Understanding use in the design of smart objects – reflections on the conception of collaborative design

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Abstract

The paper deals with the question how to understand the design process as a collaborative activity and how to facilitate design of smart objects from that perspective. We reflect on some current paradigms of design, and argue that these approaches could be improved further through considering users not only as participants in the design process, but also as designers through their practice in their normal daily actions. In design, form may not follow function but meaning, which brings the user back into the picture and strongly suggest that designers need to discuss not only the contexts in which their forms are used, but also what the formed products mean to the users. We shall demonstrate our argument with the help of an example from a field study on the implementation of a flexible manufacturing system. As a result of this study we identified a need for a collaborative design activity that was seen to comprise of a operation-oriented design and a design-oriented operation. Hence, we consider that as the first step towards a conception of collaborative design, it is necessary to understand design-like actions in users' normal operating work. With reference to our studies on anaesthesia, we then elaborate features of such actions and the relevance of these actions to design of patient monitors. We also discuss the possibilities to exploit our approach, which was developed for the analysis of user actions, to the analysis of actual situated actions of the designers.

1. Theoretical position

Because tools have a central role in shaping the structure of human activity it is important that the significance of tools and their appropriateness for use is anticipated during their design. Hence the semantics or the content of activities should become a self-evident part of the design. This puts great challenges on the design process, on the actual decisions of the designers, and on the methods that the designers exploit. Our experience of design relates to the construction of complex information and communication systems for professional activities. In these contexts the expertise that is required in the use of tools is profound, and to a large extent tacit. Hence, the dependency of the designer on the knowledge and skills of the user is basically great. In particular domains, i.e. aviation or nuclear power industries, which are characterized by critical safety demands, extensive analyses of operations as basis for developing ICT tools and human-technology interfaces has become a necessity, and it already has long traditions. Such an extensive consideration of users' activities is much less usual in the design of solutions to other industries.

With regard to the consumer products, i.e. everyday tools of knowledge society, the relationship between the designer and the user has traditionally been conceived differently. The designer represents the user and is therefore able to anticipate the users' needs. The design problem is that of mediating the designers' insight to the user through the interface of the appliance for acquiring correspondence with the user and designer models (Norman 1986). This way of thinking is currently receding, however, as the role of the user as a constructor of meaning through making use of the tools in practice has become evident. As Krippendorff writes "The increasingly appealing suggestion that form may not follow function but meaning, brings the user back into the picture and strongly suggest that designers need to discuss not only the contexts in which their forms are used, but also how these forms are made sense of, or what they mean to someone other than themselves"(Krippendorff 1998). Pressing demands for understanding user activities, emerge also because the economical success of technical innovations assume the emergence of meaningful use and usage cultures.

The attribute "human-centred" has become an accepted qualification of design. In order to take seriously the above-mentioned profound connection of design and use in creating meaning into the functionally formed artefacts we may have to reconsider our understanding of the term "human-centred". Bannon recently drew attention to this need and noted that rather than simply considering the user in design, we should place understanding people and their practices in the forefront in the design of technology (Bannon and Kaptelinin 2000; Bannon 2002). But, as Bannon further notes, such a framing does not only require adoption of certain values in design. It also assumes theoretical consideration and empirical analysis of human activity. We may, furthermore, add that the incorporation of knowledge of human practices into the design provides an unsolved important problem to the HTI research.

In the analysis of human conduct, we advocate an ecological approach and conceive behaviour as an interaction within a human-environment system (Norros submitted). This

interaction has a mediated structure, i.e. consciousness emerges and behaviour becomes controlled and communicated through external signs (Vygotsky 1978). Signs may be material tools or symbols and they are embedded not only in the interactions with the physical environment, but also in the social interactions within a community, in the form of norms, rules and in the structures of division of labour. These mediated relationships constitute a complex activity system, within which the individual actions are organized, and in which they find their societal motivation (Engeström 1987). Through the signs the environment becomes a usable and meaningful object for the human actor. One of the strengths of the theory of Engeström is that the problem of context, which has become one of the recognized issues of current human-technology interaction (HTI) research, is build in its very basis. The activity-systems constitute the meaningful contexts of actions.

Situation awareness has become another fashionable HTI issue in the past few years. There is a clear need to identify the situation of use and adapt the functions of the artefact accordingly. However, even when considered a feature of an artefact, situation or context awareness is deemed an empty phrase if it is treated as simple recording of the environmental features. Situation awareness links with the notion of intentionality i.e. things having reference outside themselves. Human intentionality expresses itself both in the rational and embodied object-orientedness of action (Dreyfus 2001). It denotes the subjective readiness to interact with the environment, which shapes perception and the construction of situated actions. This aspect of human conduct has been emphasized in The Computer Supported Co-operative Work approach (CSCW). Consequently, the advocates of the CSCW have devoted much effort to develop tools for the analysis of actions in real life settings.

The notion of context awareness refers often to a particular functional feature of consumer products for mobile users. Vicente has treated the contextual demands as a fundamental problem of design of any ICT artefacts in complex environments. Such environments may be considered open systems (Vicente 1999). Because of the context-conditioned variability within these systems, there is the inherent need for designing adaptation into the artefacts to support the situationally appropriate actions of the users.

2. Designing for adaptation in smart objects

Even though adaptation is usually not taken as a deliberate goal in the frameworks of cognitive engineering or human-computer interaction design (Vicente 2002), we claim that the strive for human-centred design may be interpreted as an expression of an attempt to create adaptation in human-technology systems. Adaptation is then understood in a broad sense as an ability of the user to act, and use artefacts entrained fluently in the changing environment. Promoting adaptation assumes collaborative design. Collaborative design is understood as an activity that comprehends design and use as one activity system that is devoted to maintaining and developing human-environment interaction through creation of meaningful artefacts.

We shall briefly reflect on some current paradigms of design, the Human-Centred Design (HCD), the Contextual Design (CD) and the Ecological Interface Design (EID) and view how these approaches view the interaction between design and use.

The human-centred design concept (HCD) is a widely accepted approach in the design of interactive systems. It has recently acquired the status of an international standard (ISO13407 1999), which may be considered an important hallmark in promoting the user-centered point of view in the design process. In the HCD the design problem is framed as to create devices that meet the user goals and needs in a specific task. Within this frame the task is to bridge the gulfs of execution and evaluation (Norman 1986) , which the HCD may be considered to sufficiently accomplish. However, because this approach is restricted to comprehending users as informants in a design process, the perspective to user actions remains limited.

The contextual design (CD) (Beyer and Holzblatt 1995) and ecological interface design (EID) (Flach, Hancock et al. 1995; Vicente 1999) approaches offer an important complementary view to the human-centered design. They emphasize the significance of understanding of the context of use and provide elaborated tools for analysing these contexts as domains that put constraints on user actions and, hence, on the design of tools for these actions.

The strength of the Contextual Design approach is that it changes the focus from the design of technical products or services to the construction of new ways of work. Consequently, in the proposed and well defined design process much effort is devoted to the analysis and modeling of the users' real practices. A further important point in the concept is that the authors do not consider the user studies as a straight forward process of gathering or eliciting user data, but instead emphasize that the designers have to learn to infer what this information means for design. The weaknesses of the CD are related to the way of defining user practices. The approach is both prescriptive and descriptive, i.e. the analyses of use restrict to definition of present or future particular realizations of action and human-technology interactions. This characterization also applies to the ethnographic studies of the CSCW approaches. The unpredictability of open systems and the context of use would, however, demand modeling of behaviour in a way, which is not restrict to any particular course of action.

The above-mentioned deficiency in the CD and CSCW is overcome in the ecological design concept by Kim Vicente (Vicente 1999). He proposed that the conceptualization of action should be conducted from a more generic functional point of view. It should make explicit the constraints and possibilities of maintaining successful interaction with the environment. The modeling approach that he developed to complement the prescriptive and descriptive modeling approaches is the formative modeling. Formative modeling should not focus on the users' tasks and actions, but instead on the domain and context, in which these actions take place, and on which the actions exercise their effects. The features of the domain are taken as intrinsic constraints that define the boundaries of action, and therefore shape behaviour. This re-

orientation with regard to the modeling approach is based on the work of Jens Rasmussen (Rasmussen and Pejtersen 1995). The formative modeling approach provides a major advantage, because through concentrating on the boundaries of action it supports adaptation.

We find the ecological approach of Vicente a significant step in defining new design practices. Vicente has also been able to provide evidence of the appropriateness of interfaces, which have been design according to the principles of ecological design (Vicente 2002). However, we find a need to complete this approach in one point. Vicente characterized an ecological approach as one, in which the analysis of practices should start from the environmental constraints and finish with an analysis of person-related factors. The latter analysis is supposed to be accomplished as a cognitivist analysis, and the traditional information processing vocabulary is introduced to guide its accomplishment. From these premises follows that the new objective of creating user practices instead of merely technologies appears less central in the methodology.

The above-mentioned consequence is, however, not a necessary result from an ecological analysis, as it first may appear. In a genuinely ecological analysis the environment and the human actor should be treated as mutually connected with each other. For example, in an ecological perspective the environmental intrinsic constraints should be defined from the point of view of the human user, whose qualifications and possibilities for interaction with the environment are historically formed. The environment itself is a human environment, and as such not definable in strictly objective terms.

A completion is, therefore, needed for analyzing the human actors' ways of making use and sense of those environmental features that the analysis of the domain may first reveal. Only then we may state, what are the actual affordances of the domain and reveal different logics of their exploitation in user actions. We may also discover completely new possibilities for interaction.

We have proposed one solution for replacing the cognitivist analysis of actions with an ecologically oriented one (Norros submitted). We make use of the cultural historical theory of activity to provide an activity systemic model of the domain. This model is completed with the functional analysis of the intrinsic constraints. The model constitutes the frame for inferring what could be meaningful reasons to act in this environment. The pragmatist concept of habit (Peirce 1998e) opens up a possibility to model the operators' potentials for action in connection with the environmental affordances that are potentially meaningful for appropriate action (Norros and Klemola in press).

The attempt to complete the methodology of Vicente in the above mentioned sense also implies that the users are considered not only as participants in the design of technology, but even more, as designers through their practice in their normal daily actions. In this way, we attempt to reach that what was claimed necessary by Krippendorff in the above cited reference.

3. An example of spontaneous collaborative design

We shall demonstrate our argument with the help of an example from a field study (Norros 1996). It focused on the implementation of a flexible manufacturing system for production of toothed wheels. Two significant findings could be made in this study. First, we demonstrated that against the expectations, in average three functional disturbances per hour occurred in the system after two years of full operation, and that 25% of available working time was devoted to handling these disturbances. This result was interpreted as a demonstration of the principle unpredictability of the system functioning, rather than of failures in design. Secondly, we found that notwithstanding the official strive for homogenous competencies and division of task among the operators of the system, there were great differences in the operators' aptitude to tackle the disturbances. We developed a five step model of disturbance orientation to explain the differences in tackling the disturbances. The optional framings of the problem varied from complete withdrawal , to a routine disturbance handling, unofficial diagnosis of disturbance, official system optimization, up to a design-oriented operation. According to our data, 2/3 of the disturbances were handled in a routine way without the operators becoming involved with a diagnosis and without having an intention to connect the problem in the generic functional conditions of the system. In one third of the cases the latter was, however, achieved and the operators started to seek improvements into the system or even to consider the boundary conditions of its design. Such a pressure to improve the system was considered a sign of design-oriented operative actions (DOO), and as an indication of potential for a collaborative design. It also became clear that such a bottom-up potential may be realized fully only if there is a readiness for operation-oriented design (OOD) (human-centred design) and if this orientation is maintained by the technical management during the operating phase of the lifecycle of the system. An adaptive tackling of the context-conditioned variability of complex open systems requires that both prerequisites for a collaborative design activity become fulfilled.

4. Design in daily work- towards collaborative design

Given that the user-centredness is currently an accepted aim in the design of modern ICT systems, there seems to be a further need to understand more profoundly the above descried "design-like" actions within the users' normal operating actions. There are two reasons for exploiting these normally invisible potentials of the users' actions:

Firstly, we may claim that the designed artefacts should promote actions that are design-like, because these actions facilitate appropriate use or mastery of work. We may formulate this argument also from the point of view of design and state that understanding differences in the ways of using artefacts may contribute to revealing important design requirements and/or validation criteria for the designed products.

Secondly, discovering differences in practices and identifying design-like actions in operations are important, because it may assumed that users who have adopted such practices contribute more effectively to design. Users that have developed design-oriented habits are extremely informative partners in collaborative design.

In the following we demonstrate such differences in operations that we claim to be relevant from the perspective of design. Our example stems from a series of studies on anaesthetists' actions in clinical situations (Klemola and Norros 1997; Klemola and Norros 2000). One of these studies included an analysis of the information content of the patient monitors. (Klemola and Norros 2002). In all studies we conducted extensive interviews with the anaesthetists and observed thoroughly their actions in operating theatres in several clinical situations of each participant.

The results of these studies allowed us to identify significant generic features in the anaesthetists' practices. These features characterized both the experts' and novices' pratices. The doctors were interviewed about their conceptions concerning the patient in anaesthesia, i.e. the object of anaesthesia activity. It was discovered that one defining features of these conceptions was the comprehension of uncertainty of the anaesthesia process and the uniqueness of each patients' reactions to anaesthesia. An orientation to the patient that was characterized by these features was also qualified by a appreciation of a communicative relationship with the patient. If the uncertainty of the process was not recognized and the uniqueness of the patient not emphasized, a control relationship to the patient was typical (objectivistic orientation). When related to the actual practices of the anaesthetists, it was discovered that the former, realistic orientation, was related to a feature of practice that was labeled interpretative. The qualifying feature of an interpretative habit of action was that the actor focused attention to the connection between his operations and their results. Consequently the actors were striving for an intensive use of situational information, and they formed a cumulative interpretation of the patient's physiological state.

In the background of identifying the characteristics of clinical practice there is a generic evaluation dimension that was derived from Peirce's conceptions of judgement processes (Peirce 1998b). Approaching the phenomena of the world both as particular and also as expression of generic regularities is considered by Peirce as sign of full-fledged abductive inference. This feature that he labels interpretativeness relates to considering the generic regularity expressed in a particular phenomenon, inclusion of which promotes mastering the contingencies of the environment. Reactiveness is, according to Peirce, the qualification of inference, which is characterized through lack of attention to this generic aspect.

The relevance of these results to our argument for collaborative design is that this practice, qualified through realistic orientation connected with interpretativeness of operations, denotes the sought design-like user practices. Thus, in the case of anaesthesia, (see. Figure 1) the discovered realistic orientation, in contrast to the objectivistic or strong objectivistic orientation, was found to relate to better conceptual understanding of the functionally significant features of the patient monitor information (INFO), to better understanding of the safety significant constrains of this information (CSTR), to better mastery of actionable (functional) knowledge (ACKNOW), and to more effective use of the monitor information in the operating theatre (interpretative use INFPR). The closer the use of information was to actual practice (from INFO to INFPR) the more clear the advantage of the realistic orientation appeared to be, as Figure 1 indicates. It could be concluded that as the realistic orientation and interpretativeness of habits are connected with a critical testing of and reflecting on the available tools and practices of action, these features of the practice enhance the emergence of new knowledge in practice and, hence, better learning through experience.

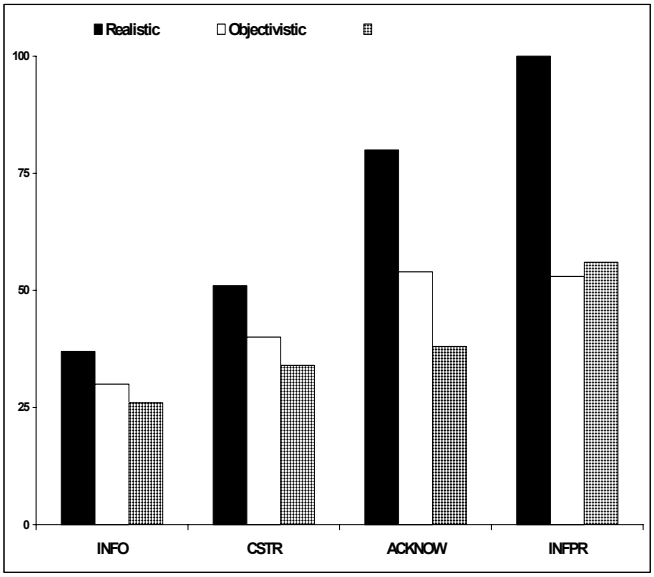

Figure 1. Fig. The conceptual and practical mastery of monitor information and actionable professional knowledge in different orientations. The results are expressed as percents of the total marks given in each assessment. INFO= conceptual mastery of monitor information; CSTR= mastery of constraints; ACKNOW= mastery of actionable professional knowledge; INFPR= role of information in practice (Klemola and Norros 2002).

It may be hypothesized, further, that such a realistic-interpretative practice would also effectively facilitate the design of new instruments. Design that would draw from a realistic orientation and interpretative practices of users would be constructive and meaningful. This follows, because the contribution of the users in this case emerges from a practice, which is qualified by observing the effectiveness of the tools with regard to the demands of various task situations. Due to the questioning of the boundaries of the tools, and their appropriateness with regard to the intrinsic demands of the task, the tools are not only taken as they are but, also, as what they could be. This is a major advantage compared to the usual situation in user studies, in which particular features of existing or prototyped tools are evaluated, instead of focusing on the intrinsic functional features of domain and the task.

5. Conclusions

We may conclude that both our FMS study and the study on anaesthesia provide evidence that the design of artefacts and their use are intertwined processes in the more global activity of maintaining and developing an appropriate interaction between the human actor with his environment. In agreement with Krippendorff and Bannon we may state that in design, form may not follow function but meaning, which brings the user back into the picture. It was also claimed that designers need to discuss not only the contexts in which their forms are used, but also what the formed products mean to the users, in the context of their societally formed practices.

We have provided some ideas of how certain current design approaches succeed in connecting design and use in the above-defined sense. We also proposed some extensions to the prevailing approaches, and emphasized that user practices should not be considered in an undifferentiated way. It is not sufficiently informative to simply state what the tasks of the user are. Instead it is necessary to identify how the users work, i.e. what habits of action or practices they have adopted and what role the artefacts play in the formation of particular types of habits. The practices of use were shown to distinguish in their developmental and innovative potential, which result has relevance for the development of both the user and the design activities. The common ground to analysis of both use and design is the domain in which the collaborative activity takes place, as Vicente has suggested. We maintain, however, that in an ecological approach the domain should not be dealt with strictly objective terms and from outside, but as the actors' environment. Therefore, we appreciate the strong emphasis on user studies that characterizes the CD approach. We see, however, that the vocabulary that both the CD and EID approaches use in explaining human action should be developed further. Our proposal is that an analysis of reasons expressed by the actors, and the study of the users' operations as habits that convey meaning, is one possibility to proceed in explaining user actions.

There is a further problem that we have not, yet, been able to tackle in this paper, nor in our research. There is a need for analyzing the real actual actions of designers in the same manner as we have tackled the users' actions. As Beyer and Holzblatt for example indicated, making use of user knowledge is not a simple collecting and eliciting of information. Rather it involves judgment and connecting this information with the design context and goals. It is clear, that as the practices of the users distinguish in respect to what meaning different features of the environment have in the connection of the activity, this must also apply the work of the designers. In the future, it should be interesting to find out, how the designers are able to deal with the essential demand of design to deal with particularites (Buchanan 1998). It should be analyzed whether the designers practices are critically dependent on how they approach this intrinsic demand, and how the very demand is balanced with the demands for strict control and comprehensiveness that the managing of the complex design process requires. "The problem for designers is to conceive and plan what does not yet exist, and this occurs in the context of the indeterminacy of *wicked problems,* before the final result is known" (Buchanan 1998).

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