Changing views of innovation and the role of science. The 'socio-technical root-system' as a tool for identifying relevant cross-disciplinary research questions

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Abstract

This paper reflects critically on the role that natural and social scientists may play in innovation processes towards sustainable farming systems. The emphasis is not so much on 'assessment tools' for sustainability, but rather on tools for improving cross-disciplinary socio-technical problem analysis in interactive trajectories. This with the purpose of arriving at more relevant and better co-ordinated research agendas across disciplines, enhanced social learning, and adequate diagnosis for policy interventions.

First, the paper discusses several shifts with regard to the conceptual understanding of innovations and innovation processes. Subsequently, it is argued that the processes that need to be supported communicatively in the context of innovation are network building, social learning and conflict management. Thirdly, the paper discusses the implications of this mode of thinking for the role of scientists. It is proposed that a key role of scientists is to explicate implicit assumptions, claims and knowledge gaps in social learning processes, and to engage in collaborative research with societal stakeholders on a coherent set of natural and social science questions. The third part of the paper discusses a specific methodical approach for making a socio-technical problem analysis, aimed at integrating and explicating insights from social scientists, natural scientists and societal stakeholders.

1. Introduction: Evolving thinking about innovation and change

Over the years, ideas about innovation and change have evolved considerably. The original hypothesis that innovations are developed by scientists, disseminated through extension and education and then put into practice by farmers and the public is called the linear innovation model, and has been refuted by many (Kline & Rosenberg, 1986; Röling, 1996; Rip, 1995). When one analyses successful innovation processes in retrospect, it is apparent that many ideas originate from practical experience and that the role of science is often limited. Successful innovations appeared to be based on the effective integration of the problem perceptions, knowledge and experience of scientists, clients, intermediaries and other parties involved.

Not only have the ideas about the origin of innovation changed, but also the ideas about what an innovation actually *is* are susceptible to transformation. It is now recognised that innovations do not just consist of new technical arrangements (e.g. a plough) but also of new social and organisational arrangements, such as new rules, perceptions, agreements and social relationships (see e.g. Van Schoubroeck, 1999). This means that there are always many different stakeholders involved. Innovation is a collective phenomenon in which social dilemmas and tensions are always likely to come to the fore. This means that it is not very useful to look at 'adoption' as something that happens at an individual level (as we thought in the past, see e.g. Rogers, 1962). What is important are the co-ordination and

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interdependencies between people. Thus, an innovation can be defined as 'a new pattern of co-ordination between people, technical devices and natural phenomena' (see also Roep, 2000).

Finally, the thinking about innovation as a *process* has also changed dramatically over the past decades. In former days there was a strong belief in the possibility of planning and predicting change and innovation. In contrast, we now see that change is affected by complex inter-dependencies, fundamental uncertainties, chaos, unintended consequences, conflicts and unpredictable interactions that cannot be understood from a reductionist perspective (Prigogine & Stengers, 1990, Holling, 1995). In connection with this, innovation processes are looked at nowadays from an evolutionary perspective. The idea is essentially that a variety of innovations and innovation processes compete in a dynamic selection environment in which the 'best fitting' survives (Bijker et al., 1987; Rotmans et al., 2001). What can be learned from this, among other things, is that sufficient variety must be created if one wishes to solve problems; it is important to back a number of horses (Van Woerkum & Aarts, 2002).

Implications for the role of communication

Against the background of these conceptual transformations there have been radical changes in ideas regarding the role of communication in innovation processes. The focus has shifted from using communication as a means to transfer and effectuate knowledge, innovations and policies developed from the top down, to the study and organisation of communication and interaction in order to arrive at common starting-points, fitting and acceptable innovations and cogent policies. Thus, ideas about the role of communication have undergone a 180-degree change in direction. Along with this, participation became an ever more important subject in research and in practice (Röling, 1996; Röling & Wagemakers, 1998; Van Woerkum, 1997). Within 'participatory' processes for arriving at 'new pattern of co-ordination between people, technical devices and natural phenomena' (i.e. innovations), three (simultaneous) processes deserve particular attention and communicative support.

(1) network building

The first process is that of the building of *networks*. Innovation requires co-ordinated action within a network of people. Such a network does not just spring into existence; it needs to be 'constructed'. And because renewal and innovation are at issue here, it will be evident that there is often a need for the forging of new relationships, both in terms of the parties involved and in terms of content (Engel, 1995), and for using these to expand windows of opportunity. This may sound simple, but it is often not at all easy because, for instance, existing networks tend to close their doors to 'outsiders', or because certain parties just do not feel that they can be of any use to one another.

(2) social learning

At the same time that the building of a network is taking place, something that can be described as a *social learning process* must also occur. This means that the parties involved slowly develop overlapping -or at least complementary - goals, insights, interests and starting-points (Röling, 2002), and also build mutual trust and feelings of dependence and responsibility. This is not 'learning' in the sense of 'knowledge transfer' or 'teaching'; rather it is about the development of different perspectives on reality through interaction with others. It is not just a question of cognitions about the natural and physical world but also of perceptions regarding one's own aspirations, abilities, responsibilities and space for manoeuvre, and of other people's views of reality (Leeuwis, 2002). Exploration of different perspectives is vital in such a learning process because it is a very important route to 'reframing' (Gray, 1997): learning to look at a situation and one's role in it in a different way.

(2) negotiation

A third process is that of negotiation and conflict management. Innovation implies changes in the status quo, which is always accompanied by friction and tension, especially in the case of innovations that go further than just optimisation within established frameworks and goals. Such innovations, which are characterised by the letting-go of existing starting points, goals and assumptions are also known as 'system innovations' or 'transitions' (Rotmans et al., 2001). This kind of innovation and change brings with it, by definition, conflicts of interest between the parties involved and also with the established social and technological system or 'regime' that in many ways needs to be 'conquered' (Rip, 1995). In order to deal with such tensions, and in order to make new agreements and social arrangements, negotiation is essential. Preferably integrative negotiation based on a social learning process (Aarts & Van Woerkum, 2002).

In view of the above, these three processes should guide and direct communicative intervention aimed at supporting innovation. This means that communications experts must lend their support to a large number of tasks that can be derived from theories about network building, social learning and negotiation. Tasks that are of great importance from the point of view of social learning might be: making the invisible visible, organising comparisons between different contexts, setting up experiments and facilitating exploration. A variety of communicative methods exist to support all this, ranging from dialogue and discussion techniques to model-based explorations (see Leeuwis with Van den Ban, 2004). In addition, negotiation literature emphasises tasks such as the making and keeping procedural agreements, joint research and uncertainty reduction, guiding the give-and-take process, communication with constituencies and monitoring the observance of any agreements reached (Van Meegeren & Leeuwis, 1999). I deliberately do not use the word 'phases' here because we are dealing with issues that remain topical throughout the lifetime of the process. Moreover, in the context of innovation, learning processes happen on a variety of fronts, and negotiation takes place with regard to a range of issues, and at different social levels. In short, we are dealing with complex and capricious series of interrelated events, with inherently unpredictable dynamics and results, the course of which can never be planned or controlled by a communications expert or facilitator. Communications experts can, however, monitor the process and can facilitate progress at certain points. In the next section, then, we reflect on the implications for another important category of relative outsiders: scientists.

2. Knowledge and the role of the scientist in innovation

In innovation processes we are essentially faced with the challenge of linking all kinds of forms, domains, sources, and bearers of both knowledge and ignorance to one another. In connection with this it would be overly simplistic to consider 'knowledge' as being only a mental capacity. Knowledge and action are two sides of the same coin; a lot of knowledge seems to be 'stored' in our bodies and in the things around us, and is expressed through our actions, without our even consciously or actively reflecting on it (Giddens, 1984). Knowledge is therefore often implicit; a large part of what we think, know, feel and are able to do is difficult to put into words. And even when we *are* able to put into words -i.e. if we communicate with others- we are usually more or less strategically selective in the words we use. Knowledge is, in short, an extremely elusive phenomenon. In light of this, how should we define the possible role of science? And what about the relationship between the natural and the social sciences?

Before addressing these questions, it is perhaps important to establish what we understand by the term 'science'. I would characterise scientific research as a subculture in which much importance is given to the development of original, valid and credible conclusions about reality. Within the scientific community, there exist all kinds of epistemological subdivisions because there exist large differences between various groups of scientists regarding the way in which they arrive at their conclusions and the kinds of pronouncements that they make. For this reason I prefer to use the phrase 'scientists' knowledge' rather than 'scientific knowledge'.

Role perception from an innovation perspective

Scientists in the domain of agriculture and natural resource management often have to deal with complex connections between technical, ecological, economic and social systems. There is much unpredictability and uncertainty and there are divergent values and interests at issue. This is precisely the kind of situation in which the philosophers Funtowicz & Ravetz (1993) argue for a post-normal approach to science, instead of a strategy in which science is only applied for the 'solving of puzzles' or the giving of situation-specific advice. With post-normal science, the scientists themselves are intensely involved in societal processes, discussions and innovation. In other words, in processes of network building, social learning and negotiation.

In such contexts, the reaching of an agreement between the parties is often hampered by a lack of insight into certain issues or because there is a high level of uncertainty in technical and/or social areas. It is also possible that the available insights are not sufficiently explicit. All kinds of implicit claims to knowledge, assumptions and knowledge gaps are concealed in any communication between the parties. It can be important to make these explicit and open to discussion in order to assist the advance of an innovation process. This is not at all an easy task and will never be completely successful. Not only process facilitators but also scientists from various disciplines can play an important role in this respect. One may expect scientists to have a certain sensitivity regarding implicit assumptions, claims and knowledge gaps in their own areas of expertise. A serious dialogue between scientists and societal stakeholders, in which the different parties have the opportunity to ask each other difficult questions, can contribute to making explicit previously implicit issues. If knowledge gaps also arise during this dialogue then the presence of researchers will naturally be helpful in developing answers with the aid of research. From the point of view of negotiation, conducting joint research is what most relevant. That is; research in which various stakeholders are involved closely in the refinement of research questions, the choice of methods and the fixing of the research location (a laboratory, an experimental station, a computer model or a field situation). This is because it is important not only to generate answers, but also that the parties involved have confidence in the results. In addition, collaboration in carrying out research can contribute to an improvement in the relationship between the stakeholders involved (Van Meegeren & Leeuwis, 1999).

This does not imply, however, that nothing remains of the individual responsibility and autonomy of the researcher. Here it is relevant to note that a crucial trigger for social learning is feedback. In innovation processes, therefore, both natural and social scientists can stimulate learning processes by providing - more or less confrontational- feedback at their own discretion. They can provide not only insights based on research with reference to that specific situation but also those gleaned elsewhere, or they can make projections about the future or point to radically different technological or social solutions.

The status of knowledge contributed by scientists

Some natural (and also social) scientists may have winced when reading the above. Not so much because I attribute a somewhat modest role to scientific researchers in innovation processes -many natural scientists are far more modest about their role than at times portrayed by social scientists- but because I have given very little attention to the role of scientists as 'referees' in situations where conflicting views on reality are at issue. Is it not the task of science to bring the truth to light? In my experience, many natural scientists feel threatened by the idea that reality is something that is constructed. It could, after all, lead to a situation where the scientist's perspective is pushed aside as being just one of the many equally valid views on reality! This is not what I am advocating. It seems to me that it remains possible and important to differentiate between sense and nonsense, and between more and less well-founded views on reality. In my opinion, the essence of constructivism is not so much that every truth is relative but rather that every truth has its limits and also that in everyday life neutral truths do not exist.

When, for example, a laboratory experiment shows a link to between the presence of the nitrogen fixating bacteria Rhizobium and crop growth, this can lead to a conclusion that is valid within the context of the experiment. That is to say: given a particular type of soil, particular climatic conditions, a particular labour input, a particular form of crop protection, a particular planting date, etc. In other words, the conclusions drawn from the experiment are only valid within the limits of its context. Many of the conditions outside the laboratory and/or experimental station will most probably be quite different. When knowledge that is valid within a certain local context (the laboratory or experimental station in this example) is transplanted directly into a different local context (an agricultural region, for example) there are bound to be problems. To put it bluntly: scientific knowledge too is a form of local knowledge.

One important aspect of such local specificity is connected with my second point; namely, the fact that neutral truths do not exist. This has to do with the fact that a particular research initiative is usually brought about by a particular issue. The question of whether there is a link between the presence of Rhizobium and crop growth is not at all a neutral one, but arises from a certain problem perception and is therefore linked to social aims. It is not a question that is likely to be brought up by the fertiliser industry but it is likely to be asked by organic farmers and development organisations. And if questions are not neutral, then the answers will not be either. Answers are used by people as 'weapons' in a 'struggle' with other interests; so it matters for which questions scientists try to formulate answers, and for which not.

In a nutshell, scientists have to realise that their knowledge has a local character and is not neutral. In connection with this Alrøe & Kristensen (2002) argue for a 'reflexively objective science' in which scientists not only realise this but make it explicit and transparent. In other words, scientists should be expected to open up the hidden dimensions of their own research questions and knowledge to discussion. Such transparency does not mean that scientists will become politicians. The opposite is true, in fact. When scientists are clear about underlying social values and goals it can only become more obvious that conflicts of interest cannot be settled by scientists and that it is up to societal stakeholders, authorities and politicians to judge the value of the different view points and to make decisions.

Working across disciplinary boundaries

The foregoing is also connected with the manner in which co-operation between social and natural scientists can take shape. The essence here, according to me, is that natural and social scientists influence and refine one another's assumptions, research questions and action plans. In other words, it is about putting the most relevant non-neutral questions on the agenda. These can also be very 'fundamental' questions. One example of such mutual influencing can be taken from the 'Convergence of Sciences' project that is being co-ordinated by the entomologist Arnold van Huis, in which nine doctoral students are being guided by both natural and social scientists from Wageningen University and universities in Ghana and Benin.

In an initial investigative stage of this project, the researchers in Ghana came across a complex crop-rotation system in which farmers attributed soil-fertility enhancing properties to a certain variety of cassava. This was interesting, because it ran directly counter to the accepted theory that cassava actually exhausts the soil. Doctoral student Samuel Adjei Nsiah set out to examine this system in greater depth and, where possible, improve it. Spurred on by his interest in the social aspects of this innovation, he eventually discovered that the rotation system is mainly applied by the native population of the area and not by the migrants who come from the north of Ghana. The latter are aware of the system but usually cannot apply it because they own no land and the locals will only agree to short-term leasing contracts. The latter, then, is associated with specific attitudes to money, inflation, the land tenure system, mutual distrust and with the role played by the local authorities (Adjei Nsiah et al., in preparation). This example illustrates once again that diversity within communities is an important subject (Van der Ploeg, 1994). We can also see that -from the point of view of the migrants- there is little advantage to be gained if the natural scientists concentrate solely on the further development of the multi-year rotation system, at least as long as nothing changes regarding the issue of contracts between landowners and tenants. It would, perhaps, be more useful to search with the migrants for single-year intercropping systems that would have an immediate effect on soil fertility. Furthermore, based on the insights gained, social scientific research could be directed towards bringing about a better understanding of the dilemmas faced by the native population and the migrants with reference to land use and leasing contracts, and towards identifying and mobilising bringing actors and institutions that could help to break the deadlock.

Such fine-tuning of natural and social science research questions is far from standard practice. For a broader application, new organisational forms, methods and tools for 'beta/gamma science' (Röling, 2000) are essential. There is still scope for immense progress in this area.

3. The 'socio-technical root system' as a tool for integrating knowledge and formulating research questions

One concrete tool for improving, structuring and visualising discussion between natural and social scientists in an interactive setting is the creation of a 'socio-technical root-system'. It is a way of unravelling the technical and social aspects of a complex problem situation step by step. The technique is inspired by the idea of 'problem trees' (GTZ, 1987; Van Veldhuizen et al., 1997) which served to jointly identify -and graphically connect- a central problem (the stem of the tree), its 'causes' (the roots) and its 'consequences' (the branches and leaves). Thus, a hierarchy of problems was identified in a more or less interactive mode, which could be used for the identification of project goals (GTZ, 1987). In this section, we will present an adapted version of this technique which is especially suited for exploring the relations between the technical and social dimensions of complex problem situations. In terms of the original technique, it focuses especially on the roots of the tree; hence the term 'socio-technical root system'. The idea is to take three basic steps:

1. Identify a *central problem* that participants are willing to take as a starting point for the discussion. The choice of a central problem in itself is rather arbitrary, and different stakeholders may have different initial ideas about what the central problem is. Thus, one may choose to draw several trees, starting from different problem perceptions.

2. Unravel what *specific technical and social practices* -by different stakeholders- contribute to the problem. This can be formulated in terms of what people do, or not do. In problem analysis these are two sides of the same coin. In an intervention context, it is usually easier to make a tree when focussing on alternative practices that are apparently not applied.

3. Identify the *reasons* different stakeholders have or may have for not engaging alternative practices (or for reproducing existing practices). Here the variables of the model for understanding human practices developed by Leeuwis with Van den Ban (2004) can serve as a checklist (see Box 1 for an overview).

Box 1: Overview of different kinds of 'reasons' that may shape human practices.

(1) *BELIEVE TO BE TRUE* about the agro-ecological and social world which includes multiple:
- . beliefs about consequences, including causal attributions;
- . perceptions of (un)certainty, likelyhood and risk

(2) *ASPIRE* to achieve as expressed through (interrelated) aspirations of various kinds, including:
- . technical / economic goals and interests;
- . relational (including 'political') goals and interests;
- . cultural aspirations, including also responsibility considerations;
- . emotional aspirations;

(3) (think they) are *ABLE* to do given their perceived:
- . ability to mobilise resources;
- . availability of skills and competence;
- . trust in the validity of their knowledge;
- . ability to control or accommodate risks;

and given their expectations regarding the:
- . effectiveness of the agro-support network;
- . effectiveness of (inter-)community organisation.

(4) (think they) are *ALLOWED* and/or *EXPECTED* to do in view of the perceived:
- . desires and expectations from others;
- . 'rewards' and 'sanctions' (resources) mobilised by others;
- . importance of -and balance between- rewards and sanctions (vis-à-vis aspirations of various kinds).

An example of the possible results of such an exercise is given in Figure 1.

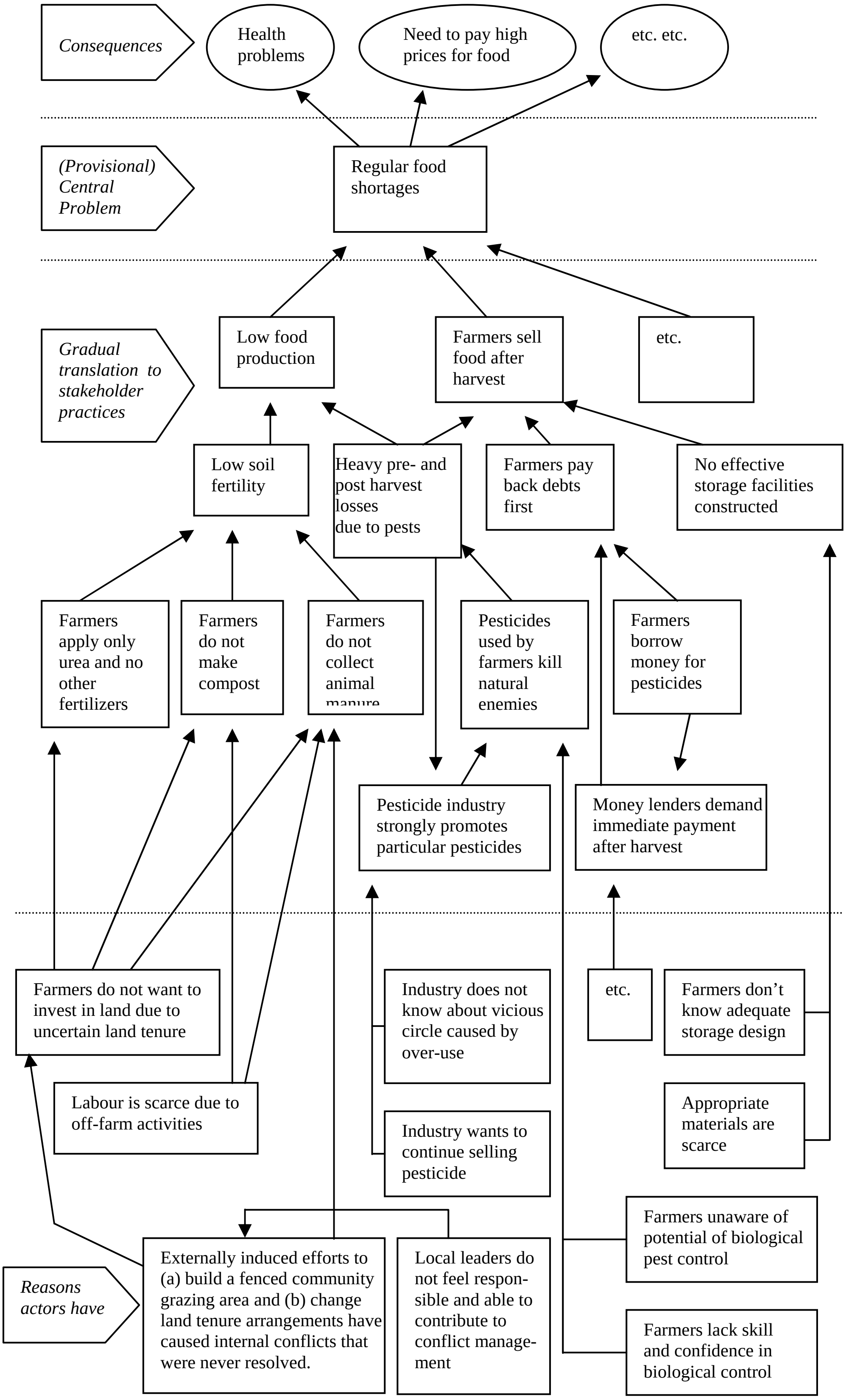

Figure 13.1: Example of an fictitious and partial socio-technical root system.

Clearly, the collection of information relevant to making the root system requires exploratory methods of a different kind, ranging from in-depth interviewing, focus group discussions, mapping, ranking, participant observation, etc. In view of its specific set-up and analytical purpose (i.e. dissecting relevant social and technical issues), this method is not meant to be used during exploratory sessions with societal stakeholders. Rather, it may be used by cross-disciplinary teams and project staff in order to integrate and debate findings arrived at with the help of other exploratory methods. The making of a tree in this manner can leads to the identification of numerous uncertainties and knowledge gaps that complicate problem solving and innovation, some of which may require joint research and investigation as discussed in section 2. In addition, a socio-technical problem root system can be helpful for making intervention decisions. Depending on the analysis of one or more root systems, one may decide on what selection of problems a project may need to focus. Moreover, the identification of reasons behind practices may be very useful for choosing appropriate communication strategies and other policy instruments in relation to problems (see Leeuwis with Van den Ban, 2004).

Some things have to be kept in mind when working on such a root system. It is important to realise that a socio-technical root system is likely to be actor and theory dependent. When man and women are asked to make a separate root system, for example, one can expect rather different trees as aspirations, problems and lifeworlds are likely to differ. Similarly, scientists from different disciplines (e.g. sociology, gender studies, soil science or entomology) and/or scholars with a different theoretical orientation (e.g. a Marxist versus an actor-oriented sociologist), are likely to come up with dissimilar interpretations of reality. Hence, when making a socio-technical root system it is important to select those stakeholders and scientists that are likely to have a relevant background in a given context. Furthermore, although the making of a root system requires valid insights, it would be wrong to approach it as an exercise of establishing scientifically underpinned 'cause' and 'effect' relations. Apart from practical limitations and the fact that these terms are problematic in the social sciences especially, the purpose of making a root system is different. It is useful first and foremost as a discussion tool, and for organising, visualising and storing (different) thoughts. At the same time it may help to identify knowledge gaps and hypothesis that require further exploration and testing. Thus, making a socio-technical root system can be something that takes place over a period of time.

4. Conclusion

This paper has argued that changing conceptions of innovation urge us to rethink the role of both communicative interventionists and scientists. It is proposed that cross-disciplinary teams of scientists connect themselves with societal processes of network building, social learning and conflict management. Thereby their main roles are to (a) explicate implicit assumptions, claims and knowledge gaps that transpire from stakeholder interactions, (b) to give independent feedback and (c) to engage in joint research with stakeholders on a coherent set of natural and social science questions. It is argued that the 'socio-technical root system' tool may help cross-disciplinary teams to more effectively play such roles. The tool builds on three basic components: (a) a variety of exploratory methods in order to increase collective understanding of a complex problematic situation; (b) a stepwise procedure based on a conceptual model aimed at understanding the reasons that underlie human practices; and (c) storage of the analysis in the form of gradually developed visual graphs.

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