The role of learning-by-using in the design of healthcare technologies: A case study

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Abstract:
New technologies typically go through significant improvements during their early diffusion. Literature suggests that these modifications follow from learning-by-using. However, the micro-level processes by which learning-by-using is actually achieved remain understudied. The present paper examines these processes through an in-depth case study of the design and use of a new health-care device. It identifies several learning processes and preconditions for learning that constituted learning-by-using. The results question the dominant image of learning-by-using as a harmonious flow of user feedback.

Key words: Learning-by-using, learning, diffusion, innovation

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Mainstream diffusion research has been most concerned with how "potential users become informed about the availability of new technology and are persuaded to adopt, through communication with prior users" (Attewell, 1992, 2). In adopter studies, early and late adopters have been compared on factors such as firm size (Davies, 1979), perceived advantage to be gained from technology (von Hippel, 1988), presence of innovation champions (Rothwell & Zegweld, 1985), and various organizational and environmental attributes (cf. Attewell, 1992). In studies on macro-diffusion, the spread of innovation has been most prominently examined in terms of gravity model of spatial spread, flowing from early adopter sites to later adopters and S-shaped curve in the extent of adoption over time (Rogers, 1995).

But diffusion is not only dependent on the signalling and learning about the availability and potential of the new technology, but also on the learning required to realize the potential in the technology. Innovation typically results from accretion of multiple, often hundreds, of small improvements, emergence of associated technologies, services, and organizational redesign that significantly enhance its value for the adopters (Rosenberg, 1979; David, 1990; Gardiner & Rothwell, 1985). Even when these improvements may require only routine engineering, they are crucial for the economic value of the innovation for its various users and thus for its proliferation. Innovation is therefore not a matter of a one-off act of invention and its subsequent diffusion, but tends to be continued by both its users and developers over a significant period of time (Rosenberg, 1979; Williams et al., 2005).

The most examined learning processes for post-launch improvements is "learning by doing", which was originally offered to explain why the cost of manufactured goods tends to decline significantly due to accumulation of skill in producing them (e.g. Wright, 1936; Arrow, 1962). Similar improvements and cost-reductions have been suggested to result from "learning by using" capital goods: the users' increasing skill and/or understanding in using the product, leading to, for instance, less maintenance and new uses. The redesign of products due to feedback of users' problems and requests and locally made modifications by the users themselves lead to "embodied" learning (Rosenberg, 1982). It is now regarded more a rule than an exception that users of new technology modify it to better suit their work, culture, and priorities (e.g. von Hippel, 1988; Suchman et al., 1999; Williams et al., 2005). Correspondingly, the importance of the flow of user-identified problems and solutions to the iteratively improving design has been emphasized (Freeman, 1979; Gardiner & Rothwell, 1985).

In this vein technology adoption has been characterized as "mutual adaptation" of technology and organization (Leonard-Barton, 1988), and as "learning by trying" to emphasize the difficulties that often ensue (Fleck, 1994). Lundvall's "learning-by-interacting" stressed the active engagement between designers and users as a prerequisite for success (Andersen & Lundwall, 1988; Lundvall, 1988). However, many studies have drawn attention to lack of such interaction in actual corporate environments and the impediments to realizing it (e.g. Leonard, 1995; Miettinen et al., 2003; Williams et al., 2005). For instance, the upsurge of user centered design (UCD) since early 1990s (e.g. Greenbaum & Kyng, 1991; Nielsen, 1993; Preece et al., 2002) created initiatives to study designer-user collaboration in industry. In well over 30 in-depth case studies direct collaboration, use of UCD-methods, or even efficient channelling of user problems and inventiveness to improvements happened in more modest scale and in more ad hoc fashion than ever expected by the researchers or by the managers of the firms studied (Williams et al., 2005; Oudshoorn et al., 2004; Miettinen et al., 2003; Hasu et al., 2004). These findings resonate with the assessment made by Eric von Hippel and Marcia Tyre: "Although the economic significance of learning by doing and using has been made clear, the *process* by which these gains are achieved is still quite unclear. That is, we do not know the micro-level mechanisms by which learning by doing is actually done" (von Hippel & Tyre, 1995, 1, emphaisis in original). Consequently, von Hippel and Tyre explored how learning by doing is actually tied to doing (von Hippel & Tyre, 1995) and how the situatedness or "stickiness" of knowledge of designers and users affects diagnosing, answering to, and collaborating around solving problems-in-use (Tyre & von Hippel, 1997; von Hippel, 1994).

This paper seeks to add to this research on micro-level mechanisms of learning-by-using by examining the interactions and learning processes between designers and users after the market-launch by a Finnish start-up firm of a new medical device—Wristcare. It is a wrist-held security device for the elderly that has an alarm button as well as sensors for detecting major ruptures in the health of the user. The alarms are routed to a helper, a relative, a nurse or an alarm-center, which then decides whether and what kind of help should be sent. The development of this device went through a number of design iterations triggered by planned and unplanned user inputs before it was successful. This paper traces this process and identifies several "learning-by-using" processes at play and provides an account of their preconditions and interrelations.

Methodology

Inquiring into the process and content of learning between designers and users poses a methodological challenge. The relevant interactions and effects of learning between designers and users span several years, while the sufficiently detailed analysis of the actual events requires content-specific attention to minutiae of design work and occasions of technology use. The methodological premise adopted in this study was to make a grounded in-depth analysis of a single case (cf.Glaser & Strauss, 1967). After all, it is detail that is lacking in the literature, not general level arguments about learning-by-using (cf. Adler & Clark, 1991).

The data presented in this paper is drawn from a four-year field-study (1999-2003) that combined ethnographic observation, historiographic document analysis, and interviews to study the development of the Wristcare and Safety phone technologies from early 1990s to 2003. The largest body of data were the 77 semi-structured interviews: 32 related to design, 38 related to use, and 7 related to the history and societal context of the new technology. Table 1 provides an occupational profile of the interviewees and details about the interviews.

Groups of interviewed people	**Interviewees**	**Interviews**	**Typical length (approx.)**	**Years**
Designers	8	10	1-2 hours	1999-2003
Founder of the producer company	1	7	1-2 hours	1999-2002
Marketing personnel and customer representatives in the company	6	8	1-2 hours	1999-2003
CEO of the producer company	1	3	1-2 hours	1999-2003
Maintenance and sales people in organisations affiliated with the producer	4	4	1 hour	2000-2003
Outside experts	7	7	1 hour	1999-2003
Rest-home managers	4	4	1-2 hours	2000-2001
Nurses, home-care workers, and alarm-center workers	16	17	40 min	2000-2001
Residents using the technology	17	17	40 min	2000-2001
Total	64	77		1999-2003

Table 1 Interviews conducted for the study.

NOTE: Some interviews with designers and nurses had 2-3 people present, and some of them were also interviewed repeatedly.

Open coding was used to sort interviews on themes, events, and informants (Strauss & Corbin, 1990). This created 758 entries in 140 categories, which were further coded axially in relation to temporal unfolding of the innovation process. The interviews were complemented by the analysis of a rich set of documents, such as business plans, pilot reports, customer feedback, web-pages, user-manuals – basically all the remaining documentation of the innovation process. The analysis of documents followed the principles of source criticism (e.g. Tosh, 1991) and was soon intertwined with interview analysis to triangulate the data to gain an understanding of the events and various interpretations of the innovation process (cf. Denzin, 1970). These two data sets were further related with a longitudinal series of 27 field observations in the designer company and user sites during the years 1999-2001 that provided detailed data without biases typical of retrospective accounts.

The research design and analysis was informed by the research tradition of social shaping of technology (MacKenzie & Wajcman, 1985; Bijker et al., 1987; Williams & Edge, 1996). Within this tradition, it drew most importantly from socio-cultural studies of action and cognition (sometimes dubbed practice theories), most notably activity theory (Engeström et al., 1999; Cole, 1996) and symbolic interactionism (Clarke & Star, 2003; Star, 1996). Because of the limitations of space, I resort to outlining the most important guiding principles stemming from these theories:

A) Examining action and cognition as mediated through the actions of other people as well as culturally formed artefacts. This implies focus on content specific actions in socio-material settings as opposed to identifying generic processes.
B) Paying constant attention to the purposes of action of different peoples, in other words, examining the actions of the designers and users in relationship to the long-term motives and short-term goals in the institutions they worked.
C) Attention to how different purposes and the way they are mediated support one another, and on the other side of the same coin, what kind of tensions and conflicts exist within and between them.
D) Equal attention to direct and indirect connections between designers and users and their asymmetric rationales, resources, and means of affecting the technology.
E) Attention to the entire span of learning between designers and users: the analysis of post-launch reported here is based on (1) concept design phase of the project (Hyysalo, in press), (2) designers further inquiries on markets and users (Hyysalo, 2003), (3) implementation, appropriation, and users modifications of the technology after market launch (Hyysalo, 2004; 2004b).
F) Equal attention to what was explicitly reported as being learned or appears clearly as a learning process in relation to outcomes as well as to more invisible preconditions that appear to have fostered or hindered learning.

Outline of "Wristcare" post-launch improvements and interaction between designers and users

In the following, I outline a six year post-launch improvement and interaction process, structured in three two year phases that also roughly correspond to major changes in the product and interactions between designers and users.

Rapid diffusion vs. users needs: Wristcare in the plans of designers and in the hands of its earliest users, 1997-1998

Wristcare was based on its designers' vision and experience in the practices related to the technical and economical aspects of the technology (Hyysalo, in press). The pre-market launch descriptions of Wristcare emphasized rapid growth, internationalization, and a focus on core technical development. A conscious decision was made to avoid any product variation or drift into development of the infrastructure or services and to stay focused on recovering the research and development costs[1]. The device was to be made as automatic as possible and fool-proof in its functions to suit all possible end-users, even those suffering from dementia. Its correct use was to be further ascertained by short instructions how to wear, remove, and store it.[2] As the founder of the company reflects:

"Any kind of programming to be done by the end-user or home-care workers has traditionally been a problem in the safety-devices. Whatever the case, it requires some technical know-how, and the things that can then be programmed are so childish and simple that we decided to make the device so that all, well, almost all, its features can be programmed remotely" [3]

In the pilots and other early use of the technology designers' primary objective was to find and fix the "bugs" inevitable in any hardware and software. The testing was to quickly pave the way to high production volumes. But the outcome of the early pilots was ambiguous for the company: while users and partner-organizations regarded the concept mostly in positive terms and the overall technical idea seemed to work by and large, there were an intolerable number of false alarms. The end-users also turned out to be in a much weaker physical shape than ever expected by the designers. The fluctuations in their conditions were harder to monitor and also differed from the presumptions built into Wristcare's monitoring algorithms. Wristcare was also received most enthusiastically by rest homes and sheltered housing, whereas there was a fairly lame reception in home-use sector, which was the originally targeted market. The home-use sector sales remained low regardless of designers' speculations over the effectiveness of marketing, adequacy of design or their estimates of what kind of people would like to wear this kind of device.

This unexpected development had further ramifications, because the intermediary-users, such as nurses and home-care workers, experienced problems in dealing with the various alarm-signals the device generated.

"It gave too much of those "acute alarms", and we had to call in [the residents] all the time… when there was a rush it was burdensome to attend such nonsense [checking in on acute automatic alarms very few of which were for real] "[4]

It also turned out that the kind of use presumed by the design was hard to enforce on the end-users, who continued to "misuse" the device in various ways, which created problems for its automated functions. Users created an increasing amount of work- arounds and site-specific procedures. Scribbled notes, tinkering with how residents were administered into the database, combining the system with cell-phone and so on were complemented by bypassing Wristcare's features with site-specific procedures:

"The use of the program is now based on knowing the personal rhythm of the residents… to many of the problems with the device and in diagnosing [the alarms] there has emerged a solution together with the particular resident" [5]

Designers responded by making small, often site-specific, changes to meet the various requirements of the end-users. The pilots were the first time the designers faced the actual environments of use and the real end-users. But any site-visit was seen as a distraction from the designers' and marketing representatives' "real work" of which there was plenty in a start-up seeking rapid growth. This discouraged a wider or more systematic inquiry into needs to change the system, even though determining the causes of problems often took considerable effort from designers. As reflected by a designer:

" The original single home-device turned out to be the most difficult to realize: if the alarm is for real, the device and help should respond quickly, but then again, you don't want to send in an ambulance for nothing. And then you don't have a clear focus on what you are monitoring the person for, you know, different people have very different symptoms and fluctuations in health, different wrists and daily rhythms. It's a lot easier if you know that the person suffers from say, dementia or epilepsy, so the device can just watch the signs for those. "[6]

The causes of problems ranged from "bizarre" actions of the users to slight alterations in the way the devices were worn, from false technical assembly in a user-site to bugs in the devices or transmitters or the unfit design of some part of the system, and, finally, to deficiencies in product design. In these initial interactions, users expected the designers to fix the system so it would work the way the users had understood it should.[7] Their involvement with the redesign of the product was restricted to complaints and occasional accounts of what had happened. Designers, in turn, did not encourage much deeper interaction. They preferred looking at the technical system directly, as most problems were simply technical bugs and users were mostly unable to provide accurate technical information about the problems (cf. Tyre & von Hippel, 1997). However, this cast of roles and responsibilities was not satisfactory for either party in the long run. In Savitaipale, a technician involved in implementing and maintaining the system reflected on the interaction around an early 1999 installation:

"The firm would benefit from paying emphasis on gathering extensive and systematic information about new kind of sites with the staff, before building up the system. Now there were many difficulties in the Savitaipale health-care center where the system was implemented in a bed ward. The company did not have much understanding about hospital environments, and the health care-center sent unclear requests, for instance, parameters that could be interpreted in many ways. We got the system running only after I stepped in between the two and started to gather what is really needed here"[8]

Whatever interaction that did occur was undermined by how the pilot sites were organized. The company could not afford to hold a number of free pilot trials. Instead, the majority of the early user-sites were also paying customers. The tension was further aggravated by the sales talk that had generated unwarranted assumptions about the device. As a result, the problems that occurred with devices were not only setbacks for the company's technical project, but also strained its customer relationships.

Towards collaborative improvement of technology, 1999-2001

Users' recurrent complaints and problems were to some extent met by re-designs. Until the late 1999, there had been several minor redesigns in the Wrist-device and transmitter unit, and a number of iterations of the software for handling the alarms. A new product-variant was created for sheltered housing. Also the manual grew from seven to 25 pages, with more illustrations and instructions. These additions had two primary goals: to avoid problems that had occurred in the actual use of the device and to make the monitoring more reliable as a response to the doubts expressed by representatives of the medical community and some user-organizations.

Parallel to these early alterations there was some rapprochement between designers and users. Gradually, designers started paying attention to people and to the spatial organization of the sheltered housing; its architecture, technological infrastructure, and social conduct. The users, in turn, entered the world of modern ICT in general, such as learning to operate PCs and electronic mail (that was new to many), and how ICT people worked and approached problems.[9]

Further rapprochement in designer-user relations took place during the design process of the 2nd generation Wristcare, 2000-2001. Particularly in the re-design of its program the company started to actively seek design suggestions from its users instead of just passively waiting for problem reports.[10] Along a formal long-standing pilot-test in one site, extended collaborations followed in six other sites to find any bugs or re-design suggestions. Company's new R&D manager reflected one of these sites as follows:

" The best thing that came in this spring was the new rest home across the street where they have 15 elderly ladies, and we can change our devices whenever we want. Of course, we should have had a place like this two years ago. People in this rest home are prepared for that we go and figure out the results together with them, and then tune our software further. This has shown to be indispensable. You know, we don't bring in any garbage but the best stuff we have available, but these are still test-devices…For us this reveals how the device works in real life, how it gathers dirt, how it wears on the arm, how they wear them, and what has actually happened [physiologically and behaviorally] when our device has sent a signal about for instance extra ordinary passiveness."[11]

While this kind of beta-testing had been part of the company strategy before, the difference now was that the cycles of iterating the design were short (e.g. testing for a specific design change for a week) and that designers sought out improvements more broadly than merely finding bugs to be fixed. The user-organization was explicitly made a development partner instead of being something in between a customer of ready products, a tester for further development, and a testing ground for the best available devices. This arrangement steered clear of the tensions that prevailed in previous user-sites which had expected smoothly working devices, for which they had paid.

The company also concentrated all its assembly, maintenance, and customer training on a newly hired person who had many years of experience with safety phones.[12] This resulted in shaking the company's confidence on their assumedly reasonably working feedback mechanisms. In the words of the company founder:

"Since he started, it has turned out that our retailers, partners, and assemblers haven't really provided us with information about how the device works in actual use. Neither do they know how the device should function… Here is the one employment that has most effectively paid for itself"[13]

Moreover, the company invested time and money to re-profile its brand, image, and sales arguments. It also changed its approach to instruction, partly because the new information and design changes allowed them to do so, partly because they had learned the limits to trying to control use through instruction:

"R&D Manager: …It was emphasized that it has to be placed firmly against the skin [to monitor properly]…Now users wear the bracelets so tight that it feels uncomfortable and they cease to wear it. Now we [have worked to] loosen it up so that it can be worn normally. It simply does not work that we write on the wall that you have to wear it so it does not move around [in the wrist, which is detrimental for us]."[14]

The variety of alarm-messages was dramatically cut down from the peak of 50 (from which users actively responded only to 7 and worked around the rest).[15] In doing so, the most ambitious quick-reaction alarms were removed from the device to reduce false alarms. The control software allowed users to time, route, en/disable, and modify alarms specifically for each site and end-user. SW interface was re-designed to enable users to make these changes themselves. This was vital, as virtually every user-site had a different layout and work-routines. Also, physical differences and preferences of the elderly required local alterations system. The previous design logic (that emphasized fool-proofing and stand-alone character of products) had great difficulties to accommodate such scope of requirements and demanded designer intervention in most cases.

The tailoring continued in the form of creating accessories for different groups of the disabled (more sensitive alarm-buttons, one-hand buttons, etc.), and by making the system to better accommodate adjoining products, such as cell-phones and organization specific portable phones to which nurses preferred to receive the alarms. Alarm-messaging, both on text and talk, was further improved. The combined effect of these actions was appreciated by the users, not only in terms of engaging in collaboration but also in regard to evaluations of the devices:

"It is ideal how I can tailor this system for each of my residents just by clicking buttons. This was absolutely a pain in the old version. We can now also change the codes by our selves, which means, for instance, that I can do all the needed testing here, and don't have to involve the resident in it"[16]

Tensions between user-collaboration and cost-efficiency, 2001-2003

As a researcher following the project I expected that the mutually beneficial collaboration between the designers and users of Wristcare would have further intensified after 2001, as suggested by strategic management literature (e.g.Victor & Boynton, 1998; Prahalad & Ramaswamy, 2004; Normann & Ramirez, 1994) suggested. This turned not to be the case. The resources of the small company were stretched in many directions. The realities of R&D department were described by one of the designers as follows:

"Usually what happens is that we need some feature or version to do business. And usually it appears that we actually need the thing now, or if it [the call] is a problem [in existing features], then we are already late when we begin to investigate it… this means the nature of the job is kind of fire-fighting… and this means that the [more long term] projects have to be handled when there is time, and there is little hope of keeping the deadlines."[17]

After 2000, the new management sought to package product offerings and the number of versions available. Stricter control was imposed over the R&D department to prevent work on any but the most vital projects. Similarly, marketing and sales were to refrain from promising anything that would require further product development. These concerns re-instate the business imperatives that were spelled out prior to the 1997 market launch:

"In terms of economics of production the dream would be to have one device that would have all the functions. And then we would just open or close some features with software. Even though we now have only one gray bracelet, it is quite a nuisance with all its variations. What has happened is that we have promised or said that we can do such and such, and the customer has then bought it, and then we have made a customization for that particular customer, and that binds our resources… and when you look at it as a whole, it ends up being no good. That particular deal may be sweet, but it disturbs everything else… and if we aim at hundreds of thousands of devices, the system just can't be this complex. Just the work that goes into selling and assembling now is too much."[18]

These business imperatives were against gradual improvements by working with customers. User-collaboration was actively practiced until late 2001, when major use-sites of the main product, the rest home-system, expressed few new requirements and previously unknown problems.[19]

In late 2001 a resolution of this tension between use and standardization was sought through a re-conceptualization of the product and division of labor between the producer company and other actors. The producer defined its responsibility in technical terms only, as a matter of correlation between the provided specification and the actual behavior of its products. It is noteworthy, that the details of this correlation took two years of in-site testing to establish and owed much to the "the activity curve" which was itself one of the results of interactions with users. This feature—showing a visual graph of the client's overall movement and activeness in the monitoring PC—was first created by company in 1998 as a showpiece illustration. However, users found that it helped in deciding whether or not to react to alarm-messages because it provided contextual information. They drew implications that had never occurred to designers, such as inferring the effects of sleep-medication, customizing their care-rounds so as not to awaken the residents and so on.[20] Later in 2001 these findings led the company to use the same activity curve as a basis for comparisons with "gold standard" medical devices in sleep research that provided the company with urgently needed scientific evidence about the adequacy of their measurement.

The limiting of company responsibility only to technical functioning was balanced by forming alliances and encouraging user-organizations to explore ways to apply the technology. This included both the medical community in the form of sleep research, convalescent care and use in bed-wards, as well as elderly care in the form of their associations and various end-user organizations. These partners were given information and consulted on how to utilize the devices. This separation of product design from the application design put an end to the gradual re-configuration of Wristcare technology:

"We emphasize that this is the product, this is what is now tested…we file the information, but we don't re-design based on any singular wishes, only integrate our system into a local protocol. This is no longer a product development project but a commercial product. But this is not the one device that we shall make in volumes of hundreds of thousands. So there is no more fine tuning to be done in this platform, but it will come with the next platform"[21]

The fundamental aim was to separate mass-production from the iteration and knowledge gathering. The tensions in the company's agenda in reconciling gradual improvement and mass-production draw attention to the cycles and timing of different aims in R&D. Iterating the product in co-coordinated partnerships with customers would take place when problems, lucrative new market, region or new user-practice required substantial changes in the product or the way it was to be deployed in use. When this was not the case, the product and commercial offering would be kept as standard as possible.

Clarifying the changes in design, interaction, and learning

Let us now re-visit this post-launch development from the perspective of learning. Innovation processes, if anything, are processes of continuous learning and accumulation of expertise. At the same time, they evade attempts to think of learning in terms of the ability to produce more adequate reactions under similar conditions, which has been customary in laboratory settings (cf. Bateson, 2000). The context changes continuously, and the relevant knowledge shifts as the construction of technology progresses. Yet, blind trials do not allow for the building of a complex technical system requiring high repeatability, standardization, and the accumulation of results. The term "learning dynamics" is here used as the shorthand for the various acts of searching, evaluating, re-considering, and building of the technology, oriented to enhancing it. These processes denote a) what typically gets reported as "learning": learning within given arrangements (the below examined dynamics one, two and five), b) preconditions for learning (dynamics three, four, and six), and c) managing of conflicting learning goals (dynamic seven). The below discussion is restricted to learning dynamics related to the use of technology.

The multifaceted and detailed data gathered in the four year case-study was vital in discerning the dynamics. Dynamics 1 & 2 & 7 became visible during my field-observations on design meetings and product's usage. They were further confirmed through interviews. Dynamics 3-6 became only visible because of the longitudinal scope of the study: At the time of my entry, the changes in products and procedures so far were noted, and then updated mappings were made throughout the study. The changes were first examined in each period with regard to six dimensions: constitution of the product, designers and users orientation to the product, physical terrain of interaction, temporal extent of interactions, the nature of contacts and their means, and contractual and normative assumptions of relationship. Data was then revisited for behaviors that had directly led to or acted as catalysts for these changes. In doing this it was vital to compare interview statements with my field-notes on actual behaviors and to support inferences with the remaining documents, pictures, artifacts, and so on. The below discussion moves from market-launch onwards to present day, highlighting the most important learning dynamics in temporal order.

First dynamic of learning: Learning about technical problems in the hardware and software in field use. The first dynamic of learning was that "bugs" and other technical shortcomings became visible and diagnosable after the device was implemented in its actual contexts of use, thus paralleling the findings of von Hippel & Tyre (1995). Many such shortcomings would have arguably been hard to prevent in the laboratory with simulations or other means of predicting field problems (von Hippel & Tyre, 1995, 10-11). As in the cases examined by Tyre & von Hippel (1997), here also diagnoses of problems involved engineers going to field site to look at the problem personally, then moving the problem back to laboratory, going back to field site, and so on.

Second dynamic of learning: Users' learning how to operate the technology and make it work in practice.

There was a rough sequence of learning efforts related to the use of technology in daily work and life of rest-home nurses and residents, that was repeated in all the four sites studied (analyzed in more detail in Hyysalo, 2004; 2004b): (1) Learning the instructions and how to put them in action, often involving producers training sessions and more informal learning efforts. This included learning what kind of immediate changes and arrangements had to be created for operating the system and ascertaining its reliability. (2) Learning how to intertwine the system in daily work and life. For instance, at first all sites reacted to all alarms by applying a categorical check-in visit, but most soon developed more differentiated responses that better fitted the rhythm of nurses' work. The implementation of the system also transformed some existing procedures, such as added flexibility to the regular "care-rounds" nurses did among the residents mostly just to see that all was all right. (3) Learning what to do in typical cases of system causing trouble or devices not working, for instance, learning how to test them against most common problems. (4) Learning how to work-around the system more permanently. For instance, writing down mnemonics on pieces of paper to remember what the codes for various alarms meant and how to best react to them; rigging the SW so it that alarms would not come through at night from residents who demanded that they should not be woken up. (5) Sharing insights and ways of dealing with technology with other nurses and residents, in other words spreading and consolidating preferred ways of working with the system. (6) Learning how to involve and coordinate external actors such as alarm-centers (that took the alarms at night), maintenance people, and company designers to solve problems that users themselves could not fix. This is discussed further with dynamic four.

Third dynamic of learning: De-stabilization of and unlearning the existing assumptions of the product and its use. The third dynamic of learning has to do with prerequisites for further learning. While the definitions for learning are (perhaps forever) subject to debate, most researchers agree that learning is about adaptive change (Bateson, 2000), and, at that, adaptive change that follows from improved knowledge and understanding (cf. Fiol & Lyles, 1985). The question of what is adaptive is far from trivial in innovations that take place in multiple overlapping contexts that set conflicting priorities for the project (Van de Ven et al., 1999). The designers working with the initial "bug fixing orientation" presumed that only deviations from the expected technical performance were relevant. This had a very tangible rationale: an orientation to get quickly back to work from customer sites was considered vital for company profits and growth through new design projects, both crucial for the survival of the start-up. The third dynamic of learning visible in the case is designers' gradual and often collective questioning of the frame within which they diagnosed problems: what aspects of the physical form of the product needed changes, the purpose of designers relationship to users, and the roles set for designers and users in gathering information about problems.

Fourth dynamic of learning: Opening new cognitive trails in the multi-organizational terrain. The questioning did not take place in vacuum, nor automatically lead to improved actions. Along with it, a gradual improvement in designers' orientation took place. At the market launch, the company entered a terrain that was largely unknown to it: Who was to use their device? How to reach them? Who were the relevant actors, and how to deal and communicate with them? Nurses and the elderly alike were unsure of how to deal with this kind of high-tech device and how to relate to its designers. Along with the mundane operations of fixing bugs, assembling, training and so on, the parties gradually learnt more about the constraints and possibilities of this technology in relation to rest-homes, alarm centers, government agencies, vendors and the like players in the multi-organizational terrain. At first, this learning did not take the form of focused learning efforts, but much of the learning remained "subterranean". It did not result in many visible changes but laid the ground for later advances (Engeström et al., 2003; Engeström, 2001). Together, the learning dynamics three and four contributed to expansion in what the designers paid attention to and how deeply they saw that user requests should affect the form and functioning of the device.

Fifth dynamic of learning: Forming networks of collaboration and learning in them. Beginning from the late 1999, the relationships formed in the interaction were gradually transformed into more formal and stabilized network relations, aimed at improving the product-system. This transformation required changes in virtually all aspects of designer-user relation: marketing, training, field-visits, way of interacting, processing information in the company et cetera. These initiatives were responded to by user organizations. The earlier means and tools for collaboration – error logs, conversations, collecting work-arounds, instructions, and assigning main-users as links to each site – came to be used more systematically.

Sixth dynamic of learning: The artifact as an expanding boundary object. The interaction and learning were significantly dependent on the means and tools available. The form and functioning of Wristcare itself was perhaps the most important mediating means between designers and users. Star has examined how partially shared objects can be effective in augmenting interaction and collaboration between social worlds. Such boundary objects can take on robust meanings that allow interaction between social worlds, while they remain able to take on more specific meanings in individual site use (Star & Griesemer, 1989). Wristcare-case draws attention to the trajectory of change related to a boundary object: an increase in the shared meaning and terrain related to the artifact during the process. In the beginning, the boundary between designers and users followed the outer shell of the product. Designers examined their devices as technical configurations, while users kept to the functioning of the (back then literally a) black box in their hands and in their daily work. There was relatively little shared in the "same" object. This spatial separation reduced with time, as designers started to pay attention to how the technology was organized in use, while users started to make remarks about the functioning of the system.

The expansion of the shared area of the object corresponded with the growth in the temporal extent of interaction (from bugs to partnerships), the contractual relationship (from transactions to reputation and collaboration) and more systematic use of other mediating artifacts. Just as importantly, there was a change in the constitution of Wristcare itself. While Wristcare prevented most user-access during its early development, it grew to encourage local modifications, which also allowed its utilizers to further articulate their wishes. In terms of learning, attention should, thus, be paid to the expansive potential in boundary objects: they may remain as means to coordinate tangential concerns and the interactions of two social worlds, or they may be made to open gates for deeper collaboration and acquaintance (Bowker & Star, 1999; Engeström, 1987).[22]

Seventh dynamic of learning: Managing the tension between co-coordinated improvement with users and the pressure to create a standardized mass-product. Along with the challenge to achieve a product that sufficiently fits users practices and requirements there remained the economic imperative to achieve high production volumes of standardized products. Hasu has characterized such tension as “critical transition”: The producer has to learn a new way of working in design and customer relations in order to survive, but, at the same time, its original imperatives in competition and organizing the company have not disappeared (Hasu, 2001).

The case featured two approaches to resolve this tension that are arguably common practice in industry, but posed the company with further learning challenges. First, the company sought to establish cycles between seeking co-coordinated improvements with users and seeking standardization. Challenges lay in recognizing and anticipating when and how standardization must give way to coordinated development with users, as well as in the extent to which a producer company must customize its stabilized products locally to keep its customers interested in the collaboration.

Second, the firm sought to stabilize its material product, while it engaged in various collaborations to ensure that users could draw utility out of Wristcare. This aim is close to the idea of co-production of value (value-star) in the interactions of the producer, users, and different instances having an interest in the coming configuration (Cf. Normann & Ramirez, 1994). The challenge remains on which levels of design — ranging from components to use of the device in different practices – the company should engage in and what are the most appropriate mechanisms for doing so in each setting—ranging from further technical development to providing information and money for developing usages for the device? [23]

Conclusions

This case study supports earlier findings on the importance of learning-by-using in the development of new technology. Its further value lies in the unpacking of some of the learning processes that constitute learning-by-using. In so doing, it points out that there is a clear need for further study on the actual mechanisms of how learning-by-using is actually done. The analysis suggests that post-launch learning between designers and users is not an issue of (automatic) flow of user-feedback to company as Rosenberg originally conceptualized. On the one hand, the “flow” required learning *for* interaction: learning how to create necessary preconditions for beneficial interactions and learning, as well as questioning and seeking resolution between the available models for thinking and action. On the other hand, the process consisted of learning *in* interaction – more commonly recognized processes of acquiring information about identified issues in the product and in regard to users’ needs for further design.

As such, the analysis provides cues for what kind of learning dynamics need to be mastered when aiming for successful and effective post-launch improvement of new technology. Most of the interaction and learning between designers and users took place alongside other concerns, such as bug-fixing, assembling, and maintaining and struggling to operate the technology. Nearly all aspects of customer relationship either augmented or hindered positive outcomes. This learning was no minor add-on to the innovation process. It took five years (1992-1997) to develop the technology to point of launch, but another five years (1997-2003) before the system had been iterated to a point where it could even start to redeem its commercial and societal promise.

While companies routinely channel user-feedback into improvements in next generation products, the case shows how there is substantial difference between making some improvements and in identifying and capitalizing on the knowledge that is vital for the future of the technology. At the same time, active collaboration with users may be inherently fragile in producer organization: it exists in tension to more established priorities such as cost-efficiency in production that requires large standard volumes. Tough customers may lead to good designs simply because they keep the active contact with users from disappearing from company’s top priorities (cf. Gardiner & Rothwell, 1985). Gaining high-quality input from users is not self-evident, requires “gardening”, and can be effectively undermined. In the case examined, it remains open whether users remain motivated to participate when their wishes only *may* be incorporated in a launch 2-3 years down the road. It also remains to be seen if the learning by few key designers and managers shall stand the test of time, in other words, whether it becomes solidified into corporate mission, structures, and practices as genuine organizational learning. In such instances user-centered design methods could prove to be effective tools for augmenting learning from users and keeping it on the agenda. However, the case reminds that even if so, their impact is likely to be dependent on more sustained, even if often more mundane efforts at learning from throughout the company.

The learning dynamics identified in this study are unlikely to form a comprehensive listing. An example of a likely direction to yield further understanding are more detailed but temporally restricted descriptions designer-user encounters (cf.Hasu & Engeström, 2000). The learning dynamics are also likely to differ in different industrial sectors and user bases, thus inviting further work before the relative importance and more overarching patterns about the processes of learning can be deciphered.

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[1] Company Business plan 13.6. 1997, 6-15
[2] Company Business plan 13.6.1997, 1-15, esp.13; Wristcare Functional description 13.01.1997; Wristcare users' manual 1997
[3] Interview with the founder of the company, Helsinki, October 22, 1999. To provide wished anonymity to the people interviewed, I refer to them through their general job description. All quotes translated from Finnish by the author.
[4]Interview with a rest-home nurse, Espoo, December 19 2000.
[5] Interview with a rest-home nurse, Savitaipale, November 1, 2000.
[6] Interview with a designer, Helsinki, October 22, 1999.
[7] Interview with home-care workers in Resthome in Espoo, February 29, 2000; August 22, 2000.
[8] Interview with a technician, Savitaipale, November 01, 2000.
[9] Interview with homecare workers and manager of a sheltered housing, Espoo, August 30, 2000.

[10] Observations of the design and product development meetings of the company, Helsinki, August 1 - October 1, 2000.
[11] Interview with R&D manager, Helsinki, May 14, 2001.
[12] During this time the company also hired several other key personnel (CEO, R&D manager, product manager, heads of marketing and production) with earlier careers in larger high-tech firms. The safety phone expert aside, the newer hires initially paid less attention to seeking out user-requests than the existing staff, but once its importance became evident, they went further in pursuing it. However, I would refrain from inferring that this was due to their experience from previous firms, but rather that they were less confident with the existing design they had not been involved in constructing.
[13] Interview with the company founder, Helsinki, September 17, 2001.
[14] Interview with R&D Manager, Helsinki, May 14, 2001.
[15] Observations in Savitaipale on November 30, 2000, and Espoo August 30, 2000 nursing homes.
[16] Interview with a home care-worker, Espoo, September 13, 2000.

[17] Interview with a designer, Helsinki, November 25, 1999.
[18] Interview with CEO, Helsinki November 13, 2000.
[19] Interview with product manager, Helsinki, November 25, 2002.
[20] Interviews and observations in Espoo, August-September, 2000 and in Turku, November, 2001.
[21] Interview with CEO, Helsinki, November 25, 2002.
[22] Emphasis on the change in what is shared about boundary objects is congruent with the original work with the concept and later reconceptualizations of its original developers (e.g. Star, 1991; Bowker & Star, 1999; Clarke & Star, in press). Such stance is uneasy with explanations that suggest boundary-objects lead to "shared understanding", seen as a fusion in (or dissapearance of) divergent perspectives (cf. Carlile, 2002).
[23] Conversely, how do the mass-produced and marketed devices need to be supported and remain configurable to optimize customer satisfaction and profit?