The sources of use knowledge –
towards a framework about use, consumption and industrial dynamics

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Abstract: This paper reviews three strands of the innovation literature that have presented innovation as a distributed process that combines knowledge of users, designers and manufacturers: user innovations, Science and Technology Studies (STS), and the study of consumption. These literatures have explored different aspects of the micro-processes through which use and design are locally aligned. This paper pulls together insights from these literatures, and identifies an important gap: the connections between the local alignment of use and design and the macro dynamics of industrial and technological change. The paper then calls for an analysis of the social processes that link the dynamics of the use environment, where forms and meanings of use are actively created, with the technical knowledge bases of industries. It concludes with a number of propositions towards an integrated framework of use, consumption and industrial dynamics.

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1. Introduction

Technological innovation is a process that comprises designing, manufacturing, and using new technology. This has long been established in various strands of the innovation literature. Yet, insights of how these different aspects of technological change are coordinated in innovation processes are still fragmented. Hence, a number of studies has demonstrated that the diffusion of technology is an important source of learning, and thus a part of the innovation process (Rosenberg, 1982; Georgiou et al., 1986; Fleck, 1988; Dougherty, 1992; Leonard-Barton, 1995). Eric von Hippel, in a number of seminal publications, has further qualified the manufacturer-active paradigm of innovation by showing that users are frequently the actual source and proponent of an innovation (von Hippel, 1976; 1978; 1988; 2005). And finally, the study of consumption has reminded us that technologies have, besides functionality, meanings and symbolic values, and that users collectively define these dimensions through the process of consumption (Miller, 1987; McCracken, 1988; Silverstone et al., 1992; Silverstone, 1994; Tuomi, 2002). What is still missing, however, is a conception of the mechanisms through which the different processes of knowledge creation in designing, manufacturing and using are linked and coordinated in innovation, i.e. how these processes jointly feed the emerging knowledge base of a new technology (or technological system, so to speak). This paper strives to close this gap and makes a number of steps towards an integrated framework for the analysis of use, consumption and industrial change.

In particular, I review three discourses in the innovation literature that have focused on the distributedness of innovation across sites of using, designing, and manufacturing. These discourses – stemming from the areas of innovation management, Science and Technology Studies (STS), and consumption studies – have dealt with the micro-processes through which use and design are locally aligned, yet they have done so with markedly different emphases. I argue that, while these discourses have indeed provided rich accounts of local learning processes, they have failed to pay sufficient attention to each other and thus to integrate findings into a broader understanding that links these micro-dynamics to the macro-dynamics of technological change. In other words, they have not shed sufficient light on the co-evolution of the use environment, where forms and meanings of use are actively created, with the knowledge bases of industries in which the form and the production process of a technical object are generalized in design rules (Baldwin and Clark, 2000). Indeed, innovation processes are constructed at the sites of both manufacturers and users; but their success depends on suitable institutional forms that coordinate and align these distributed sources of knowledge and capabilities (Hoogma and Schot, 2001; Dougherty, 2004) into stabilizing processes of change. In this respect, the existing discourses have tended to highlight either side of the innovation process at the expense of looking closer into the interactions between these sides.

The results of this paper are twofold. First, it pulls together insights from three discourses in hitherto largely unrelated literatures. For this purpose, Section 2 revisits early studies that
have tried to reconcile the demand and supply side of innovation, and extracts two long-standing challenges for the study of the co-evolution of use, design and manufacturing – non-local interactive learning, and the embodiment of use knowledge in design rules and modifications. With these challenges in mind, Section 3 then reviews the three ongoing discourses, and asks how they explain the local alignment of the use and the design of a new technology. In the user innovation model, von Hippel and others could establish that users often realize local alignment themselves; the model is fleshed out and discussed along four propositions (3.1). Science and Technology Studies (STS), by complement, have looked closer into the sources of use knowledge across types of innovation. Thus, while the user innovation model underpins that all types of innovation incorporate some kind of use knowledge, studies in STS have provided detailed empirical accounts of the manifold sources of use knowledge for a continuum of manufacturer to user innovations. In this sense, the sources of innovation and the sources of use knowledge span up a two-dimensional space in which innovation processes can be positioned (3.2). Finally, the study of consumption, in particular the strand of studies that has looked at the domestication of technology, has explored the consummation of technical objects during use. This allows for an extended notion of user innovations that sheds light on use as a social process (actions and interactions) where functions, meaning and symbolic value of a technical object are negotiated (3.3). In Section 4, finally, a number of conclusions are drawn that integrate the discussion. Furthermore, directions for further research are identified.

2. Early Comments on Demand, Innovation, and the Market

In neoclassical models of economic life, markets mediate between supply and demand by transmitting information on prices and volume between producers and buyers. In this tradition, theories of technological change and innovation typically explain the emergence of new technologies either as a result of technology-push (most prominently in the tradition of Schumpeter) or demand-pull (most prominently in the tradition of Schmookler). That is, two sorts of disequilibria account for the creation of new technologies by manufacturers – the availability of new technological opportunities, or the recognition of an unsatisfied demand. Economists in the neo-schumpetarian, evolutionary tradition have long criticized such models of technological change to show that innovation is a process that responds to supply and demand side factors simultaneously (Nelson and Winter, 1982; just see Dosi, 1984; Dosi et al., 1988; Heertje and Perlman, 1990). While it is not my intention to recapitulate this broad debate here (but see Andersen, 2007), I want to focus on two particular criticisms that have been raised with regard to demand pull models of innovation – the confusion between demand and user needs, and the inability of pure markets to communicate user needs.

A first criticism was expressed with regard to the notion of market demand itself. Most prominently, Mowery and Rosenberg (1979) reviewed a series of then frequently cited studies in support of a demand-pull model of innovation. They concluded that these studies
failed to establish an analytically sharp definition of demand in the first place. In particular, Mowery and Rosenberg organized their critique along two major points. (i) The investigated studies typically propelled an extremely broad definition of demand that rendered the claims based on this definition virtually pointless. While all studies could show that demand is necessary for the success of an innovation, this was, of course, a tautological statement. What these studies, according to Mowery and Nelson, should have shown instead is that demand is sufficient to explain the origins and the success of an innovation. Indeed, for Mowery and Rosenberg the incorporation of both demand and supply side factors were necessary conditions for the success of an innovation. It was, therefore, essential to conceive of innovation as an iterative and co-evolutionary process in which supply and demand side factors are aligned (ibid.: 143). (ii) All investigated studies confused the formally very specific notion of demand with the broadly defined concept of user needs. While Mowery and Rosenberg did not deny that market or customer needs influence the directions of innovation, “[i]t is the identification of 'needs' with 'market demand,' and the dominant role in commercial innovation ascribed to this amorphous variable” (ibid.: 130) that they criticized. In fact, as Mowery and Nelson pointed out, the relationship between need recognition and market demand is a rather tenuous one (ibid.: 140). Mowery and Rosenberg argued that, while the reviewed studies had frequently been cited in support of demand-pull models, none of them specifically dealt with demand. Rather, less strictly defined notions of “latent” or “anticipated” user needs were at play when scholars had looked into demand side factors.¹ User needs, however, are a completely different matter than market demand, mostly because they refer to a quality rather than a quantity.

Lundvall (1988), in another seminal publication, more systematically explored the quantitative and qualitative information hidden behind demand and supply curves. In particular, he proposed to look at interactive learning that occurs between producers and users in innovation processes. For Lundvall, innovation would not be possible if pure markets separated producers and users of a technology. Indeed, he argued, pure markets, while suitable to convey quantitative information about volume and prices, fail to communicate the quality of demand (ibid.: 357). In other words, markets fail to transmit and combine the intimate knowledge of user and producers in innovation. Hence, more direct relationships between economic actors are necessary in the process of innovation, and Lundvall identified the organized market as the primary organizational form of product innovation that facilitates quantitative as well as qualitative knowledge flows. In organized markets, producers and users are interdependent, i.e., linked through a blend of market like, hierarchical and cooperative relationships.² Through these links, firms regulate the

¹ For an early formal distinction between market demand and user needs see Teubal (1979). In support of Mowery and Rosenberg’s argumentation, Teubal also found that need determination, i.e., the increasingly specific definition of user needs in terms of product class, performance dimensions, and features, is a process contingent on supply side factors.

² In fact, Lundvall’s concept of an organized market is an antecedent to later, more systematic works on innovation networks that facilitate interdependent relationships between actors in the innovation process (Powell, 1990; Freeman, 1991; Rammert, 1997).
uncertainties of innovative activities and engage in a process of interactive learning that could not be accommodated by pure market relations alone.

The implementation and diffusion phase of an innovation has, of course, long received scholarly attention (Rogers, 1962; Georgiou et al., 1986; Leonardi-Barton, 1988), and a number of authors has specifically explored this phase as an important source of learning. Thus Arrow (1962) looked into the knowledge underlying a production function, and demonstrated that experience in producing a certain commodity can lead to a reduction of labor costs. This learning by doing occurs when manufacturers encounter and solve unanticipated problems of the production process (ibid.: 156). Rosenberg (1982) identified a similar process for the use of a product. While Arrow was concerned with learning how to operate a given production process, and, indeed, has hidden much of the details of this process "behind the learning curve" (Adler and Clark, 1991), Rosenberg established an important distinction between embodied and disembodied forms of learning (Rosenberg, 1982: 124). Learning by using, he argued, can indeed result in an improved understanding of a given product and how to use it (disembodied learning), but it may also result in actual design modifications (embodied learning). In fact, most real world cases of learning by using will include elements of both.

Learning by using typically occurs due to an initial misfit between product characteristics and its use environment that leaves room for improvements through the operating experience (Rosenberg, 1982; Hippel and Tyre, 1995). This, however, assumes that there is an initial product that can be operated. Against this background, Fleck (1994) added a third form of learning – learning by trying – that is particularly relevant for complex and systemic technologies. Doing and using, he claimed, refer to the operation of already functioning production entities. For systemic technologies, however, users often have to try to make a particular system operable (and quite often, he showed, this process would fail). For such instances, it becomes obvious that the distinction between innovation and diffusion is fuzzy, and Fleck coined the notion of "innofusion" to describe joint processes of innovation and diffusion (Fleck, 1988) where users repeatedly configure components into systems that fit particular contexts. Learning by trying refers to the knowledge created during innofusion and may occasionally amount to significant changes in technological knowledge bases (Peine, 2008).

These early studies have highlighted two aspects of the innovation process that are crucial for the further discussion in this paper. First, innovation is a co-evolutionary process where the alignment between demand and supply as well as between use and design determines much of the success of an innovation. Indeed, at the outset of an innovation neither product characteristics are known nor user needs are "out there" to be elicited. Users have to develop their needs and forms of meeting these needs through experience with the evolving product characteristics. Clark (1985) most prominently illustrated this point when he showed how, based on experience with horse carriages, customers of cars

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3 Von Hippel and Tyre also established that, once it is understood that producing a good is using the production process, the boundaries between doing and using become blurred. Thus, producers that learn to produce a good learn to use a process.
gradually learned to perceive the car to be more than a “horseless carriage”: a “roadster”, a “touring car” or a “coupe”. The important point raised by Clark is that when cars were first introduced, criteria for their evaluation were not genuinely available, but had to be created based on earlier experience with horse carriages. In this sense, the first cars, when leaving the manufacturer site, were incomplete proposals, and users had to complete them by defining “what the product is, how it meets needs, and how it functions in different situations” (ibid.: 245). User needs are thus not static but co-evolve with different versions of an innovation. That is, user needs shape trajectories of technological change while they are at the same time contingent upon such trajectories.

This is an aspect not well covered in the concepts of learning by doing, -using and -trying – a critique that has been raised by Hoogma and Schot (2001). Indeed, in these concepts “users are mainly perceived as knowledge providers for manufacturers, who consequently learn to make better products” (ibid.: 229). Hence, learning by doing or -using regards users’ preferences as static and independent of the actual use of a product. For the case of electric vehicle innovation, Hoogma and Schot have qualified this implicit assumption and demonstrated how users learned as much about their own needs as they did about the product itself. Learning by using thus not only improves forms of use towards a static optimum, but that optimum itself is object to innovative activity and change. For Hoogma and Schot, therefore, “double loop learning” is most important, where, during use, users learn as much about their own preferences as they learn about the new product. In sum, this perspective shows that using is as much part of the innovation process as is designing or manufacturing. And it is so not only because the diffusion phase improves understanding of a product, but because it improves understanding of use and develops new forms of use.

Secondly, however, these early studies have also pointed out an important gap in the knowledge about the mechanisms and spaces that facilitate, or fail to do so, the alignment of use and design. As especially Foray (2004) has shown, the different forms of learning by – doing, -using, or –trying are initially local phenomena. It is thus an important question how the knowledge thence produced is spread among a wider set of actors in the innovation process and how it becomes part of the general knowledge base that constitutes a technology. Lundvall has recently commented on this problem and argued that learning by interacting allows for the generalization of local knowledge produced by “doing” or “using” (Lundvall, 2006). This, again, puts center-stage the interdependent relationships between various users and producers in the innovation process as the key channel through which relevant knowledge is transmitted, stabilized and accumulated in the innovation process. With regard to the co-evolution of use and design, a key challenge is the understanding of these interdependent relationships as socially rich, i.e. shaped by actions and interactions of embedded actors.

Two challenges can thus be summarized. First, product design and forms of use co-evolve in interdependent interactions between users and manufacturers (interactive learning), i.e. they are contingent upon each other. In Section 3, I review a number of key literatures that have dealt with learning between users and producers. I shall demonstrate that while these literatures indeed offer a detailed picture of local learning processes, they
widely neglect the issue of cumulative and non-local learning. Secondly, therefore, a particular and hitherto not satisfyingly tackled challenge exists with regard to the embodiment and diffusion of disembodied learning into design modifications and further into the generic knowledge bases of industry. In Section 4, I propose a scheme to remedy this gap. This scheme particularly highlights the importance to understand the interactions between disembodied and embodied forms of learning, i.e. the changes of a generic technological knowledge base due to knowledge generated during use.
3. Approaches to Users and Use in Innovation

Various strands in the innovation literature have dealt with users and use in innovation. However, these strands have been developed in separate communities, and have hitherto largely not interacted with each other. In this section, I review and pull together results from these literatures. In particular, I explore the model behind the user-innovation concept, discuss the conceptual underpinnings of user innovations, and complement these views with insights about the process of consumption. I shall dedicate special attention to the sources of user knowledge, the local processes of aligning use and design, and the links between these local processes with technological and industrial change.

3.1. The Sources of Innovation: Exploring the Conceptual Model

Eric von Hippel and others have explored different sources of innovation. In particular, they could show that users are frequently not just important in innovation but the actual source of innovation, i.e., users often invent, prototype and field-test significant increments in functional utility themselves (von Hippel, 1976: 212). In a wealth of empirical studies, they have supported and demonstrated the relevance of this phenomenon of user innovation. In what follows, I explore the underlying conceptual model of user innovations along four propositions to highlight a number of broader implications with respect to the role of users in innovation processes:

(i) Functional Relationships: Economic agents can be distinguished according to their functional relationship with a technology (von Hippel, 1988). If an agent manufactures a technology to sell it, he is a manufacturer; if he uses a technology to benefit from its functions, he is a user; if he supplies input to produce a technology, he is a supplier, and so forth. While economic agents normally are manufacturers, users, or suppliers at the same time in different contexts, they have only one such functional relationship with a specific technology. Profit motives of innovators thus differ depending on the functional relationship an innovator has with the innovation. To establish the most relevant distinction: a manufacturer benefits from selling an innovation while a user profits directly from the enhanced functionality of an innovation (Riggs and Hippel, 1994).

(ii) Sources of Innovation: Based on this distinction, von Hippel has defined the source of an innovation according to the functional relationship between innovator and innovation (von Hippel, 1988). The sources of innovation can differ considerably, and quite often it is the user, be that an individual or an organization. User innovations are those innovations whose functional source is the user. In contrast to manufacturer innovations, user

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4 Von Hippel (2005) presents a book-length overview of these studies; a concise introduction is to be found in von Hippel (2006).

5 In principle, user innovations are relevant for both industrial and consumer goods. However, studies of user innovations of consumer goods have thus far been restricted to (extreme) sports equipment, software, and juvenile products (see Franke and Shah, 2003; Lüthje, 2004; Shah and Tripsas, 2007). While these are highly specific areas of technology, the relevance of the user innovation concept for the development of mass consumer goods such as white goods, consumer electronics, etc. remains an issue for further debate.
innovations are directly tailored to the particular needs of the innovator that profits from an increased functionality (ibid.: 17). Frequently, user innovators are particularly knowledgeable users ahead of market trends, i.e. they are lead users (von Hippel, 1986; Urban and Hippel, 1988). At the outset, user innovations are local phenomena that constitute the adaptation of generally available pieces of equipment to a local use environment (Slaughter, 1993).

(iii) Diffusion of User Innovations: User innovations are often attractive for other users as well, precisely because they embody intimate knowledge about the use environment. Hence, two channels exist for the diffusion of user innovations (see Franke and Shah, 2003; Lettl et al., 2006; von Hippel, 2007; Shah and Tripsas, 2007). First, user innovators often share information so that other users can replicate the original innovation.6 The innovation thus becomes diffused within a community of users, some of which might eventually turn into small-scale manufacturers or user entrepreneurs. Secondly, large manufacturers may sooner or later pick up a particular version of a user innovation and produce it for a large set of users who are not willing or able to reproduce the original innovation themselves. Any of these steps can function in separation, but often the diffusion of a user innovation ultimately comprises all of them.7 In particular more recent, and more debatable (Oost et al., 2008), studies have emphasized the importance of user communities for innovation without the involvement of large manufacturers (Hippel, 2007).

(iv) On a more general level, the work of von Hippel and his collaborators has highlighted that two types of information must be combined in any innovation process – use information and solution information. These types of information, however, are assymmetrically distributed among manufacturers and users, and they are normally “sticky”, i.e. can not be transferred at reasonable costs (von Hippel, 1994). The user innovation model proposes one path for the combination of use and solution information – knowledgeable users, i.e. users that possess some degree of solution information, modify or invent designs based on their intimate, local and “sticky” knowledge of the use environment (see Slaughter, 1993; Lüthje et al., 2005). More generally, however, the user innovation model has also suggested that such paths, while always necessary for innovation success, may differ considerably depending on the source of innovation.

The user innovation model distinguishes, although implicitly, between embodied and disembodied forms of learning. This is particularly evident in Slaughter (1993) who has investigated minor adaptations of stressed-skin panels that were more or less spontaneously realized on construction sites by construction companies.8 Slaughter reported that, while

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7 See Baldwin et al. (2006) for a formal model.

8 Slaughter (1993) looked into a range of construction projects employing stressed-skin panels, provided a broad definition of innovation as “anything new actually used in a project” (ibid.: 85), and identified 34 such innovations, 28 of which she recognized as user innovations.
less than a third of these users’ innovations were commercialized by manufacturers, all of them diffused into the repertoire of techniques construction companies regularly employed to deal with the peculiarities of specific projects. Indeed, the original innovations spread in a way that generated a particular division of labor between manufacturers and users: the users accumulated knowledge about how to adapt stressed-skin panels to local particularities, and the manufacturers signaled their contentment with the situation with the sustained provision of generic solutions (ibid.: 91). In other words, they refrained from commercializing the local knowledge of users, even though this knowledge was available to them. Slaughter indicated that this created a host of inefficiencies in terms of the collective learning about stressed-skin panels. “[W]hen learning and innovation are concentrated on immediate problem-solving, there is little opportunity to connect the discrete innovations to overall system changes.” (ibid.: 92)

Here, Slaughter has pointed out a critical element in the user innovation model because she has shown that user innovations can also be too specific or too local. Manufacturers then interpret such innovations as “custom orders” that are not worth further pursuit (ibid.: 91). This suggests an important threshold: user innovations have to contain a certain level of commercial attractiveness; otherwise they do not give way to changes of a generic solution. From this follows an important distinction between embodied learning and repeated embodiment of disembodied learning. While this, at first sight, appears to be hairsplitting, it in fact marks the fine line between interactive and separated learning about use and design. Indeed, Slaughter’s study has described a situation where learning at the sites of manufacturers and users has remained separated even though designs are frequently adapted to local circumstances. So far, the fine line between repeated local adaptations and interactive learning has remained somewhat blurred in the use innovation model.

In summary, two aspects of the user innovation model are particularly important with regard to the challenges identified in Section 2. First, if the source of innovation is a user, this user safeguards the local alignment of use and design for the innovation, i.e. embodies use knowledge into design modifications. Therefore, the user innovation model calls for the presence of knowledgeable users that possess enough knowledge about a technology to innovate themselves. User innovators are thus not only experts of the use environment, but they are also experts, at least to a certain degree, of technical know-how about the object they use. Secondly, the user innovation model proposes one specific channel for the immersion of thus produced local knowledge into technical knowledge bases – versions of an artifact move back and forth among a wider set of actors that comprises users, designers, and manufacturers (von Hippel, 1994). The user is both the source of use knowledge and the actor that translates use knowledge into a design modification. In this sense, interactive learning takes place after the innovation has occurred. For such cases, the user innovation model indeed has provided a rich and multi-faceted description of the innovation process.

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9 In open source software development this intricate balance seems to be represented by the decision to include a particular innovation into the “official version” of the software. The subject is one of striking the balance between the local and the global.
What happens, however, if use and solution knowledge is truly separated between the sites of users and manufacturers has received far less attention.10

3.2 The Sources of Use Knowledge: Formalizing the Disembodied Learning Experience

The user innovation model has pointed to the importance of combining use and solution information or knowledge. Moreover, it has proposed that in many instances users themselves realize such a combination locally. At the same time, however, this model has downplayed another important dimension— the sources of use knowledge across types of innovations. Not all innovations stem from users, but all innovation process knowledge of some kind about a (possible) use environment. Hence, as a negative to the cases presented by von Hippel, it is possible to conceive of innovations that are to a large degree conceptualized at the manufacturer site. In such cases, the innovator may not have a clear idea of future users and their needs. In the social studies of science and technology, a number of sources of use knowledge have been identified that inform, knowingly or unknowingly, manufacturers. These sources range from the pure imagination of designing engineers to the participation of users in corporate R&D. In what follows, I discuss a number of insights that are relevant for the present paper.

In a seminal study, Woolgar (1991) has proposed to explore the metaphor of a machine as text. The strength of this metaphor, he argued, is that it allows for the distinction between the writing (construction) of a machine, and its subsequent reading (use). Just like a text, a machine, by virtue of being written in a particular way, suggests a certain reading. Interpretative flexibility is thus limited to the extent that not all interpretations of a machine are possible or even equally probable. Rather, certain kinds of usage are encouraged by the way a machine is written, while others are rendered difficult or impossible. In this sense, a machine, just like a text, mediates between its writers and readers. The essential point Woolgar derives from the analogy is that a user is socially constructed during the writing (construction) of the machine. This social construct is subsequently inscribed into the machine, so that certain types of actions are readily available to users. In this way, “the evolving machine effectively attempts to configure the user” (ibid.: 61).

Woolgar investigated this process of configuring the user through an ethnographic field study in a medium-sized company that designed a new micro computer. For this project, he demonstrated how “the user” (singular) was constructed from multiple conceptions of users and uses (plural) that were present in the discussions among the different departments involved in the project. Woolgar showed that this construction of a user took place completely within the company. Subsequently, the company conducted a series of usability trials to evaluate if the machine together with its manual would indeed lead real users to the “correct” use of the machine. Hence, the metaphor of the machine as a text reveals how “the user” was co-constructed with the machine. Subsequent efforts within the company were dedicated to ensure that the machine would indeed configure real users in a way congruent

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10 And it has to be emphasized, of course, that the user innovation model has not been proposed to shed light on such situations.
with the user previously constructed. In Woolgar’s case study, the company not only constructed a user, but it also dedicated a considerable amount of effort to design the machine in such a way to configure real users accordingly.

To capture the influence a technical object exerts on the relationships users can entertain with it, Akrich (1992) coined the term “script” to offer a perspective on the writing phase of technical objects. It is designers and innovators that inscribe in a technical object a vision of future users, uses, and relations between them. “Thus, like a film script, technical objects define a framework of action together with the actors and the space in which they are supposed to act.” (ibid.: 208) In contrast to Woolgar, however, her analysis focuses more on the interplay between the designers’ projected users and real users, i.e. “between the world inscribed in the object and the world described by its displacement” (ibid.: 209). According to Akrich, technical objects become real only through the actual users, uses, and networks they describe, and it is, therefore, the adjustment between projected and real users that determines the fate of a technical object. Notabene, real users may not subscribe to the script presented to them, and they may even try to renegotiate the original script, i.e. choose for de-inscription rather than subscription (Akrich and Latour, 1992).

These studies have established that use knowledge is frequently constructed in innovation before real use takes place. In this sense, use knowledge may be inscribed in a technical object without any explicit consideration of future users and use. Indeed, Akrich (1995) has claimed that the “T-methodology”, where designers project themselves as future users of an artifact, is a widespread way to tap into knowledge about future use. Subsequent empirical studies have elaborated upon this general perspective in greater detail to specify the source of use knowledge that inform design processes. I shall briefly summarize the results of these studies;[11]

(i) The use environment is not explicitly considered as such in the innovation process. This has for instance been demonstrated in Woolgar’s study. In such situations, designers frequently project themselves as future users, and implicitly refer to their own preferences and skills as source of use knowledge (“T-methodology”, Akrich, 1995), or they infer such knowledge from stories circulating within their professional networks (Miles et al., 1992; Cawson et al., 1995). In this context in particular Hyysalo (2006a; 2006b) has pointed out that technical traditions are a powerful carrier of use knowledge as far as they may contain vestiges of use information based on earlier experiences from related fields. Oudshoorn et al. (2004) have presented a good example for this: they identified designers and their practices as an important vessel of ICT’s gender bias spreading to other fields. In such cases, the source of use knowledge is described by a set of assumptions implicit in the practices and the imagination of designers.

(iii) Users and use are frequently represented by others. First, end-users are often spoken for by clients or interest groups. This is the case, for instance, when managers represent the user organization in user-producer interactions of an innovation project that is targeted at

end-users in other parts of the same user organization (Mackay et al., 2000). Rose (2001), more generally, has pointed out that user needs are often formulated by interest groups, and that these load the use knowledge thus created with their own vested interests. Secondly, experts often represent users in design processes. This is the case, for instance, when usability experts enrich design processes with general principles of ergonomics. In particular Haddon (2002) has demonstrated that this is indeed a widespread source of use knowledge. More importantly, of course, systematic attempts to involve users in design processes are ubiquitous these days, and formal procedures of marketing research and user involvement have become standard practice also in innovation processes of non specialized industrial goods (for an overview, see Chapters 13-16 in Kahn, 2005). Naturally, this is the case when marketing departments conduct consumer research, and more sophisticatedly when social scientists immediately participate in design processes (Sanders, 2002; Rosenthal and Capper, 2006).

However, a word of caution is necessary. While the widespread celebration of the myth (cf. Meyer and Rowan, 1977) of user involvement suggests that explicit concerns with the use environment have gained a strong influence on new product development, the available empirical studies put this into perspective. In fact, a major strand in the marketing literature has long concerned itself with the obstacles that typically hamper the productive cooperation between marketing and R&D departments (see Rein, 2004, for an overview). Furthermore, the influence of social scientists on design decisions and processes is limited by the need to formalize and articulate the knowledge inferred through in-depth studies of potential use environments (Hughes et al., 2002), and thus the impact of user involvement and marketing research on design decisions and processes has indeed remained rather limited in many cases (Haddon and Paul, 2001; Haddon, 2002; Mallard, 2005). In this context, Stewart and Williams (2005) have talked about a “design fallacy” – the widespread belief that technology design improves with knowledge about the use environment, only if this environment would be known better. Against this background, the diagnosis that explicit methods of user exploration have gained great legitimacy over the past years is not sufficient to establish that these methods have also significantly altered design practices. In fact, it is this very relation between formal methods of user exploration and design practices itself that still awaits further inquiry. In a nutshell, mediators of different kinds function as a widespread source of use knowledge. How well this source indeed enriches practices and imagination of designer, far from being a trivial issue, remains a question to be analyzed for each empirical case separately.

The strand of studies discussed in this section have above all demonstrated that the sources of use knowledge are manifold, that they are regularly not identical with the end-users, and that use knowledge affects innovation processes through various forms of mediation, e.g. by interest groups or experts. Hence, also for manufacturer innovations, use knowledge is an integral part of design; however, this knowledge is constructed rather than just elicited in any straightforward sense. Therefore, in spite of widespread and far-reaching claims about the growing relevance of user involvement in innovation, use knowledge is
still in many cases just implicitly co-constructed in design processes by designers together with a particular solution. For this paper, however, the studies just discussed have reminded us to investigate carefully who exactly participates in the construction of use knowledge. A wealth of empirical material has demonstrated that, when the source of innovation is not the user, the combination of use and solution knowledge may take many alternative forms. For sure, prototypes that embody specific combinations are most important in this respect (Suchman et al., 2002), but quite often their creation is more complex a social process than the user innovation model suggests.\textsuperscript{12}

Use knowledge frequently becomes part of an innovation before real use takes place, and then technical objects pre-structure the interactions real users can subsequently entertain with the object (see in particular Grint and Woolgar, 1997: 65-69). Interactive learning to diffuse knowledge about an innovation may thus initially continue without actual use, and, in this sense, the studies above have emphasized that also manufacturer innovations include knowledge from distributed sources. Moreover, they suggest that embodied forms of learning can precede disembodied forms of learning, i.e. design modifications imply assumptions about the future use environment rather than the outcome of an actual learning experience in such an environment. Thus, the work of Woolgar and Akrich has shown that embodied learning may pre-structure disembodied learning as much as the other way around. The important point in this respect has been made by Rip and Schot (2002: 163) – a protected space with a limited set of actors is often necessary for an innovation to survive through its early stages. This underpins the importance to understand how use knowledge is created in such a protected space, and who participates in this creation. Studies in STS have provided explorations of the different forms such protected spaces can take, and they have particularly explored the actions and interactions of the specific sets of actors that have shaped knowledge production. However, they have emphasized the social process of design as a source of use knowledge much more than the social process of use and the interactions between the two processes.

3.3.  \textit{The Sources of Innovation Extended: Domesticating Technology}

In Section 2, the notion of “double loop learning” has already been established where users “construct their own meanings and preferences during technology development” (Hoogma and Schot, 2001: 228-229). This points at an aspect that has remained underexposed in the literature discussed so far – users not only develop an increased understanding of how to operate a technical object, but they create meaning and symbols to relate that object to their everyday, be that at home or at the workplace. This is a major topic in the study of consumption that has looked at users in their everyday, i.e. the consumer,

\textsuperscript{12} In particular, this implies that prototypes often combine knowledge from sources that transcend the boundaries of a single organization, as Schot and Albert de la Bruze (2003) have pointed out.
and at the process through which users link artifacts to their everyday, i.e. the process of consumption.\textsuperscript{13}

In the vocabulary of innovation studies, the study of consumption has focused on the diffusion of technical artifacts, and here this research has explored cultural aspects rather than economic aspects, and the sign value of things rather than the use value (cf. Silverstone, 1994; Oudshoorn and Pinch, 2003). The main message is that, in the sphere of users and use, artifacts undergo an intricate process through which use is defined and put into practice. Hence, the study of consumption has reminded us that users not only have to learn how to use an artifact, but that they have to work towards, i.e. negotiate, define and arrange, an understanding how to use an artifact in the first place. While the mainstream of consumption studies, has not concerned itself with technological dynamics, one remarkable exemption is domestication research that has investigated consumption as part of the innovation process (Silverstone and Hirsch, 1992; Silverstone, 1994; Lie and Sörensen, 1996; Berker et al., 2005; Haddon, 2006). In particular, Silverstone and Haddon (1996) have argued that the “domestication” of artifacts is as complex a process as design, and involves “quite literally a taming of the wild and a cultivating of the tame” (ibid.: 60), where artifacts transgress the boundaries between the public sphere of commodities and formal economies, and the domestic sphere of objects and moral economies. What are the ingredients of domestication research?

Silverstone et al. (1992) have specified a formal framework in which they distinguish between four elements of domestication – appropriation, objectification, incorporation, and conversion.\textsuperscript{14} Appropriation takes place at the point of purchase, when an individual acquires a commodity. Through appropriation, commodities turn into objects and achieve authenticity and significance. They do so in the context of the moral economy of a household, i.e. the distinct economy of meaning that is “defined and informed by a set of cognitions, evaluations and aesthetics, which are themselves defined and informed by the histories, biographies and politics of the household and its members.” (ibid.: 18) Appropriation describes how households transform the products and meanings of the public sphere; it describes both a process – the process of consumption – and a moment – the moment when an artifact leaves the public sphere to enter the domestic.\textsuperscript{15}

Through appropriation, an artifact becomes part of the spatial and temporal patterns of a household, and thus changes these patterns and is at the same time changed according to them. Objectification describes the disposition and display of the artifact that objectifies “the values, the aesthetic and the cognitive universe, of those who feel comfortable or identify

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\textsuperscript{13} This particular tradition of studying consumption is marked by a number of seminal works: Veblen (1925), Douglas and Isherwood (1980), Baudrillard (1981), Bourdieu (1984), Miller (1987), McCracken (1988), among others.

\textsuperscript{14} While this framework has undergone slight modifications over time, it has persisted to be, in different shadings, the main framework for empirical studies of domestication (Haddon, 2006).

\textsuperscript{15} Note that in fact domestication research has originally concerned itself with the household and its individual members. While this bias is reflected in many empirical studies, it is in no way a necessity. Indeed, many contexts can be conceived of as domestic spheres (Silverstone and Haddon, 1996), and recently “professional domestication” has received more attention (Pierson, 2005; Haddon, 2006).
with it” (ibid.: 23). Through objectification, artifacts become part of, contribute to and signify the domestic aesthetic culture, which in turn is “constrained by material circumstances as well as by preferences and interest” (ibid.: 23). Hence, artifacts are not objectified in isolation, but their display occurs in an “already constructed (and always reconstructable) meaningful spatial environment” (ibid.: 23), part of which is constituted by other technical objects. By complement, incorporation focuses on the way artifacts are used, and describes how they are incorporated into the routines of daily life. Through incorporation into social practices, artifacts change the temporal patterns of domestic cultures, and they do so when they become functional in the context of these patterns. Artifacts, however, may become functional in many ways, and these may differ markedly from those intended by designers (ibid.: 24). Hence, objectification and incorporation together complement clear-cut notions of functionality with meaning, and underscore the constant redefinition and alignment of both functionality and meaning within and between households.

Finally, conversion constitutes a reverse process of appropriation. In the domestic, meanings are negotiated and redefined for “potentially alienating commodities” (ibid.: 25); through conversion, these meanings are released into the public sphere again, where they are, at least partially, displayed and accepted. It is conversion that safeguards the significance of domestication work outside the home – in the more immediate environment of the neighborhood, the work or the peer groups, but also as signals “for producers and their allies in the market” (Silverstone and Haddon, 1996: 46). Through conversion, households indicate and shape their participation in the public sphere, while at the same time actively contribute to the construction of the public sphere and to the learning about products and services.

Appropriation and conversion describe links between the public and domestic spheres, whereas objectification and incorporation relate to the internal structure of the domestic. Objectification and incorporation thus provide “a basis for the constant work of differentiation and identification within and between households” (Silverstone et al., 1992: 25), and these processes together create spatial and temporal boundaries around the home. The molding of both the sign and the utility value of artifacts in domestic spheres have considerable influence on the meaning of these artifacts as commodities in the public sphere.

What is unique about domestication research is that it links insights from the study of consumption to the theory of innovation, particularly by emphasizing the importance of the design/domestication interface (Silverstone and Haddon, 1996). For this paper, domestication research offers two possible readings. First, domestication can be interpreted as a specific form of user innovation – individuals (as members of a domestic sphere) actively work towards private redefinitions of an artifact’s meaning, and traces of these redefinitions subsequently shape the public meaning of that artifact. Hence, “design is completed in domestication” (ibid.: 46), and in this sense the notion of domestication enriches our understanding of learning-by-using – it highlights the intricate ways in which
objects are not only used but also consumed and consummated in commodification. User innovation is thus described not so much in terms of technical functionality, but in terms of the practical and symbolic work that the arrival of a new technology in a domestic sphere entails. As such, domestication describes forms of local and disembodied learning. But it does not stop there – through conversion the outcomes of local learning are generalized and define a technology’s identity and meaning in the public sphere. Domestication thus describes a collective and cumulative learning process through which disembodied knowledge is diffused, and domestication research has indeed provided us with a rich account of this particular form of user innovation.

The approach, however, is at pains to specify how the domestication/design interface is organized. In fact, its scope does not include fully this interface where meaning transferred from the domestic into the public sphere finally gains significance for industrial innovation. What is missing is a specification of the mechanisms and channels through which results from the collective learning of domestication are embodied into the materiality of new or modified artifacts. It is thus a second reading that seems to be most relevant for the discussion of this paper. Domestication underpins (i) that users may spend quite some effort to realize uses, and (ii) that this effort has consequences both for the user (learning opportunities) and the artifact. In this sense, it has enriched any straightforward notion of use, where the criteria of improved or better use are clearly defined. Rather, domestication has reminded us that the use environment is actively and collectively constructed. This in turn, has consequence for the design and modification of artifacts. Innovation has a symbolic dimension, and domestication research has made available the rich insights about consumption to understand that dimension of innovation. However, it has failed to specify how the symbolic and functional/material aspects of technological change are connected.

4. Conclusions

In this paper, an attempt was made to integrate knowledge about the co-evolution of use and design from different literatures – management studies, Science and Technology Studies, and the study of consumption. These literatures have hitherto paid only little attention to each other. I have organized the discussion along lines suggested by early economic studies about the relevance of demand and supply for technological change. First, I have built on Rosenberg’s distinction between disembodied and embodied learning-by-using, and have explored how the literatures discussed deal with these forms of learning and the connections between them. Secondly, I have focused on the local-global link in combining use and solution knowledge. While all literatures discussed implicitly provide

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16 Note that for instance the French word consommer does mean both, to consume and to consummate. This double meaning is particular present in the work of Baudrillard (cf. Silverstone, 1994).
17 In fact, this is the first attempt to integrate results from management studies of user innovations with insights from Science and Technology Studies (STS) on an equal basis. There are other recent attempts to reconcile von Hippel’s work with STS, yet these attempts have a clear emphasis on the STS perspective and pay relatively little attention to von Hippel’s underlying conceptual assumptions (cf. Oost et al., 2008; Oudshoorn and Pinch, 2008).
insights about particular aspects of this link, none of them has explicitly addressed it within a broad theory of industrial change.

Hence, a more general gap comes to the fore with regard to the current knowledge about the co-evolution of use and design. While already Foray (2004) and Lundvall (2006) have acknowledged the importance of interactive learning between demand and supply, available studies in this context have paid little attention to the micro-processes that link (or fail to link) user requirements and product characteristics. The studies discussed in Section 3 have done just that – shed light on particular aspects of the micro-dynamics at work when knowledge about use is combined with knowledge about design. We still lack, however, the conceptual framework to understand how these micro-dynamics are linked to the macro-dynamics of industrial change. In what follows, I provide a number of cues on the way to such a framework:

1. The sources of use knowledge are manifold; they differ across the types of innovation described by the functional sources of innovation. In particular, when users are not the source of innovation, the construction of use knowledge becomes crucial for the micro-dynamics of combining use and design. When users are not sufficiently knowledgeable to realize such a combination themselves, real world experience with the use environment is regularly not available. This does, however, not imply that use knowledge does not become part of an innovation. Rather, such knowledge is then likely to be based on implicit or mediated representation of the future use environment.

2. Use knowledge has a symbolic dimension. Thus, during the diffusion phase of an innovation, users not only learn how to handle (better) the new product, but they define and negotiate use and criteria to evaluate use. “Double loop learning” (Hoogma and Schot, 2001) is thus a crucial part of the innovation process, where users develop requirements and symbolic significance collectively along with the (evolving) technology. The construction of use knowledge is thus an ongoing process, and the participating actors change during different phases of the innovation process. These changes have to be traced in order to understand the feedbacks that exist between the redefinitions of an artifact in use, its occasional modifications in use, and the dynamics of the underlying knowledge bases of industries.

3. Innovation processes are distributed in a specific sense: the search for knowledge cuts across the sites of production and use of a technology. While this has already been acknowledged with the concept of user-producer interactions, this notion has not fully addressed the many forms these interactions can take. User-producer interactions are indeed the main vessel of cumulative learning about a technology, but they are socially rich and distributed processes where sometimes users or producers may be represented by others, or even completely be absent. This transcends a locally bounded notion of user-producer relationships, and points at the global and evolving structure of such relations in technological domains. This has to be understood better:

4. Learning-by-using as a local phenomenon can take many institutional forms that differ with regard to the actors participating in it, the sources of use and solution knowledge these
actors turn to, and the kind of learning that takes place. Available knowledge about these institutional forms and the interactions and actions within them has to be integrated better. In particular, the discussion in this paper suggests investigating more closely the embodiment of knowledge about the use environment in technical objects. This has a local component – to explore how innovators, be that users or manufacturers, make sense out of the functional and symbolic values of technical objects.

5. The notion of interactive learning describes the link between the micro-processes of combining use and design and the evolution of a technical knowledge base. Industrial dynamics comprise global knowledge flows, and these incorporate, explicitly or implicitly, assumptions about demand, use and consumption. These assumptions are initially produced locally, but then negotiated and diffused within industries (and beyond). Domestication research has most clearly addressed this issue for disembodied forms of learning, yet failed to specify links with industrial innovation. The proposition made here is that the nature of the user-producer interactions changes with the development of industries. In this sense, an important topic for further research is the evolution of the institutional forms of user-producer interactions as a part of industrial dynamics. A specification of interactive learning, therefore, has to shed light on different forms of local learning, and the mechanisms that account for the stabilization and accumulation of the knowledge thus created.

6. The success of innovation processes depends on the alignment between use and solution knowledge. Hence, technological dynamics comprise the development of links not only with users but with full blown future or current use environments that are loaded with functional and symbolic value. On this note, innovation indeed is a co-evolutionary process where a complex understanding of use evolves together with the technology. Use, in this perspective, is thus not just out there, with user needs to be elicited, but it is actively created and structured in the interactions of specific constellations of manufacturers, users and mediators. A theory that links use and consumption to industrial dynamics has to cover these links.

References


