User producer interaction in context

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ABSTRACT

User producer interaction (UPI) increases chances for successful innovations. It is not always clear, however, what type of interaction is necessary in a particular context. This article identifies seven different types of UPI: constructing linkages, broadening, characterizing users, upstream involvement, first user enrollment, feedback, and downstream innovation. Specific contextual dimensions from which these UPI types derive relevance are discussed. The technological dimension of this context is conceptualized based on a distinction between types of technologies that differ in the degree to which they are customizable to user demands. Four case studies show that technological characteristics indeed matter for UPI, as do the heterogeneity of users and the phase of technology development.

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1. Introduction

The importance of user producer interaction in technological evolution has been recognized since the 1980s [1]. Producers are interested in societal acceptance of their products, in access to users' knowledge and in mobilizing the creative potential of users [2,3]. Users are increasingly recognized as important sources and co-developers of innovations. Various studies show that users often develop new functions for technologies, solve unforeseen problems and propose or even develop innovative solutions [4–8]. A growing body of literature in the fields of Science and Technology Studies and Innovation Studies addresses the variety of ways in which users can be involved and the question how interaction between users and producers can contribute to the quality of innovation processes. This article draws on both literatures and wraps together the results of these studies to bring some order in the variety of what we call 'types of user producer interaction'. The aim of this conceptual paper is: i) to map and cluster notions of user producer interaction and ii) to explore the relevance of contextual dimensions, especially technological characteristics, for the study of user producer interaction.

The concept of user producer interaction (UPI) has been coined by Lundvall [5] to denote interaction processes that form the backbone of innovation systems. In contrast to pure markets, innovation systems comprise organizational links to exchange information and knowledge about potential user needs and usability of new products. Moreover, because users and producers not only develop, but also optimize information channels, develop a common language for knowledge exchange and develop mutual trust, learning by interacting leads to stronger user producer links within innovation systems. Especially in cases where either technological characteristics or user demands are highly complex and uncertain, strong organizational links can be expected.

Innovation systems consist of interconnected institutions to create, store and transfer the knowledge, skills and artifacts which define new technologies [9]. They contain individual or organizational users, industrial firms, universities, research institutes,

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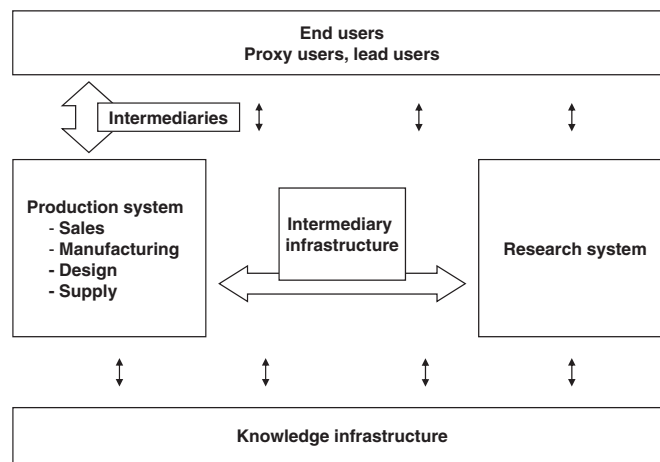   *E-mail address:* r.nahuis@hotmail.nl (R. Nahuis).

Fig. 1. Schematic representation of an innovation system.

infrastructures and various kinds of intermediaries (see Fig. 1). Our focus is on relations between industrial firms (producers) and users.[1]

Producers of technology are firms that transform knowledge, skills and artifacts into products or services to be offered on the marketplace. Producer firms can be divided in four categories according to Pavitt's [10] taxonomy: supplier-dominated firms (e.g. textile, agriculture), scale-intensive firms (e.g. basic materials, consumer durables), specialized suppliers (e.g. high-tech instruments, machinery), and science-based firms (e.g. pharmaceutical, electronics). This distinction is among other things based on different user requirements. Characteristics of sectors thus matter in the way firms relate to and interact with users [11]. In this article, however, we do not explicitly address this factor, because we want to emphasize other dimensions that have received much less attention in the literature.

Users are individuals, groups of individuals or organizations that employ products or services to fulfill a particular need or, in a broader sense, transfer knowledge about usability or user needs. Accordingly, there are different sorts of users. Proxy users are people who are representative for a larger group of anonymous end users. Lead users are people who are representative for future users. Instead of interacting with large groups of end users, innovating producers often recruit proxy or lead users for usability trials and early adoption [12,13]. Another distinction is between intermediate and final users. Intermediate users, for example physicians and pharmacists in the case of medicines, function as knowledge brokers between final users and producers. One could furthermore distinguish between different institutional forms of users, like (lay) consumers, professional users, or the government as client. Partly, but not necessarily, coinciding is the distinction between users as co-producers and users as implicated actors. The first are active agents in technological development, whereas the latter are affected by technology but rather invisible during its development [14]. These distinctions appear particularly relevant when discussing user roles implied in different types of user producer interaction.

The characterization and agency of producers and users also depends on the level of technological detail. Disco et al. [15] distinguish between four levels: components (materials, nuts and bolts), devices (pumps, engines), artifacts (refrigerator, bicycle), and systems (transportation system, electricity network). It is important to keep these levels in mind, because a user at the level of components or devices might be a producer at the level of artifacts. A firm interacting as user with a science-based firm might interact as producer with a scale-intensive firm, being a specialized supplier itself. To avoid confusion, we focus on producers and users at the level of artifacts, without excluding that our findings also apply to other levels. At this level of artifacts, Fleck's distinction between discrete, system and configurational technologies is taken as a starting point [51,52]. We follow and further develop his argument that technological characteristics assume different roles for users in innovation processes [53]. When referring to technology as artifacts, we do not mean that knowledge, skills and techniques are irrelevant. Regardless of level, technologies are configurations that work only because of the interplay between material, social and cognitive elements [16].

Having situated processes of user producer interaction (UPI) about technological artifacts, the paper is structured as follows. First, seven different types of UPI are introduced. Then, the specific contextual dimensions in which these UPI types are relevant are discussed. These dimensions include the type of technology, the phase of technology development and the heterogeneity of users. The next part elaborates on four exemplary case studies to illustrate the UPI types in their particular context. The paper ends with a conclusion and discussion.

2. Types of UPI

We broadly define UPI as interactive learning processes between users and/or producers leading to or aiming at the reduction of uncertainty about the relation between product and demand characteristics. There is a growing literature that addresses UPI in

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[1] According to Lundvall [5] user producer interactions are not exclusive for product markets. Even in basic science there are user producer interactions, although users of science are often scientists too.

technological innovation, accommodating many insights about the different objectives of UPI and their underlying assumptions about the circumstances in which they are important. Our definition covers several concepts that have been introduced to this literature from different theoretical traditions. In this article we review the literature, identify UPI concepts and distil a limited number of more generic types of UPI. We distinguish between constructing linkages, broadening, characterizing users, upstream involvement, first user enrollment, feedback, and downstream innovation.

2.1. Constructing linkages

Any UPI presupposes adequate linkages among and between users and producers. Such linkages develop by interacting and they are getting stronger when they are frequently used. *Learning by interacting* refers to this time-consuming process of *constructing linkages* through which information can pass, including a common code of information to make the transmission of messages effective [5]. It is a prerequisite when frequent interaction is required, e.g. when information and knowledge are tacit and difficult to communicate or when actors have to rely on one another's expertise [5,20,21].

2.2. Broadening

In early phases of technology development it is difficult to identify and characterize the range of potential users and affected actors. There might be a need for *broadening* to create awareness of possible impacts. Van Merkerk defines broadening as "widening the perspectives of actors in terms of identifying a broader set of actors and aspects" [22, p. 42]. As an important element of constructive technology assessment (CTA), broadening is a constructive intervention in an early phase of development, when technology is still sufficiently malleable to steer it in desired directions [23–25]. By broadening their perspectives, actors become aware of how technologies might affect others, and are stimulated to address societal questions and to accept a shared responsibility for sometimes barely predictable outcomes [26]. According to Smits broadening significantly contributes to the success of innovation: "Success and failure are strongly associated with the ability of all parties concerned to form wise alliances and – partly thanks to this – on the ability to mobilize and use the creative potential of users to improve the innovation process" [3, p. 869].

One source of successful innovation is *frame sharing*, i.e. emerging alignment among social groups pertaining to goals, key problems, problem-solving strategies, theories, tacit knowledge, users' practices, perceived substitution function, and exemplary artifacts [27–29]. Frame sharing thus means that interactions move actors in the same directions and, as a consequence, relevant social groups establish a consensual frame and a dominant meaning of the artifact [27]. Although broadening is often associated with frame sharing, it is important to note that the articulation of diversity and dissent can also be key outcomes. Broadening the debate about emerging technology then aims at the revelation of diversity of interests and expectations and the undoing of stable elements of existing frames in order to open up spaces for learning and probing.

2.3. Characterizing users

Marketing research is a discipline engaged with the *characterization of users* and markets. Marketing research may offer important insights for design decisions. Marketing departments may be institutionally divided from design departments, reflecting a linear model of innovation. In this model, product design is seen as an activity of scientists and engineers, whose products are not handed over to marketing until a prototype has been created.

The flaws of this model are twofold. First, increasingly more firms are becoming vertically integrated and improving the feedback and feedforward links between design and marketing. Innovating producers try to determine user needs and requirements in advance [30]. Second, also without involvement of marketing specialists images of users are constructed and used to inform design decisions, though perhaps in a more implicit way. The concept of *user representation* captures both these explicit and implicit modes of user characterization [31].

How are adequate representations of users, including their needs and capacities, constructed in design contexts? Akrich mentions six representation techniques: personal experience, experts, comparison to other products, surveys, user testing, and user feedback. The process of user representation is of interest, because it is a way for producers to deal with the unpredictability of the demand side when products are radically new and there is no established market yet. User representation is the outcome of "techniques employed by system designers to construct and then appropriate […] representations (in a cognitive and political sense) of what the supposed users are and what they want" [31, p. 168].[2] Especially when users are heterogeneous, representativeness cannot be taken for granted and there is a clear need for adequate and specific user characterizations.

2.4. Upstream involvement

Broadening and user characterization are often acts by either producers or intermediaries in order to let various users and implicated actors enter the scope of producers. With *upstream involvement* users become active agents themselves, who participate

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[2] It is important to note that Akrich' [31] concept of user representation covers more than merely characterizing users. Her point is both socio-technical and political: designers make assumptions in the face of heterogeneous users and inscribe these assumptions in the content of the technology. Underlying values and prejudices may be reproduced when these technologies are implemented.

in the process of research, design and development. Upstream involvement is a learning process, because users often do not have precise knowledge, demands, needs and requirements in advance [32–34].

Enriching is an important element of upstream involvement. Technological innovation processes are generally very complex and difficult to control, but are certainly not autonomous. Loci for influencing innovation do exist [35]. But users may not become effectively involved until users are enriched with understanding of the dynamics of technology development and their space for maneuver [22,35]. Enriching refers to the enhancement of actors' capacities to contribute well-considered and effectively to decision making. It is defined as "increasing the understanding of actors in the complex dynamics of innovation processes and their role therein" [22, p. 42].

One of these roles is upstream *demand articulation*. Following Boon et al. demand articulation may be defined as "an iterative, inherently creative process in which stakeholders try to unravel preferences for and address what they perceive as important characteristics of an emerging innovation" [32, p. 645]. To this definition Rip [33] adds two notes pertaining to ambiguous and/or costly technologies. Firstly, he points to the importance of involving spokespersons or representative organizations (like consumer or patient organizations), who are usually better organized and informed than actual users and have better access to upstream developments. Secondly, he argues that the articulation of concerns has become more important in addition to the articulation of needs. Upstream involvement thus comprises both demand articulation and acceptability articulation.

2.5. First user enrollment

The selection and *enrollment of first users* are important for several reasons. According to the lead user argument, most potential users will not have the real-world experience needed to provide accurate data to market researchers. For innovative products, market researchers therefore focus on lead users, who are familiar with conditions that lie in the future for most others. Lead users' perceptions and preferences can therefore serve as a need-forecasting laboratory for marketing research [12].

Another reason for strategic first user enrollment is to gain competitive advantage under increasing returns to adoption [36]. Increasing returns occur when one adoption decision leads to another, for example because uncertainty decreases. Increasing adoption depends on first users' capacity to influence other potential users. Because potential users with similar profiles of social relations as lead users are also likely to make similar adoption decisions, it is strategically important to select representative first users [37].

In a comparative case study of road navigation technologies, Mangematin and Callon [36] make two important contributions to this argument. First, lead users who seem strategically important for the first technology are not necessarily the same as those targeted by promoters of the second technology. The first technology was based on pre-existing broadcasting infrastructure and important first users were car owners. The second technology relied on new infrastructure and first users were rather municipalities of large cities and municipal fleet owners. Their second note is that the choice of first users may influence design decisions. Because persuading first users is crucial in situations of technological competition, producers may need to adjust their technology in line with the specific requirements and expectations of the first users targeted.

First user enrollment overlaps with some other types of UPI like user characterization by means of usability trials. The distinctiveness of this type of UPI is its emphasis on strategies of producers vis-à-vis competitors. First user enrollment is of crucial importance just before market launch.

2.6. Feedback

Production and use of technological artifacts are coupled via feedforward and feedback interaction loops. The abovementioned anticipatory types of UPI are typical examples of feedforward. *Feedback* is another important type of UPI.

One form of feedback is learning by using, focusing on technological performance characteristics. *Learning by using* is a success factor in the majority of incremental innovations. According to Rosenberg, learning by using "begins only after certain new products are used. […It] constitutes a feedback loop into the design aspect of new product development" [17, p. 122/124]. With examples from the aircraft industry Rosenberg shows that many performance characteristics of components (e.g. their lifetime) cannot be properly understood until after prolonged experience. R&D efforts insufficiently yield such understanding, especially in case of a high degree of systemic complexity when the outcomes of interactions and contingencies in user contexts cannot be precisely predicted.

Another type of feedback is about the characteristics and capacities of users. In a case study of usability trials, Woolgar [18] has shown how innovators observe users' confusions, mistakes and other responses to innovative (computer) technology in order to find ways to redirect users and teach them how to use the technology. Innovation is henceforth conceived of as a process of *configuring the user*, a process of "defining the identity of putative users, and setting constraints upon their likely future actions" [18, p. 59]. While this definition suggests that producers force users into a certain role, Mackay et al. [38] insist that organizational and extra-organizational aspects also influence the interaction between producers and users and that the direction is much more bi-directional than Woolgar suggests. Nevertheless, the concept still denotes the necessary encouraging and teaching of users who are interested in exploring the opportunities of new technology.

Learning by using and configuring the user denote two distinct forms of feedback: the first is concerned with technological characteristics, the second with user characteristics. These processes contribute to further demand articulation, but more downstream than is assumed in constructive technology assessment.

2.7. Downstream innovation

Although feedback often leads to useful improvements, users remain relatively passive in the process of innovation. Users may also be actively involved in *downstream innovation* and design beyond providing producers with important feedback. They come up with creative ideas for product development or even make improvement themselves. To capture this role of users as sources of innovation, notions like *innofusion* [39,40] and *user innovation* [6,41] are introduced. These refer to the adjustments to the technology deliberately made or initiated by users.

Innofusion is a contraction of diffusion and innovation [39]. It refers to the adaptations and improvements that users suggest or make when they implement technology into their local situation. Exploiting the flexibilities in design, users customize technology to their specific needs and create an optimal combination of affordances and constraints. Innofusion is especially relevant when users have diverse demands and needs, because this situation calls for customized solutions [19,39,40].

User innovation refers to the recognition of design possibilities, the exchange of innovation related information and the sales of user products within user communities [6,8,41,42]. That is: enthusiast and skilled users are dominant agents in all phases of the innovation process [43]. Flexible, configurational technology is suitable for user innovation, because of the multitude of design possibilities these offer [44]. Another favorable condition for user innovation is when the industry is very much oriented at (compromising) mass products despite a high level of user heterogeneity [44]. Under these conditions, demanding users may want to design their own 'prototypes'. But user innovation also occurs when industry fails to recognize a need or design possibility. In this case, however, one would expect that new manufacturers emerge or existing manufacturers try to appropriate the knowledge because of economies of scale.

Several concepts have been introduced in the literature dealing with user producer interaction. In this section, we have mapped these concepts and clustered them into seven main types of user producer interaction. How, then, do these types relate to contextual dimensions?

3. The context of UPI

In this section we argue that different contexts or circumstances demand different types of UPI. It elaborates three important dimensions – the type of technology, the phase of technology development and the heterogeneity of users – that together shape the context. An argument for distinguishing these variables can be found in an inspiring article about user involvement in ICT innovation, in which Stewart and Williams [19] distinguish between two perspectives – a design-centered perspective and a social learning perspective – and show how types of UPI are associated to either one of them.

The 'design-centered' perspective has its roots in early technology studies, which emphasized how values, interests, biases and priorities of designers become embedded in the material content of technologies. Such values are reproduced, or at least favored, once these artifacts are put in use. Improved UPI from this perspective would entail techniques to include users in early phases of technology development so that design decisions are much more likely to reflect values and desires of users. Human centered design, constructive technology assessment and participatory decision making can contribute to this aim.

In contrast thereto the authors put another perspective in which the innovative role of users and other actors is played in the context of use. This 'social learning' perspective starts from the assumption that technologies are essentially 'unfinished' when they enter the user environment. Technologies only work if they are well embedded into an often already existing context of use, comprising not only machines and systems, but also routines and culture. This means on the one hand that users need to adjust to the new technology and get familiar with its affordances and limitations. On the other hand, social learning often also leads to technological adjustments (innofusion). If the use of technology reveals certain shortcomings of the original design, which designers overlooked due to their limited knowledge of the local context, then users among others can be important sources for improvement. In this perspective users are innovators even when they have been virtually absent in decision making in the context of design.

This article proposes a somewhat more differentiated perspective on contexts in order to generate additional understanding about the role of UPI in technological development. One dimension of contexts is the *type of technology*. The use aspect of a technology can be seen as a set of affordances and limitations that prescribes or suggests how an artifact should or could be used [45–48]. Affordances and limitations do not determine user behavior and capacities, but one can discern degrees of coercion [2,49]. Moreover, these affordances and limitations usually are not immediately clear; they must be discovered and learned when the technology is fit into existing networks and life worlds [2,50] and such learning processes may give rise to technological adjustments [17] or induce further technological innovation [39,41]. The point is that technologies differ in their degree to which affordances and limitations are specified, depending on the interrelatedness of system components, the level of standardization, and the stability of performance parameters [51,52]. This degree, we argue, is crucial to understand the role of UPI in technology development.

Molina [53] has reviewed several categorizations of technologies under the headings of innovation-focused taxonomies, firm-focused concepts, and technology-focused concepts. He hints at Fleck's [51,52] technology-focused typology as the most relevant from a UPI point of view. At the level of analysis of this study – technological artifacts – Fleck distinguishes between discrete technologies, system technologies and configurational technologies.[3] We concentrate on implications for UPI of these three types of

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[3] Fleck [51,52] also distinguishes component technologies, being the elements which system and configurational technologies are made of.

technological artifacts. Having distinguished seven main types of UPI, it is possible to be more specific about these implications. We formulate a number of hypotheses based on and beyond Fleck's analysis and revert to these hypotheses in the case studies and conclusions.

Discrete technologies are self-contained products that end users can make use of in a direct and immediate way (e.g. matches or Aspirin). Design specifications and user prescriptions are relatively well defined and stable. Therefore, innovation of discrete technologies allows for a strict division of labor between R&D researchers and users. For users, it is a 'take it or leave it' adoption decision. According to Fleck [51,52], the development of discrete technologies does not require active user participation beyond decisions in the marketplace. Nevertheless, we hypothesize that UPI types like user characterization and providing feedback are important, because even the design and use of self-containing technology must be learned.

System technologies are complexes of component technologies that mutually condition and constrain each other. They just do not work if one component of the system is changed without changing others (e.g. refrigerators). Their affordances and limitations fundamentally depend on this interrelatedness of components. Innovation in system technologies requires collaboration between experts at the level of components as well as with those involved in overall system design. According to Fleck [51,52], the role of users depends on the extent to which systems are stabilized and standardized, and the extent of customization that henceforth remains. We hypothesize that, akin to discrete technologies, a narrow extent of customization requires a lot of social learning about how to use the technology. When components are more loosely related, the extent of customization is larger, and more technological variation is to be expected at the system level. Since these variations compete for the market standard, we expect that UPI types like adequate user characterization, linkage construction and first user enrollment play an important role.

Configurational technologies consist of mutually interacting components, both technical and non-technical, which may be deployed in a variety of ways to offer variable affordances and meet diverse user requirements. Configurational technologies lack a single standard for overall system performance. Instead, the components may be deployed in a wide range of ways in order to match externally set requirements. Thus, the main difference with system technologies is that their affordances and limitations are shaped during the implementation process instead of prior to it. According to Fleck [51,52], UPI will mainly be oriented at the mobilization of local expertise. User participation is required as only few of the configurational possibilities are fully understood and it remains unclear how new possibilities should be configured to become what users want. This supposes the importance of downstream innovation [40].

Apart from the type of technology, it is widely acknowledged that the nature of innovative activity also changes along different *phases of technology development* [54,55] with important consequences for the types of UPI that should be employed in these different phases [19,35]. In early phases, technology promises to bring various opportunities for innovation and it is difficult to predict which directions will become successful. In later phases, outcomes of technology development are easier to predict but more difficult to reverse, due to earlier decisions and investments [54]. Rip and Schot [35] argue that these phases can also be distinguished on the basis of typical activities. Accordingly, the relevance of particular types of UPI can be expected to vary along phases of development, as terms like upstream, downstream and feedback already indicate.

The concept of phases also draws attention to the evolutionary relations between Fleck's types of technologies. Configurational technologies, for example, often evolve into system technologies when configurational activity becomes path-dependent, user requirements converge and system standards emerge. Even further in their stabilization and standardization, some generic systems may evolve into discrete technologies and eventually become constituent components of other systems and/or configurations. But there are also examples abound of situations (e.g. in robotics) in which local contingencies continue to resist standardization and systematization [56]. What is more, technologies may evolve from systemic into configurational technology over time, for example when enthusiast user communities acquire sufficient technical skills to deconstruct integrated systems or to reconfigure them into technologies that serve their own purposes, or by the introduction of standardized parts in the supply chain. The use of automobiles as a stationary power source in rural America or the invention of mountain bikes are nice examples here [8,29].

A final concept for understanding the importance and type of UPI is the *heterogeneity of the user population*. The more heterogeneous users are, the more complicated it is to align technological opportunities to user demand. In case of discrete or system technologies such alignments may occur by closure of controversy [27], for example due to standardization or convergence of demand. Similar dynamics may also appear in the development of configurational technologies, which would then evolve into system technologies. However, if technologies are highly configurational, then heterogeneous users may also be served with differentiated products [44].

There are several sources of heterogeneity: user contexts are often unique as a consequence of contingent historical developments (e.g. existing technology, routines and institutions) [40,57]; there may be different kinds of users of the same technology that have different needs and concerns (e.g. medical professional, nurses, patients, hospital administrators in case of medical technologies) [2]; and these users may have very different capabilities and knowledge bases (depending on e.g. education, skills, experience) [31]. We use the notion of relevant user groups to define user heterogeneity [27–29]. A relevant user group is a social group among engineers, market researchers, governmental agencies and other users groups involved in innovation. We define user heterogeneity then as the existence or emergence of multiple relevant user groups. These could be end users, proxy users or intermediary users, lay users or professional users. User groups are relevant when they are involved or implicated in disputes and interactions, for instance because they have a problem for which one variant of the technology might offer a better solution than another. Heterogeneous users thus put various, and sometimes conflicting, requirements to a certain technology.[4]

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[4] In this context, Bijker's notion of a technological frame highlights that users do not attach meanings to technologies at random. Meaning attribution, and hence social group identification, take place with reference to these more widely relevant and historically patterned technological frames [27] or even broader to persisting socio-cultural power divisions [63].

4. Four cases of UPI in technological innovation

In the first part of this paper, several types of user producer interaction (UPI) are discussed and three dimensions, i.e. the type of technology, the phase of technology development and the heterogeneity of users, were introduced that determine the demand for types of UPI in a particular context. The second part of the paper provides illustrations of the claim that types of technology demand different types of UPI. We present different technology types in four case studies and investigate whether different UPIs indeed can be identified. The case studies furthermore reflect on the role of UPI in the co-evolution of technology type and user heterogeneity in specific phases of technology development.

The four case studies reflect the different types of technologies in the following way. The first, clinical anesthesia, is an example of a discrete technology. The second, the refrigerator, is a typical system technology with early standardization and stabilization of design. The third, Video Cassette Recording (VCR), is a case of two system technologies competing for the market standard. And the fourth, the bicycle, is an example of a configurational technology that evolved into a generic system and back to configurational technology. These examples are chosen due to their eligibility to underline technology and user characteristics and are based on existing and well documented cases in innovation studies literature [8,27,28,58–65]. Although we rely on secondary literature and studies that were partially conducted for other purposes, these studies contain sufficient empirical detail to distil information about UPI. We do not aim at a full account of the evolution of the technologies, but at constructing stylized examples of UPI. The function of stylized examples is to find anecdotal support, not full evidence, for the hypotheses we formulated in the context of Fleck's typology of technologies and the examples are approached mainly as a trigger for speculation, in line with the conceptual objective of this paper. Each case is introduced with some background information in order to show how relevant UPI types highlight certain activities and interactions in the dynamics of innovation.

4.1. Discrete technologies: the case of clinical anesthesia

Discrete technologies are products, which consumers can directly use without much learning or interfacing with other elements. Obvious examples are 'plug and play' mass products like matches or toothpaste. We selected the case of clinical anesthesia in nineteenth-century American surgery to elaborate on the implications for UPI. Like with other discrete technologies, the role of users is mainly to make selection decisions in the marketplace. But in this case, adoption assumed several complementary types of UPI. The case, which is carefully documented by Pernick [61], is therefore interesting for the purpose of this study.

The two anesthetic products used in the mid-nineteenth century were ether and chloroform. While these anesthesia themselves were discrete technologies – the same substances were used, though in varying doses – different groups of surgeons and dentists attached diverging meanings to the new technology. There were many opponents with fundamental objections, who considered anesthesia as unnatural, as an inhibitor of the self-healing capacity of the body, as an encouragement of unnecessary surgery, as a deprivation of the patient's autonomy during surgery, or as an unacceptable risk (some patients never woke up, wrong limbs were amputated). Against these fundamental objections, a group of pragmatically oriented surgeons rapidly emerged. This group perceived objections against anesthesia use much more in terms of disadvantages, risks, and reservations, which could be weighed against benefits and the need for anesthesia. They varied doses according to presumed sensitivity of patients and the kind of surgery, a successful approach given the rapid growth of this group compared to the other groups.

Factors accounting for the selective but growing use of anesthetics do not include the availability of ether and chloroform. Thanks to pharmaceutical pioneers (like Edward R. Squibb), improved and purified anesthesia were readily available and affordable soon after their first introduction in 1846. Neither was patient demand a key factor. Patient demand by far exceeded the willingness of surgeons to use these new anesthetics.

This draws attention to the role of pragmatic surgeons as *first users*, whose adoption decisions contributed to adoption considerations of others in the community. These first users were prepared to selectively use anesthetics on the basis of a 'calculus of risks and benefits' in which individual differences with regard to age, race, sex, social class, nature of ailment, etc. were believed to determine pain sensitivity and response to anesthesia. This wide orientation on individual differences was an intervention in the process of *broadening* that other groups of surgeons had initiated, pointing to a spectrum of principle objections. The pragmatic approach had to take these objections into account. Broadening thus affected the adoption process in the sense that it forced the first users to include a wide set of aspects in their justification of using anesthesia in well-defined circumstances. Although these first users particularly consisted of mainly younger surgeons and surgeons differed in weighing particular aspects, their approach attracted ever more surgeons to the debate in which ideology only played a minor role. The group of users grew as they developed common values, codes, guidelines, and visions of the future.

The arising new frame of using anesthesia started to stabilize when statistically sound procedures and rules were developed to guide decision making about the use of anesthesia and became part of more general notions of good medical practice. This points to the importance of *feedback*. Statistical evidence was based on medical records of hospitals. Guidelines and procedures, including debates about these procedures in journals and meetings of associations, were indirectly based on experiences of surgeons using the new anesthesia. In this sense, feedback contributed to the diffusion of anesthesia, but targeted medical guidelines rather than product improvement.

Of further interest here are the linkages through which feedback via medical records led to formulating medical guidelines. *Constructing linkages* refers to the development, maintenance and optimization of channels and codes for interaction. The case of anesthesia took place in a context in which such channels and codes were already being developed, mainly thanks to the rise of new communication and transport technologies like the telegraph and railroads. Forums for debating standards and

guidelines for the selective use of anesthesia, such as medical (reform) conferences and special committees, were more easily organized and new organizations like the American Medical Association were founded. Moreover, as rules, procedures, standards and guidelines were increasingly based on statistical knowledge (displacing prejudice), the stratification of patient populations provided the codes for interaction. Platforms and codes for debating medical guidelines were the outcome of a process of constructing linkages.

To conclude, the example of clinical anesthesia well illustrates how concepts like broadening, first user enrollment, feedback, and linkage construction are relevant for understanding UPI about discrete technology. Moreover, these types of UPI appear to contribute importantly to the convergence of the user population. The case also shows that most interaction processes occurred among users instead of between users and producers. The reason for this is that in the case of anesthesia, and in discrete technologies in general, processes of adoption were far more crucial than for instance user involvement in investment decisions by producers.

4.2. System technologies with early stabilization: the case of the refrigerator

System technologies consist of mutually conditioning components and a specific overall identity. Examples of system technologies are mass market products like grass-mowers, computer games and mass produced consumer electronics. In each of these examples, a multitude of design directions is possible from a technological point of view, but one dominant design finally turns out to offer the best fit for large market segments. After the establishment of a dominant design, innovations tend to be only incremental, because of the intertwinement of components. In this paper we distinguish between a situation in which one dominant design soon emerges and a situation in which multiple designs compete for dominance. To illustrate the types of UPI relevant in this first situation, we discuss the case of the domestic refrigerator based on literature that describes its development and diffusion from 1914 until the 1930s [60,62,64].[5]

Consisting of a large number of components, the refrigerator is an example of a system technology. Its dominant design stabilized in an early phase of development, partly because its working mechanism prescribes a particular configuration of components. A liquid, called the refrigerant, transports heat from the inside to the outside through a process of compression, cooling, expansion and evaporation. Because these components mutually require each other, most machines for domestic use were similar[6] and competition was a matter of price and design style [60]. Another reason for the similarity between most early designs is that cost saving mass-production methods created a powerful disincentive to variety.

UPIs have importantly contributed to the development and diffusion of refrigerators. Initially, however, *characterizing users* was not considered a very difficult part of the innovation process. Pre-existing iceboxes informed entrepreneurs (and investors) in an early phase about the likely role of refrigerators in future households. These boxes (wooden cabinets that were kept cool with blocks of ice) already embodied relatively new household practices of (weekly) shopping, food preservation, and the use of leftovers [60]. Manufacturers derived the expected demand for refrigerators from the growing demand for iceboxes [62].

The most prominent type of UPI was *feedback*. In the development phase and the first years after market introduction, most issues were technological, such as finding the best refrigerant, designing reliable components, and protecting the system against freezing and leakage [62]. Enhancing technical performance of refrigerators happened at design departments, but continued through a process of feedback after early models had entered the market. With regard to user demand, feedback entailed issues of price, size, weight, automatic control, reliability and safety. These demands were addressed in subsequent product cycles and amounted to the path-dependency of the development process and to a relatively stable design. For example, early market surveys had learned that price was a crucial adoption factor, so producers chose to minimize costs rather than to develop alternative models for relatively small niche markets [60].

During the 1930s, manufacturers started to pay much more attention to the *characterization of users* for design purposes. User characterization processes were mediated by consumer research, analyses of competition, and retailers. For example, market researchers went door-to-door with scale drawings and models and even with a number of real refrigerators loaded on the trailer of a truck [60]. Several lessons were learned. Though design style was important, housewives particularly appreciated features like cleaning simplicity, efficiency, and convenience. Models inspired by an engineering logic (e.g. the Monitor-Top produced by General Electric with the compressor on top of the box) were least attractive. In this case user characterization was a mediated process and mainly involved emphasizing the disadvantages of existing refrigerator models.

Collecting *feedback about behavioral aspects* of refrigerator use also occurred via the work of intermediaries (like home economists and industrial designers). This type of UPI covers gathering information about potential mismatches between values inscribed in the technology and the behavior of users as well as suggesting solutions to better align users and technology. Solutions could involve the reconfiguration of the technology, but also the reconfiguration of users [18]. Home economists, a professional class of mainly women who informed the general public about matters of health and hygiene, were employed by refrigerator producers and visited households to promote the idea of 'scientific housekeeping' and to remind women of their responsibility for the health of the family. Refrigerators came to embody values that typically belonged to this idea. Their white color reflected the importance of hygiene, the size and the interior assumed housewives buying milk, meat, and vegetables in

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[5] In this paper we do not discuss the very first phase of mechanical refrigeration. See [55] for the transition of harvested ice to manufactured ice and the adoption of ice machines in restaurants and cruise ships.

[6] A differently assembled type is the refrigerator based on absorption instead of compression. Schwartz Cowan [62] describes how this type never really acquired a sustainable market position for other reasons than consumer preferences.

bulk to reduce shopping trips, and using leftovers. This middle-class way of life was very appealing for those who could not afford servants (anymore). Hence, technology design as well as advertisements promoted the 'electric servant' as a way to configure the refrigerator user, a configuration informed by feedback from modern housewives.

The case of the refrigerator highlights the work of intermediaries, who took part in a process of *linkage construction* between producers and users. Intermediaries were involved in characterizing users and organizing feedback to improve both technological performance and user behavior. Accordingly, this case illustrates how technology, users, intermediaries and cultural contexts co-evolved even after the early stabilization of the refrigerator as system technology.

4.3. System technologies in competition: the case of video cassette recording

The refrigerator is an example of a system technology with early stabilization. Technological interrelatedness of components, economies of scale and converging demands quickly contributed to the establishment of a generic identity that governed overall system design. In the case of video cassette recording (VCR), the literature rather points to competition between multiple system designs [58,59,65]. Due to its configurational flexibility, different types of VCR co-existed for some time between 1965 and 1975. Design options existed with regard to tape dimensions, number of heads, scanning method, track dimensions, tape and rotation speed, electronic circuitry, mechanical parts, etc. Between 1965 and 1970 eighteen prototypes were developed by nearly as many manufacturers, all configured differently [59].

In this early phase, Sony seemed to be the most successful pioneer. Its U-Matic (1971) was successful on the market of schools and other institutions. However, to persuade consumers on the mass market the U-Matic still had too many limitations, such as size and weight of the machine, the size of the cassette, recording time, inconvenience and costs. In this context, pioneers made different decisions. Sony decided to focus on miniaturization of cassettes and JVC (and others) on increasing recording time. They were aware of the importance of one standard to enable interchangeability of cassettes. In this standardization battle, mainly between Sony's Betamax and JVC's VHS system, the latter survived and nearly all other producers would in the end adopt the VHS standard.

For the purpose of illustrating the role of UPI we focus on Sony's self-confidence and its consequent neglect of desires and trends in the context of use. Sony failed to persuade potential collaborators, because Sony had not sufficiently invested in *user characterization*. Based on the diffusion of television and VCR developments in the film industry, Sony was the first to envision a mass market for video recording. The company focused on miniaturization, i.e. reducing size and weight of machines and tapes, but neglected other aspects: its first Betamax model only allowed for one hour recording time. For user characterization, American television manufacturer and video pioneer RCA had just performed a market study, in which it had given 200 of its own VCR's to customers in the US, and concluded that recording time should be at least two hours [58]. Sony ignored this outcome, while its potential collaborators in Japan (Matsushita, Hitachi, Sharp, Mitsubishi) decided to wait for the VHS format with 2 hours recording time, which JVC announced a couple of months later. Together with most European and American manufacturers, including RCA, they jumped on the VHS bandwagon.

This responsiveness to user needs is one element of what Cusumano, Mylonadis and Roosenbloom [58] call the 'strategic maneuvering' of JVC and Matsushita. Considering whether to focus on one best design or on increasing production capacity to prepare for mass production, JVC and Matsushita opted for the latter. Sony, quite convinced of its own technology and production capacity, pressed commitment and reputation in the persuasion of potential partners to adopt the Betamax standard. In contrast, JVC showed more modesty and flexibility, because JVC needed others to be able to produce enough quantities for the different markets across the globe. JVC thus aimed at *upstream involvement* of others to improve the VHS standard, by providing assistance in manufacturing and marketing. "One outcome of JVC's approach was that prospective manufacturing partners truly believed they would have some stake in the future evolution of VHS features. Allowing partners to share in development also improved the VHS in ways that Japan Victor [JVC] might not have pursued itself" [58, p. 16]. Their approach was to *construct linkages* through which important collaboration was organized, in order to form alliances and increase production capacity.

Another manifestation of this strategic maneuvering was the choice of *first users*. The two-hour recording time allowed JVC to enroll movie rental companies in their networks. JVC's American partner RCA developed an important alliance with Magnetic Video Corporation (MV), a manufacturer of pre-recorded videos for education and training and the first company to offer feature films on cassette. RCA offered two free cassettes as well as a MV membership to all their VCR customers. The demand for MV pre-recorded VHS tapes increased relative to Beta tapes and MV expanded capacity for producing VHS tapes. In general, the emergence of a video rental business and a growing availability of movies on tape was a decisive element in the standardization battle. The sudden possibility to watch erotic content privately, for example, pushed the exponential growth of VCR ownership in the early eighties. Similarly, renting a video machine and some tapes for a child's birthday party or just organizing a weekend of watching movies was a common practice in the mid-eighties [65]. In effect, in 1980, VHS' share in cassette sales was estimated to be between 70% and 90% [58].

To conclude, VCR is a system technology that could be configured in a variety of ways, but stabilized in one particular way. The case shows how the very interactive approach towards partners, proxy users and first users allowed JVC and Matsushita to gain a sustainable and winning position. They strongly anticipated the role of the rental business in the adoption of a standard. UPIs, such as user characterization, linkage construction and first user enrollment seemed to be most relevant for the stabilization of the VCR technology. Insofar other manufacturers can also be seen as first users of the VHS standard, upstream involvement also played an important role.

4.4. Configurational technology: the case of the bicycle

Configurational technologies are adaptable configurations composed of loosely coupled and changeable components without overall system identity. Configurational technologies can be applied in a diversity of user contexts, because they can be tailored to the specific desires, needs and requirements of users. Examples are computer software, robots, but also homemade meals and bicycles. We take the development of bicycles as an example to explore UPI in configurational technologies. Due to its assembled nature, the wide availability of components, the relative ease of reparation or modification, and the variety of available models the bicycle is a typical example of a configurational technology [20].

A number of important types of UPI are distilled from the literature [8,27,63]. In the early phase of development, until the late 1860s, most bicycles were fairly simple constructions produced by hobbyists, local blacksmiths and carriage makers. In the relative absence of upstream design, we regard this activity as *downstream user innovation*, because these local producers stood very close to users or were users themselves. The technology was very flexible, meaning that various designs were reasonably possible. In this situation, users were important agents in the creative process of idea generation and prototype construction. Examples of user innovations are the 'fast-running machine' (1817) by Karl Drais and the 'hobby-horse' (1839) by Kirkpatrick Macmillan [27].

Feedback processes were an important driving force in the succession of a variant. One problem with the first wood-made 'running machines' was the impossibility of steering and keeping ones balance. While this problem was solved by adding and improving a steering mechanism, other problems remained, such as muddy feet due to the absence of treadles. Treadles with levers connected to the rear wheel then turned out to require great effort from the rider. These problems inspired the development of a solid wrought-iron front-driven vehicle with cranks directly connected to the axle of the front wheel, a relatively successful model that would become known as the 'Ordinary' [27].[7] In this process of bicycle development, feedback and downstream innovation were indispensable activities

The concept of *first user enrollment* draws attention to the focus on sportive young men by bicycle producers who organized racing contests as a way to promote their products [27]. Racing contests targeted sportive macho men. As in Mangematin and Callon's [36] case of road navigation, first user enrollment had implications for design. Early producers focused on maneuverability and speed rather than on safety aspects. Accidents could be said to belong to the activity of racing, not to bikes as such. Had elderly and women been selected as first users, other kinds of demonstrations (e.g. with women in dresses riding bicycles) would have been organized and other kinds of bicycles would have been produced. This, however, did not happen until pedestrians, women, elderly and other typical non-users of the high-wheeled Ordinary started to articulate their concerns and worries about the increased appearance of dangerous Ordinaries in parks and streets. This *broadening* of the debate about what a proper bike is included aspects of comfort and safety. Other models such as tricycles, lower ordinaries, and low-wheeled chain driven vehicles were proposed as solutions for the safety problem. These models co-existed with the Ordinary for some time. Such unproblematic co-existence is not unusual for configurational technologies. But in this case the safety discussion raised the demand for a single type of bicycle that would be fast, comfortable and safe for both riders and pedestrians. The introduction of 'high speed' air tires instead of energy consuming anti-vibration springs would eventually close the controversy and lead to a dominant design, which was both safe and fast [27].

Over time, an industry for mass production of bicycles as well as components (saddles, tires, etc.) emerged. Next to this, local blacksmiths and mechanics continued to produce small numbers of bicycles against competing costs. Most bicycles shared a similar design based on the historical outcome of a social construction process. Yet, some niches existed for special, more expensive, 'de luxe' bicycles, both produced by special departments of factories and by local workshops [27].

Nowadays, niche markets exist for mountain, race, folding, electric, recumbent, and beach bicycles. The mountain bike in the 1970s is a nice example for illustrating *downstream innovation* in later phases of bicycle development, giving rise to new industrial life cycles. In the early 1970s, groups of some young cyclists began using bicycles off-road, for which they constructed radically new 'clunkers' themselves: strong old bike frames with balloon tires to which they added motorcycle lever-operated drum brakes for better stopping ability [8,63]. These bikes were subsequently produced by small specialized manufacturers, soon followed by major bicycle manufacturers. But downstream user innovation continues when new groups of cyclists adapt mountain bikes to rather unexpected conditions. Lüthje et al. [8] mention examples such as 'anti-spin foam rings' for pedals on stunt bikes, 'winter tires' on ice bikes and a 'thumb-activated stopwatch' on a training bike.

To conclude, the bicycle is an interesting case of configurational technology. Downstream innovation, first user enrollment, broadening and feedback played an important role in the various product cycles in the history of bicycle development. We have taken multiple cycles into account, because they very well illustrate downstream user innovation typical for configurational technology [39,56]. It is furthermore noteworthy that a configurational bicycle evolved into a system technology, with a dominant design, and back into a configurational technology again, when user groups reconfigured that design.

5. Conclusions and discussion

Innovation processes take place in the context of systems of innovation, in which producers and users depend on each other's knowledge and capacities. Such context dependency is especially strong when new technological opportunities are just emerging, when users are very heterogeneous, or when there are relatively many design options. User producer interaction is indispensable

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[7] This short summary admittedly reintroduces an assumption of linearity that Bijker carefully circumvents in his historical account [27]. See his book for a more evolutionary account that puts failing variants at an equal footing.

in these circumstances. Users have to learn how to assess the usability of new technology, to articulate needs and concerns, to intervene in important design decisions, to get technologies to work, to adapt technologies to their specific circumstances, and to establish effective modes of interaction. Producers have to learn what users want, how new technologies fulfill such wants, how to deal with concerns and resistance, how to cooperate with users, how technologies perform in a user context, whether interfaces are clear, whether users are capable of adjusting technology to their needs, what adaptations should be made, and how to receive such feedback at all. Different types of UPI serve this variety of objectives.

In the first part of this paper we draw on two strands of literature: Science and Technology Studies and Innovation Studies. Although these strands have different origins (sociology of science and evolutionary economics respectively) and different journals and conferences, they deal with a very similar subject matter, especially with regard to user producer interaction. We think that more efforts can be made to combine these literatures and show similarities and tensions. In this paper, both literatures are used as sources to identify a large variety of notions related to user producer interaction. The first aim of this article was to map and cluster several of these notions. We discussed their relations and aggregated them into seven more general (though sometimes overlapping) types of UPI: constructing linkages, broadening, characterizing users, upstream involvement, first user enrollment, feedback, and downstream innovation. These types of UPI assume different objectives and roles for producers and users. This typology of UPIs can form the basis for further research into UPI. It imposes new questions, for example about the different kinds of linkages that need to be constructed for upstream involvement, broadening or feedback. Or about the way in which first user enrollment affects downstream innovation. Future research could deepen the understanding of UPI in context by testing whether our typology of UPI should be further aggregated or differentiated. To what extent, for example, do types of UPI still overlap or is one type of UPI embedded in another? In the literature, demand articulation is introduced to emphasize the role of users upstream the development process. We have argued that demand articulation is also an important element of feedback and downstream innovation.

The second aim of this paper was to explore the relevance of three contextual dimensions: the type of technology, the phase of technology development, and the heterogeneity of the user population, for the study of UPI. We have conceptualized the technological dimension of this context on the basis of Fleck's distinction between discrete technology, system technology and configurational technology. System technology is further differentiated in systems with early standardization due to technological interrelatedness of components (akin to discrete technologies) and relatively flexible systems that leave room for variations to compete for the standard (more like configurational technology). This differentiation acknowledges the gradual differences between Fleck's types of technology, which is also reflected in the possibility that one type of technology might evolve into another (and in which UPI often plays an important part).

To illustrate the potential value of this conceptualization of UPI, four examples of innovations with varying technological and user characteristics have been explored: clinical anesthesia, the refrigerator, video cassette recording, and the bicycle. These case studies draw on secondary literature, which has some repercussions for the conclusions that can be drawn. For example, some of the original studies focus more on the producer side (e.g. in the case of VCR), whereas others take the context of use as an entry (e.g. in the cases of anesthesia and the refrigerator), which may be reflected in the types of UPI that can be highlighted. Another repercussion is that these studies have not attempted to cover the full range of UPIs that played a role in the development of the technology. For our purpose, it was unavoidable to sometimes read UPI between the lines of the source material. Having said this, the literature provided sufficient empirical detail to construct stylized examples of UPI in technology development. For each of the four examples, the relevant UPI types have been discussed and it is shown how these types highlight certain activities and interactions during key events of innovation processes. These examples provide empirical support for and further speculation about the claim that different types of technology demand different UPI types.

In a case of a discrete technology, clinical anesthesia, notable UPIs were broadening, first user enrollment, feedback, and linkage construction. These findings confirm Fleck's assumption that users are hardly involved in production processes, because discrete technologies do not leave much room for customization. But they do not imply that users are absent in the innovation process. Observed interactions occurred among users rather than between users and producers and had to do with implementation issues and the challenge to find support for the technology among a highly divided user population.

In the case of the refrigerator, a system technology with strong interrelatedness between components and good prospects of a mass market, producers decided to serve the market with very similar models. UPI therefore concentrated on user characterization and feedback about both technology and users, mainly after market introduction. The role of intermediaries was part of linkage structures facilitating the consultation, representation and shaping of users.

Video cassette recording was selected to illustrate the relevance of types of UPI in case of competing system technologies. The focus appears to be on user characterization, linkage construction and first user enrollment in an early phase. The characterization of users as movie watchers (two-hour tapes) and, later, the enrollment of the rental business as one of the first (intermediate) users, affected both the shape of the technology and its success on the market. These UPI strategies were part of an interactive approach that enabled VHS system to become the standard system.

The bicycle, finally, is a case of configurational technology. As expected, downstream innovation and feedback were very frequent, both in very early phases of development (the first bikes were not really the result of an upstream design process) and in later phases. Interestingly, a standard emerged in the meantime. Instead of customized solutions for different groups of users, a broad debate about safety in the streets took place, which led to one dominant design. The new design temporally transformed a configurational technology into a system technology. Over time, user groups as well as producers challenged the dominance of this design and started reconfiguring bicycles. The contemporary heterogeneity of users and variety of bicycle designs illustrate the regained configurational character of bicycles very well. Note that similar dynamics can be observed in the ICT sector [19].

Quite unexpectedly, at least from a design-centered perspective, we did not encounter an example of upstream user involvement in these four cases. A hypothesis for future research is that upstream involvement is rather a contemporary prescriptive concept for controversial areas like nuclear, bio- and nanotechnology, than a descriptive one for historical cases like those we explored. Upstream involvement has been promoted since the 1980s in the context of the Collingridge dilemma, which assumes that technology is still malleable in early phases – so that it makes sense to involve users in early decision making – but it is also hardly possible to predict the impact of such involvement [54]. In our case studies, producers limited upstream UPI to user characterization and learned from (downstream) feedback whether they made the right design decisions or not. The only exception is the bicycle, in which case (of configurational technology) early involvement coincided with user innovation and downstream customization. The concept of development phase hardly applied in that case.

This paper discussed the role of users especially in relation to the flexibility of technology. In the literature it has been postulated that the more flexible a technology is, the more actively users can contribute to innovation, and the better technology serves their needs [13,51,54,66]. We draw two general conclusions that moderate this claim. With regard to technology flexibility, we conclude that UPI took place in innovation of any type of technology. Although users may not be designing discrete or system technologies, they do provide important feedback about the role of technology in practice and first users are crucial for attuning technological opportunities to user demands. A broad and differentiated conceptualization of UPI renders these roles explicit. With regard to the normative part of the claim, that flexible technologies better serve the needs of users, we want to argue that being locked into inflexible technology might be good if the direction of technology development has been selected with care (for users). No doubt that clinical anesthesia and refrigerators contributed importantly to modern welfare.

We end this paper with some suggestions for further research. This paper shows the relevance of different types of UPI in different contexts. It also discusses how UPI affects the dynamics of innovation. A further contribution to understanding the co-evolution of technology, users, and cultural contexts could build on our observation that the influence of UPI is not limited to the success or failure, but also to the direction of technology development. Technologies may even transform from one type into another over time.

Further research could also shed more light on how the degree of user heterogeneity is both an incentive and an outcome of UPI. For example, the homogeneity of American middle-class refrigerator users was in part the outcome of feedback about user behavior by home reformers, industrial designers and marketing specialists, who collectively engaged in the shaping of refrigerator users. In a similar vein, the broadening of the meanings of anesthesia and bicycles contributed to the convergence of different (non)user groups or gave rise to the establishment of new, more homogeneous user populations.

Furthermore, the case studies suggest important influences of different kinds of institutions such as patents, OEM agreements, regulation, professional associations, and professional norms. The influence of such institutions was not spelled out extensively in our endeavor to put UPI in context, but is highly relevant when UPI is deliberately organized in a real life context.

Finally, the classification offers an outlook on developing a 'toolbox' for organizing and managing UPI in context, but our reflections also imply that this metaphor should not be taken too literally. The 'tools' will need to be interpreted in relation to the specificity and contingency of particular technologies and markets. Nevertheless, much more can be learned about the particular forms, mechanisms and conditions for effective UPI. In our research, cases were primarily selected to illustrate the type of interactions in a particular context; they are not necessarily examples of effectively organized and managed interactions. With that in mind, our study could support analysts, policy makers and practitioners to contextualize innovation processes and to sensitize them to relevant types of UPI in those contexts.

Acknowledgments

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