole paradigms should not be overlooked. By paradigm we mean the special way of thinking, of posing problems, framing and demarcating fields of study, the perceived relevance structure of different methods and practices, as well as a specific scientific way of seeing the World. Incommensurability in turn simply means nontranslatability of scientific information between paradigms. Instead of the no doubt most renown proponent of the concept of incommensurability, in his book "The Structure of Scientific Revolutions", the historian of science Thomas S. Kuhn, we prefer to refer to Ludwig Wittgenstein's ideas about the relation of language to its referent.

The Wittgensteinian approach attaches meaning to words by observing their use in a context that provides linguistic communication with a motivation. Such a context Wittgenstein calls 'lifeform'. It is a common life-form which warrants that the use of language makes sense. We may also infer that where the commonness of the life-form would turn questionable there should problems of communication resulting from ambiguities of meaning ensue, too. If we can think the scientific practice as constituting a separate 'life-form' distinct from any practices and ways of thinking outside scientific projects, research processes, and their peer reviewed public discourses then the following elaboration of a partial explanation of the origins of communication problems within modern science may make sense.

The specialization of science into distinct fields of research can be seen as a process of divergence of a common scientific life-form into distinct subdisciplinary life-forms consisting of unique practices relevant only in relation to the scope of relevant objects (object domain) to be studied or - from a Foucauldian point of view - to appear in the field of study in question. There is the pragmatic imperative of demarcation in every domain of scientific research. This is not inconsistent with the empirically observed increase in the division of labour in science (Gibbs, 2003).

There are also several logical aspects that justify assuming science as a practice distinct from non-scientific cognitive practices. The opening up of these aspects is more or less concomitant with attempts to resolve the following problems. Firstly, there is the general problem of induction, i.e. the fact that there is no principle of induction that is absolutely true (Popper 1963; Sismondo, 2007, p. 3). Secondly, the Duhem- Quine thesis posits a problem of deduction by showing that a plethora of confusing factors can intervene otherwise consistent logical deductions (Sismondo, 2007, p. 5). Thirdly, the problem of under-determination is potentially present in every empirical research that aims to find a theoretical explanation to observed data. Fourth, the problem of foundationalism says that it is not possible to maintain, without an unfounded commitment, a belief that scientific knowledge (or any knowledge for that matter) can be tracked back without a residue to firm foundations

(Sismondo, 2007, p. 15). Fifth and final, theory construction may be seen as a powerful and at the same time an incontrollable asset of scientific progress. By taking seriously the theory-dependence of empirical observations as well as their interpretations (Feyerabend, 1975; Tudor, 1982) it is easy to see both why theory is important and how it may become problematic as a motor of scientific progress at the same time.

As we have already noted, there are also more pragmatic than purely logical reasons for the emergence of incommensurability within science. Whitley (2006, p. 29) observes that incommensurability may result from differentiation rather than from scientific revolutions. Differentiation in terms of a paradigm shift may be a means to succeed in academic competition. By indicating that there may be more or less natural reasons for communication problems or incommensurability between fields of scientific specialty we do not deny the possibility of overcoming these limitations. We believe that there are limits to incommensurability (cf. (Sismondo, 2007, p. 17)) but at the same time efforts and resolute action will be needed in order to succeed.

In the area of popularization of science as well as within basic academic or, for that matter, nonacademic curricula on science there is the tradition of presenting a modified truth for so called unprepared minds about science. I.e. for audiences well versed in science a different story is told from that which is presented in the presence of a lay public (Fuller, 2004, p. 22; Fuller, 2000, pp. 27, 32- 33, 92-23). An important point of diffraction is the presence and absence of contemporary and /or still relevant past scientific disputes in the narratives about scientific progress.

Despite the problems of internal and external communication of science, a vital part of scientific practice is that it deals with the relation of the unknown to that which is known, in other words, with uncertainty in our knowledge. Investments in science are motivated not only by aspirations to get more funding for research by inventing new problems, uncertainties, or terra incognita at the proxy of vital interests. Science is first and foremost expected to help finding solutions to problems, to reduce the area of the unknown, or make uncertainties manageable.

In the field of nuclear energy, the parliamentary imperative has its raison d'étre in the fact that uncertainties in the production of nuclear energy are such that a significant part of the risks of this activity must be externalised in order it to be paying back. In principle, the risks to be externalised must be less than the benefits from nuclear energy to those people and processes that will be exposed to the risks in question. Otherwise, the parliamentary licensing of the activity would be jeopardised. We refrain from touching the important issue of transnational liability in this paper. Needless to say, the assessment task which opens up here on the relation of risks and benefits spans a vast field of inquiry in which several fields of scientific and technological expertise are understandably expected to engage. Thus the problem of internal as well as external communication has hopefully been theoretically posited as a relevant issue with regard to nuclear waste management.

In addition to the sources of distortion of communication described above, tacit knowledge constitutes a problem of its own kind related to communication. Tacit knowledge is knowledge that cannot be captured or transferred in any formal way (Polanyi, 1966; Nonaka and Takeuchi, 1995). In the nuclear waste disposal project, it appears as expert judgements that are not justified by documented reasoning. It is stated in response letter of STUK (2008) to Posiva's so called Evolution Report (Posiva, 2006):

”The arguments behind the conclusions made in the report are difficult to assess in some cases, because they possibly exist but are not presented, or they are not mentioned and therefore remain as working hypotheses. ” --- ”In the present form, the report represents primarily a qualitative description based on expert judgements, which Posiva is required to support by quantitative analyses that include different kinds of interactions.”

Posiva is going to include an elicitation and validation process of expert judgements (Hukki, 2008) in its procedures. The process is very time consuming and requires a lot of human resources. By the end of year 2009, no documents were published on success of this process thus far.

The public trust

The parliamentary imperative stresses the importance of a well-informed public opinion. Typically, those in managing positions as well as those who are well educated do have a more rational than purely emotional attitude toward issues of nuclear energy (Kantola, 2007, pp. 53-55). However, as regards the Finnish public opinion about the safety of nuclear waste disposal, the constellation of opinions and the qualities of the respondents opens up quite differently. What follows is based on a reanalysis of the data of a survey made in 2005 (Kiljunen, 2007).

To give an aspect to the role of knowledge, it is useful first to look back at the stage of the disposal project at the time. In February 2005, Posiva published a plan for the Safety Case (Posiva, 2004). The Safety Case is a collection of documents that proves the safety of the system at the level required by the legislation. This plan was updated in 2008 (Posiva, 2008). It is clear that the safety of the system was not demonstrated in 2005. Therefore, belief in safety of the system could not be based on knowledge. Other explanations can be found by analysing attitudes towards technology. The survey was conducted in 2005 and it was commissioned by TVO and Fortum, which was formed when IVO and the oil company Neste merged in 1998. There were a lot of questions that did not concern nuclear waste in the survey, which opens up an interesting opportunity for analysing relations between attitudes toward different aspects of technology and knowledge in the context of the given attitudes toward nuclear waste safety. The results are based on answers of 1240 persons. About 36 per cent of the respondents believed in the safety of a deep geological repository. It means that they completely or somewhat agreed to the claim “Nuclear waste can be safely disposed in Finnish bedrock”. About 42 per cent of the people completely or somewhat disagreed. Mode of the answers was “completely disagree” with 27 per cent of the answers. About 40 per cent of the respondents thought, that it would be better to hold the waste in interim storages and wait for better solutions. In 2005, about 64 per cent of the respondents considered nuclear waste as a continuous threat to the future generation and 20 per cent of them thought that it does not constitute a significant threat. These figures had changed from the results in 1997. One explanation is that memory of the Chernobyl disaster was slowly fading.

When the answers to the questions about safety of nuclear waste are analysed against the background variables, significant variation can be observed. Especially interesting are the relations to education and gender. Firstly, confidence in safe disposal increases with rising level of education. As noted before, this cannot be explained by knowledge, since only modest details of the Safety Case were available. More likely, education shapes attitudes toward science and technology in general by increasing trust in authority granted by education. Secondly, women and men have almost opposite distributions of answers with clear majority of female respondents not believing in the safety and about half of the men having trust in Finnish bedrock. How does this relate to male rationality and emotionality of women? Since rationality can be ruled out, the explanation that remains is that the genders have different values and emotional associations when safety issues are considered.

Cross-tabulating answers can yield deeper insight to the values and attitudes involved. One factor is the experience of being empowered or not. About 28 per cent of respondents agreed completely to that citizens’ opinions had not been sufficiently heard in energy politics. About 75 per cent of those did not believe in the safety of the repository plan, but 70 per cent of the minority believing in the power of the citizen’s voice trusted at least somewhat in the safety. A second factor is the attitude toward technology. It is rather obvious that those who strongly oppose to nuclear energy are also very sceptical to the deep repository plans. More interesting is the result obtained by comparing belief in the safety of the disposal plans and attitudes toward alternative energy sources. Majority of those who think utilisation of solar power is possible in near decades completely disagree to the safety claim. About 57 per cent of those who completely agree to the claim ”Alternative energy sources such as wind and solar power could be taken into wide use in our country already rather soon if only there be willingness to funding research and development concerning them” find nuclear waste repository completely unreliable. Only one fourth of those who thought windmills are ugly had a negative attitude toward the DGR. Obviously, the respondents can be divided in those who support ”soft” those who support ”hard” technologies. ”Soft” technologies bear low environmental risk and are relatively simple, whereas ”hard” technologies involve risks and are highly complex. This can be posed in another way: cheap, small and simple units against expensive, big and powerful. Third important factor consists of economy and current standard of living. Majority of those who thought that reducing consumption is the solution to energy problems found the deep disposal an unsafe solution, as well as three quarters of those who did not believe in significant increase in electricity demand. These respondents were also sceptical to requirement of low price of energy.

Sources of disagreement

In discussing the disagreement of scientists studying environmental issues, Sundqvist (1990, 23) distinguishes two kinds of scientific controversies: those based on the specialization of researchers into different areas of research and those based on scientific uncertainty. According to him, both of these factors of disagreement are omnipresent for all scientific practice.

Elsewhere, the topic of differentiation of scientific praxis as well as of scientists disagreement about the methods of dealing with uncertainty has been amply exposed. Recently, the first one has received an increasing amount of scientific as well as political attention thanks to policies aiming at enhancing multidisciplinary research as a means of producing innovations. Instead, issues of dealing with uncertainty seem to receive a relatively small and constantly diminishing amount of attention. Yet there is, as it seems to us, a wider body of accumulated scientific literature on issues of uncertainty than on issues of multidisciplinary communication.

Inherently multidisciplinarity is, we think, more economic than political. A contrast to that, scientific uncertainty seems to have a much more direct connection to politics. Resolving a dispute about uncertainty - the choice of rules for defining limits to acceptability of exposure to harmful materials, processes, etc. - is greatly reminiscent of finding a political solution for conflicting interests. Instead, the case of multidisciplinarity opens up itself better as an economy of constellation of discourses, as in Foucault (1969, 92-93).

As to the controversy on uncertainty, we think, Shrader-Frechette (1991) is an elegant analysis the problematique. There is the Scylla of social constructivism and the Charybdis of naive positivism. In between them the author shows a third stance: scientific proceduralism (Shrader-Frechette 1991, 29-52). The solution looks much like the project of social epistemology (Fuller 1988; ibid. 2000; Fuller & Collier 2004). At a closer look, the crucial elements of scientific proceduralism or social epistemology were there already in Scheffler (1972): "objectivity requires simply the possibility of intelligible debate over the merits of rival paradigms" (quoted in Shrader-Frechette 1991, 52).

Innovations meet standards

As a part of scientific practice, standards of validation of knowledge resemble systems of accounting (Latour 2007, 229). Standards dictate which elements are taken into account or internalized and which elements are externalized, i.e. not taken into account. Standards also have a moral task: they allocate the burden of proof among the actors. The fact in turn that different domains of science and technological expertise obey different standards of valid knowledge pertains to problems of communication within multidisciplinary projects.

Standards constitute economies (Latour 2007, 229-230; Callon 1999). With the help of expanding metrological chains economies attain globality - if not universality! Innovations, instead, are always local. Obviously, their locality is more or less at odds with the universality of global metrological chains or systems of accounting.

Powerful innovations have the capacity of changing the standards. Likewise, an innovation that does not change any standard at all must be doomed to be forgotten as a curiosity or some such. Paradoxically, perhaps, both entrepreneurs (industrialists) and scientists pursue innovations as a vital part of their professional activity. In this respect they continuously risk the very standards on which their practices are based. However, the paradox disappears once the capacity of successful innovations to change the very standards is considered. For the entrepreneur as well as the scientist a successful innovation, of course, must mean a better social standing. Actually, entrepreneurs as well as scientists can be said to have vested interests in changing the standards of validation as well as valuation.

The interdisciplinary trust in multidisciplinary projects has been granted a vital role with regard to the success of those projects. Likewise, explanations of failure of such projects often blame distrust. Trust in this respect is clearly akin to the web-shaped belief outlined in Quine & Ullian (1978). And what is more, both can be translated into 'Latour-speak' as quasi-standards (see Latour 2007, 229).

Now, quasi-standards do not easily fit with the requirements of validating the Safety Case. Consisting of a set of documents the Safety case is expected to prove the safety of the proposed method of dealing safely with the nuclear waste. The proof is expected to obey the standards of validation of scientific knowledge.

Trust, belief, commitment, and loyalty tend to contradict critical discussion, openness, and receptivity to reasonable changes in the course of action or thought. Defending vested interests may entail concealing items (facts) relevant for fair reasoning. What, then, is the place of science as self-reflective critical discussion? After all, does it not seem to be the case that critical scientific discussion does not fit well at all into the scheme of nuclear waste management?

Considering this kind of problematique sociologically one can bear into one's mind that the relation of trust and critical reasoning has a central place already in the thinking of the classics of sociology: Marx, Weber, and Durkheim. For Marx, rationality and critical thinking is subsumed to the dynamics of the relations and forces of production. For Weber, the end state of rationalization is the adoption of economic rationality in every sphere of life. For

Durkheim, it is the very process of rationalization in the form of an increasingly specializing division of labor that will give irrationality (i.e. trust, belief, commitment, and loyalty instead of critical discussion and open reasoning) an increasingly important place at the core of modern societies.

A more recent scene of different but at the same time meaningful sociological articulations of the relation of critical communication and trust opens up in the thinking of Jürgen Habermas about the ideal conditions of rational communication and Niklas Luhmann with his idea of a perfect system of communication. While the first one yields a consensus truth the latter substitutes subsystemic resonance for knowledge.

Discussion

From the classical sociological as well as the more modern perspectives of rational communication and linguistic systems the problem of nuclear waste, perhaps, takes the form of a twist in ideology (Marx), a defect in economization (Weber), a threat to social integration (Durkheim), a distortion of communication (Habermas), or a confusion of the subsystemic division of coding labor (Luhmann).

While each of these sociological orientations may well capture some of the essential features of the nuclear waste problem, a common problem for all is the role of the non-human actors in the dynamic network of nuclear waste which remains unelaborated. Fortunately, today we have STS and especially its Latourian branch which has taken the task of giving a voice to the non-humans too.

At its best, STS not only gives voice to the muted ones but voices the veiled interests as well. To do this, any STS of nuclear waste will need substantial funding from sources independent of institutions and companies in charge of constructing and monitoring the system of nuclear waste management.

Finally a short comment on the Internet and its usability in issues of develepment. It seems to be the case that although the Internet is a revolution in communication it contains too much information for the citizens concerning the forming of a knowledge based opinion. Interpreting knowledge, especially when it is hidden behind scientific or technological jargon, requires discussion in which also experts and specialists must take part. Anonymity facilitates discussion but also decreases its reliability. Although practically all the expert knowledge is now available to everyone in the Internet, extension of discussion and the process of decision-making into the sphere of expertise - into the very knowledge formation of the experts - has not substantially advanced within the case of the final disposal of nuclear waste in Finland. Reason for this may be that Internet is a young structure and as such apparently still immature. Developing countries will have a good chance to learn from mistakes already made elsewhere while investing in content production as well in the instruction for it. As an object of research in this context China would be extremely interesting although such a project would probably be very difficult to accomplish.

The case of making a parliamentary decisions in nuclear energy related issues shows that there is too much information in the Internet from which it is difficult to filter out knowledge on the basis of which to make conclusions. The Web is a good source of knowledge but it is very difficult to get to grips with the right kind of knowledge via the Web. All knowledge available is not necessarily essential with regard to forming a reasonable opinion within the scope of a finite set of questions.

The nuclear waste problem is characteristically interdisciplinary (Mays & Poumadere 1996, 139). It is the very long time scale involved in the disposal of the highly active nuclear waste that turns out to be a major source of uncertainty. In principle, the behaviour of nuclear waste over long periods can be predicted by applying mathematical modelling on the basis of physical facts (see e.g. Anttila 2005). Uncertainty enters the picture when modelling the local contexts in which the waste should be stored. The divergence of epistemological positions of the special fields of scientific expertise necessary for a comprehensive grip of the local situation now poses yet a different kind of uncertainty (c.f. Mays & Poumaderie 1996, 139). As such nuclear waste fits the characteristics of a Latourian hybrid or a quasi-object. To the extent that the missing links of the metrological chain of the Safety Case are being substituted by general trust in science, scientific progress, and technological expertise it may be justified to characterize the system of the Finnish National Nuclear Waste Management System as a hybrid of the web of belief yielding public trust and the piecewise metrological chain expected to be a consistent whole while not being one.

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