DESIGNING FOR

INSTRUMENT-MEDIATED

ACTIVITY

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Abstract

The need to design information processing systems based on an anthropocentric approach, i.e., one where the design of technical objects deliberately draws from and is geared to the user's activity, is a critical issue in the modernization of life and work environments. Within this framework, we propose a developmental approach to instruments in which they are not just understood as fabricated material objects but are also psychological and social entities. We present a model and propose ways of approaching the design of information processing systems.

Keywords:

MEDIATING INSTRUMENTS: A DEVELOPMENTAL AND ANTHROPOCENTRIC POINT OF VIEW

In psychology and ergonomics in French-speaking countries, the term "work activity" has been a key concept since the initial studies by Ombredane and Faverge (1955) and their successors (Alain Wisner, Jacques Leplat, Maurice de Montmollin). These studies (both theoretical and practical), have allowed French language ergonomics to build up a solid background in the study and analysis of work situations, which has contributed to the development and validation of the method called "work activity analysis" (Wisner, 1972, 1995; de Keyser, 1991). In this method, human intelligence and inventiveness are the focus of analysis. Several studies have attempted to demonstrate that in the workplace, individuals explore, interpret, and transform goals, means, and their technical and organizational environment (Weill-Fassina & Coll., 93). Initially, this research trend was based on the work of French-speaking psychologists such as Wallon and Piaget. More recently, "activity theory", which first emerged in the Soviet Union in the 1920s (Vygotski, 1930, 1931; Leontiev, 1972, 1981; Rubinstein, 1958), has contributed to generating new interest in many fields of research, ranging from occupational psychology to anthropotechnology (Rabardel 1995, 1999, Verillon & Rabardel, 1995; Clot, 1995, 1999; Wisner, 1997). In line with other authors (Bannon & Bødker, 1991; Bødker, 1989, 1991; Kuutti, 1996; Kaptelinin & Kuutti, 1999; Nardi, 1996), we believe that using activity theories to provide conceptual tools in design offers several advantages. However, further development is necessary. As a field of research, activity theory is more immediately applicable to psychology (especially to educational psychology) than to what could be called design sciences (see Kuutti, 1996). Hence, the purpose of this chapter is not to present the concepts of activity theory, nor its utility in HCI (the reader may wish to refer to Bødker, 1989, 1991; Kaptelinin, 1992, 1996; Kuutti, 1992, 1996). Rather it is to develop activity theory so as to construct methods that are effective in instrument design.

For activity theory specialists, instruments are not just devices with which subjects interact (Kaptelinin, 1996). Users act "through the interface", to borrow S. Bødker's expression (Bødker, 1989). But just what is an instrument? Apparently, there are no particular conceptual or epistemological problems, given that the terms "computer", "tool", and "artifact" are used interchangeably (with a few notable exceptions; see for example Bødker, 1996). Yet, if we hope to make a contribution to the design of technical devices, we need to be able to accurately describe what allows mediation to take place. Furthermore, in line with activity theory, we must also be able to conceive instruments as psychological and social entities, and to describe the developmental process.

The need for a developmental approach has been a widely debated topic in the literature (see Nardi, 1996). Introducing an artifact in a given situation at best solves old problems. At the same time it changes the nature of the task, creates new problems for which new instruments are necessary, and so forth. Note that the process we need to define is twofold. First, novice users become experts (Caroll, Kellog, & Rosson, 1991), so we must examine how their activity evolves. Furthermore, users adapt and modify artifacts and their environment, whether temporarily or more permanently (Ehn, 1989, Henderson, 1991, Greenbaum & Kyng, 1991) in an attempt to solve unforeseen problems encountered in action, so we must take into account the inventiveness they bring to their activity.

P. Beguin & P. Rabardel

The developmental process can nonetheless be viewed from two angles: in terms of the development of artifacts, or the development of the needs and projects that individuals and groups of individuals acknowledge as their own. These aspects are the grounds for the distinction between "personal view" and "system view" proposed by Norman (1991) and stressed by Korpela (1995, herein). This is a key distinction in our approach. From the standpoint of the technical system, the only relevant part of the activity is that which concerns technical problems. Such a "technocentric" approach, where the technical dimension dominates, is very different from an "anthropocentric" approach, where the psychological and social activities of people are the focus. Anthropocentric and technocentric approaches are not inherently contradictory. On the contrary, they must work together. However, the technocentric point of view currently dominates the design process, sometimes despite designers' intentions. As a result, human activity is often regarded as a minor, even marginal aspect of the problem. This is why we believe it is crucial to devise a developmental conceptualization of the mediating instrument based on an anthropocentric point of view, and then to develop methods on these grounds.

This paper is organized into three parts. The first is devoted to presenting a conceptual framework for defining what an instrument is to its users. In particular, we develop the idea that the instrument is a composite entity made up of both the subject and the artifact. The second part argues the importance of this conceptual approach from a developmental standpoint. Here, we put forward the idea that the design process continues throughout use, and we make a number of proposals to describe instrumental genesis. The third part looks at potential applications in both theory and design. Our proposals are based on examples drawn from two studies. The first was commissioned by the unions and management of an engineering firm where the introduction of a CAD system had caused many problems (Béguin, 1993; Rabardel & Béguin, 1995). The second was a study commissioned by engineers in order to design an alarm for a chemical plant (Béguin & al., 1999).

THE MEDIATING INSTRUMENT: BETWEEN SUBJECT AND OBJECT

An activity consists of acting upon an object in order to realize a goal and give concrete form to a motive. Yet the relationship between the subject and the object is not direct. It involves mediation by a third party: the instrument. As M. Korpella (herein) reminds us, this approach, put forward by Vygotski in 1930, underlies several original proposals regarding the use of computers. With the growth of the field of human-computer interaction (Kaptelinin, 1996), Vygotski's initial approach has evolved considerably. Studies by Leontiev (1978), then Engeström (1987, 1991) offer a systemic approach (see also Korpella, herein) aimed at defining the relationship between subjects and the community in which they act. This work has led to some major developments, and allows us, for example, to make proposals in CSCW (Kuutti, 1996).

However, we feel other developments are needed. In this section, we propose to go back to Vygotski's initial view. An instrument cannot be confounded with an artifact. An artifact only becomes an instrument through the subject's activity. In this light, while an instrument is clearly a mediator between the subject and the object, it is also made up of the subject and the artifact.

The following case study on working with a CAD system will introduce and illustrate this conceptualization.

An example: working with a CAD system

This section outlines the results of an analysis of some of the difficulties encountered by users of a CAD system designed for electrical engineering. The purpose of the system was to facilitate the designer's job, particularly some of the more tedious and repetitive tasks, such as numbering the thousands of wires in the electrical cabinets [1] and designing the input and output connectors (which serve as an interface between the cabinet and the rest of the electrical network).

To start with, the designers tested the software. Although it was supposed to carry out the task from start to finish, designing on the screen turned out to be too restricting. As a result, the activity was divided into subtasks: the designers would work on paper first, as before, and then once all diagrams had been produced, they would enter the data into the computer. The causes of the difficulties were hard to understand, both for the management staff and for the unions, especially since so much money and effort had been invested in the system.

Our study focussed on a designer who was asked to produce a design in the traditional way (i.e., with a pencil on a piece of paper). We then asked him to accomplish the same task on the computer. The two situations were videotaped and the recording was analyzed, image by image. In this way, we were able to carry out systematic comparisons between the two situations using the following elements: (1) two types of behavioral cues in the designer's activity: spontaneous verbalizations and direction of gaze (visual areas explored), (2) the production activity in progress. This revealed the dynamics of the process by which the designer generated the specifications. Two types of data were gathered for analysis: the order in which signifiers were produced, and the nature of the production (production of new signifiers vs. modifications such as crossing out, new production following crossing out). Furthermore, we carried out interviews with the operator and watched the video recordings with him so as to define goals and motives.

Paper-and-pencil design

When designing on paper, the designer produced a rough draft of the electrical structure (see Figure 1). The draft was not produced in a "linear" way. Rather, its elaboration went through various periods. The designer repeatedly referred to the initial specifications (in this case, the functional diagram [2]) and annotated them to mark off the stages of the designing activity. According to the designer, "This way, you know where you are up to..." For this reason, the annotations can be considered valid markers of periods in the draft production process. We thus identified five periods.

Analysis of the data showed that each period of the activity was organized in the same way: at the beginning, the designer analyzed the functional diagram and then drew an initial rough sketch. Only new signifiers were produced and no modifications or corrections were made at this point. By the end of the period, the activity was quite different: the marks made were either confirmations (the designer went over already drawn lines with a pencil) or corrections (crossing out followed by an addition). This type of backtracking was characteristic of all periods, even the initial ones (Figure 2). An analysis of the direction of the designer's gaze confirmed this pattern. At the

P. Beguin & P. Rabardel

beginning of each period, the designer looked more at the initial specifications than at the draft, but by the end of the period, the opposite was true: more time was spent inspecting the draft than looking at the functional diagram. Finally, spontaneous verbalization ("Here ... now here ..., that looks good, ... okay"), which did not occur at the beginning of the periods, appeared later. This indicated that the designer was mentally simulating the opening and closing of connections and the flow of energy.

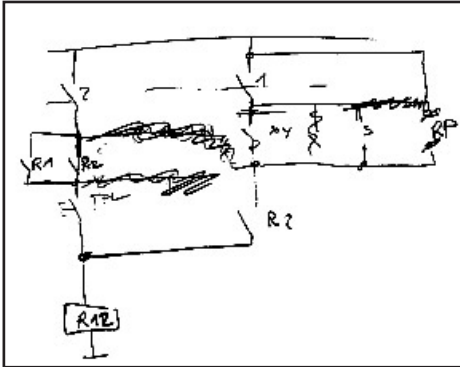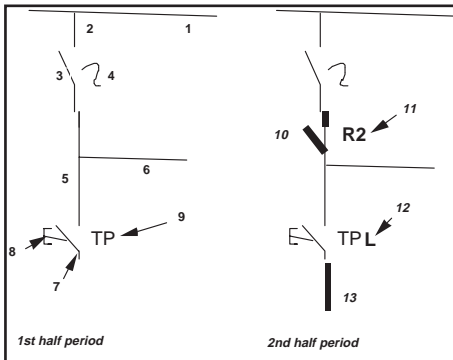*Figure 1. First draft produced by the designer.*

Figure 2. Graphic production process during the first period. The lines shown in boldface were produced during the second half of the period.

Analysis of the data by quarter periods gave us a clearer understanding of what was happening within the periods (see Figure 3 for a graphic representation), each of which can be described as a cycle. The first half of the cycle can be called "generative". In the first quarter the designer extracted the required properties of the electrical "object" from the initial specifications. He focused mainly on exploring and analyzing the source document (the functional diagram). The properties were then transposed onto the sketch of the electrical structure (second quarter). During this first,

generative half of the cycle, the designer seemed to be reasoning as follows: "The functional diagram calls for this type of conceptual relationship, which means that type of electrical entity." During the second half of the cycle (third and fourth quarters of the period), the designer assessed and modified his output, so this phase can be called the "backtracking and assessment" phase. This phase started with an evaluation of the intrinsic feasibility of what had just been produced (third quarter). This is when the designer verbalized the opening and closing of connections and made changes and corrections. The evaluation led either to confirmations by retracing the lines or to corrections. The backtracking and assessment phase ended with a verification period in which the designer ensured that the electrical structure conformed to the initial specifications (last quarter). During this second half of the cycle, the designer's reasoning seems to have been something like: "For this electrical structure, given this state of connections, what happens in functional terms, and does it conform to the initial specifications? In short, our analysis revealed a cyclical organization of each period [3], which we call the "design scheme". We will come back to the concept of scheme later.

Figure 3. Evolution of the time spent looking at the draft (in %, by quarter period) for each of the five periods.
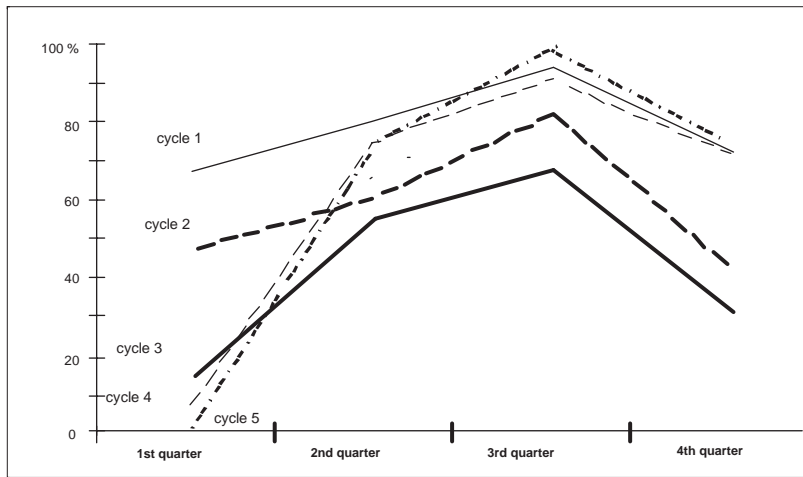
Designing on the computer

What instrumental changes took place in the transition to working "on the screen"? We observe a design scheme breakdown and a specialization of periods.

As was the case in "paper-and-pencil" design, the computer-assisted design process also appeared to be made up of periods during which sketches were made. In the present case, six periods were identified. The designer's activity on the screen could no longer be described as a micro-cycle: the periods became specialized. The first three periods were exclusively generative, whereas the last three periods concerned only backtracking and assessment.

How can we explain this specialization? When working on the computer, the designer is faced with two tasks. On one hand, there is the design task, which requires an attitude of uncertainty [4].

P. Beguin & P. Rabardel

As we have seen, the sketches based on the initial specifications are not immediately validated. Backtracking is necessary. On the other hand, entering the data into the computer demands a high level of precision given that the process is automated. To avoid data entry errors, which are practically impossible to diagnose, designers apply "entry rules". The two dimensions – of producing within a standardized format for automated treatment, and the uncertainty and backtracking required for design – are contradictory.

In the situation we analyzed, the designer implemented the entry rule during the first three periods so the file corresponded to requirements of automation. However, the electrical system suffered from several functional disorders. Modifications were necessary. They were made during the last three periods. Yet these modifications disrupted the computer file. An automated production of data was no longer possible.

In the case of "paper-and-pencil" design, the artifacts available to designers, i.e., those associated with the design scheme, allow them to maintain the required level of uncertainty. With the computer, a high level of certainty is required, given the available artifacts (screen, software, etc.), and the associated constraints (entry rules). Hence, the design process is disrupted. The necessity of keeping the instrumented design scheme intact leads to the division of the task into two distinct sub-tasks: design on paper, then data entry.

The mediating instrument: a composite entity

The traditional situation, which we have called "paper-and-pencil design", is a design activity mediated by an instrument. The instrument is made up of two types of structures:

- psychological structures, which organize the activity: in our example, these structures constitute the "instrumented design scheme"; the activity is always organized in the same way, even though, as we have seen above, some variability is possible;

- artifact structures, which in our example are the signs and symbols in the code used to think of and express solutions, along with the paper, pencils, erasers, and so on, that serve to produce and modify the diagrams.

Figure 4. The mediating instrument, a composite entity.
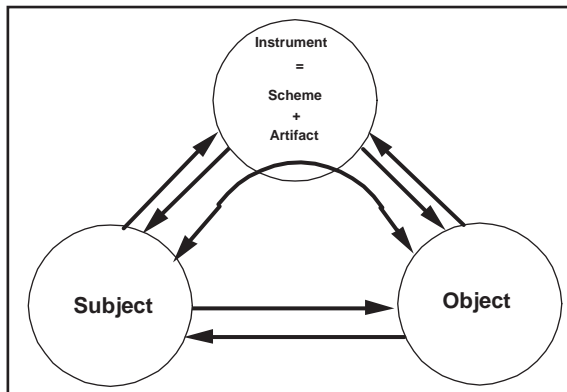
These two types of structures are the resources the designer jointly implements to carry out his object-oriented activity. Thus, the mediating instrument has two components (fig.4): (1) an artifact component (an artifact, a part of an artifact or a set of artifacts), which may be material or symbolic, produced by the subject or by others; and (2) one or more associated schemes, resulting from a construction specific to the subject, or through the appropriation of pre-existing social schemes. Together they act as the mediator between the subject and the object of his/her activity. The conventional diagram of this mediated relationship can thus be expanded to depict the instrument as a composite entity made up of both the subject and the object (in the philosophical sense of the term). Analysis of the instrument used by the designer allows us to define the different dimensions of mediation.

First, there is mediation between the subject and the object (in our example, the object being designed), which is of two types: (1) During the (generative) production phases the instrument enables the designer to produce the various stages of the electrical system, thereby performing "pragmatic mediation" between the subject and the object of the activity. This type of mediation is what generates new, software-linked constraints requiring the designer to produce objects whose degree of certainty is incompatible with the flow of the activity. (2) During analysis of the functional diagram or of the draft produced, the instrument performs "epistemic mediation" between the subject and the object of the activity, thereby making the subject aware of the nature of the object.

Finally, there is a kind of mediation allowing the designer to manage his activity. This takes place during the phases where annotations are made on the functional diagram. This is "heuristic mediation": the subject orients and controls his/her activity in line with the progress of his ongoing activity.

It is clear from the joint presence in the same instrument of these different dimensions of mediation that the mediating instrument is both technical and psychological in nature, not just one or the other as Vygotski (1930) assumed [5].

THE PROCESS OF INSTRUMENTAL GENESIS: PERSPECTIVES FOR DESIGN

Above, we presented an anthropocentric definition of instruments. Now we will attempt to show how this conceptualization enables us to describe developmental processes. "Catacreses", in the sense intended by Faverge (1970), are the prototype of these processes.

The term "catacresis" is borrowed from linguistics and rhetoric, where it refers to the use of a word in place of another, or in a way that goes beyond its normal meaning. By extension, the idea is employed in the field of instrumentation to refer to the use of one tool in place of another, or to using tools to carry out tasks for which they were not designed. The possibility for a subject to temporarily associate a wrench with the hammering scheme ordinarily associated with a hammer, is a catacresis.

One might think that catacresis would be declining in the context of modern technology. The contrary is true, as evidenced by the following example. During preparation for landing, aircraft pilots who are unsatisfied with the descent speed proposed by the on-board computer actually enter false information (for instance, they may specify that there is a tail wind when no such wind

exists) so that the computer will define a landing speed that fits with their desires. This example shows that even with automated technologies, users are able to regain control as long they have an entry point into the system (in this example, the entry point is the input data the pilot must supply because the computer cannot acquire it on its own). Comparable behavior has been observed in truck drivers using automatic transmissions (Galiner, 1996) and in operators of numerically controlled machine tools (Duvenci-Langa, 1997).

Catacreses are traditionally regarded as deviant uses of an object with respect to the functions intended by the designers [6]. However, an interpretation in terms of deviation is not the only one possible, nor in our minds is it desirable. Catacresis can also be an activity in which the subject constructs his/her instruments and more generally the means employed to complete his/her action. We thus suggest considering catacresis as an indicator of the user's contribution to the development and use of an instrument. The existence of catacreses reveals that the subject creates means more suited to the ends he or she is striving to achieve, and constructs instruments to be incorporated into the activity in accordance with his or her goals [7]. These processes may be relatively simple, as in using the wrench artifact as a hammer when associated with the hammering scheme. They may also be large-scale processes that develop over a period of years and involve scheme building as well as transformations of the functions, or even the structure of artifacts. In this case, we speak of instrumental genesis. The concept of instrumental genesis encompasses both the evolution of artifacts as the user's activity unfolds, and the building of utilization schemes, both of which participate in the emergence and development of an instrument. Instrumental genesis occurs at both poles of the instrumental entity (the artifact and its utilization schemes), and thus has two dimensions: instrumentalization, which is artifact-oriented, and instrumentation, which is subject-oriented. Both of these dimensions are related to the subject. What distinguishes them is their focus. In the instrumentation process, the subject develops, while in the instrumentalization process, it is the artifact that evolves. The two processes contribute jointly, and often in a dialectic manner, to the construction and evolution of the instrument, even if, depending on the situation, one of the processes may be more developed or prominent than the other, or may even be the only one implemented.

We will now present these concepts in greater depth, and determine how they are linked to artifact design and utilization.

Utilization schemes and instrumentation

Instrumentation processes lead to the emergence and evolution of utilization schemes - their construction, functioning and enhancement - and to the incorporation of new artifacts into preexisting schemes. It is not possible here to give a comprehensive report of the research on the concept of the scheme (studies have been carried out within several theoretical frameworks, in a variety of disciplines including developmental and social psychology, psycholinguistics and artificial intelligence) as it was developed at the Center for Genetic Epistemology in Geneva (Piaget & Beth, 1961). What we propose to call a "utilization scheme" (Rabardel, 1995, 1999) is an active structure into which past experiences are incorporated and organized, in such a way that it becomes a reference for interpreting new data. As such, a utilization scheme is a structure with a history, that changes as it is adapted to an expanding range of situations and is contingent upon the mean-

ings attributed to the situations by the individual. We chose this concept because it allows us to identify the processes through which an activity is adapted to the diversity of the outside world, in accordance with the particular content to which the scheme is applied. Two processes are at play.

Firstly, schemes assimilate, which means that they can be applied to several different kinds of artifacts. For example, the hammering scheme, which is usually associated with a hammer, can be momentarily associated with a wrench. In our case study, the preexisting instrumented design scheme failed to assimilate the computer artifacts. Secondly, schemes are accommodating: they can change when the situation changes. In our example, the disruption of the instrumented design scheme and the appearance of specialized periods indicate that a process of accommodation was underway within the instrumented design scheme. Such accommodation leads to the gradual diversification of uses.

Utilization schemes have both a private and a social dimension. The private dimension is specific to each individual. The social dimension, i.e., the fact that it is shared by many members of a social group, results from the fact that schemes develop during a process involving individuals who are not isolated. Other users as well as the artifact's designers contribute to the elaboration of the scheme. Schemes are transmitted informally from user to user, or formally through organized training in complex technical systems, and include various types of user aids (manuals, operating instructions, different kinds of help systems and assistance, which may or may not be incorporated in the artifact itself). This is why we speak of "social" utilization schemes. It is the social nature of utilization schemes that makes it possible to invent and distribute artifacts within a given community and which makes them interchangeable with others of the same category. The idea that the forms and functions of artificial or instrumental behavior are the outcome of the historical development and successive acquisitions of humanity was already put forward by Vygotski (1930) in his historical-cultural view (this idea was taken up later by Leontiev, 1981). In their social form, utilization schemes bear the fruit of what history and culture have taught us about human action.

Scheme-based design

The social dimension of schemes, and assimilation and accommodation processes, are important elements to consider during design, both before the process (analysis and design) and after it (introduction and sustained support).

Understanding the assimilation and accommodation processes is particularly important when evaluating and introducing an artifact. In one case, children observed during tests of an electric toy (a train), repeatedly behaved in a way that put them in danger: they attempted to plug wires that were supposed to go into the low-voltage transformer, into a high-voltage outlet (220 volts). The children had a preexisting scheme that might be called the "plugging in" scheme, to which they assimilated the "electric toy/wires/plug" situation forthwith. The assimilation of the scheme was relevant. The children were indeed dealing with an electrical plugging-in situation, but using this scheme was dangerous nonetheless. The assimilation of the artifact with the preexisting plugging-in scheme had to be supplemented by a scheme-accommodation process. Once a scheme has been instilled socially, however, accommodation is not always possible. For example, all at-

P. Beguin & P. Rabardel

tempts on the part of automobile manufacturers to modify the relative positions of the brake and accelerator pedals have ended in failure; in emergency situations, drivers continue to act as if the positions had never been changed.

Accommodation and assimilation processes can be long and difficult, or even impossible. This is why we advocate engaging in a pro-active analysis of social schemes, before specifications are generated.

One of the questions raised by this proposal is whether it jeopardizes innovation. Arguing that it is necessary to organize the design process around pre-existing uses when inventing could indeed be regarded as an anti-innovative position. Yet this is not the case. The design scheme presented above, for example, is a source of creative development at the artifact level. We have seen that it is cyclical in form, being composed of an initial "generative" phase followed by an "assessment" phase. During the assessment phase, the designer talked to himself about opening and closing connections (e.g., "Here ... now here ..., that looks good, ... okay"). In some cases, gestures accompanied the verbalizations, e.g., the designer placed his arm and hand in a position that simulated the flow of energy. This behavior could be used as a starting point for design. For example, the computer program could assist the designer in his thought process by simulating the electrical flow, say, by highlighting entities on the screen. Yet in this particular case (given the software), this proposal came up against seemingly insurmountable problems on a technical level. To start from social schemes, then, is not incompatible with invention. On the contrary, this is an anthropocentric approach, where creative developments serve the needs of users.

The intrumentalization process

Above, we illustrated the part that schemes play in instrumental geneses. We will now look at instrumentalization processes. These processes concern the emergence and evolution of the artifact component of the instrument - selecting, grouping together, producing, and defining the functions - as well as the transformation of the artifact (structure, operation, etc.). They extend the artifact's intended use.

Instrumentalization is a process based on the inherent attributes and properties of the artifact. It gives them a temporary status depending on the given action and situation (in the example of the wrench that replaces the hammer, the initial properties are its heaviness, hardness, and graspability). These properties may be retained after the action is completed. This takes place if the subject gives these functional properties what he/she sees as an instrument status within a given context. Heaviness is a specific property of a wrench, but it is not crucial to the original function of this artifact (whereas it is obviously a key feature of a hammer). Nonetheless, the subject uses the weight of the wrench to grant it a new function (e.g. hammering in a nail), and this function, once retained, takes on the new status of acquired property of the now-instrumentalized artifact.

Thus we can distinguish several levels of instrumentalization in the attribution of functions to one or more of the artifact's properties.

At the first level, instrumentalization is local. It is related to a particular action and to the specific circumstances under which that action occurs. The artifact's properties are given a function temporarily. The artifact is momentarily instrumentalized. At the second level, the artifact's property is more permanently linked to a function that the instrument can perform within a class of ac-

tions, objects of the activity, and situations. The instrumentalization is lasting if not permanent. At both of these levels, the artifact itself does not undergo any material transformations. It simply takes on new properties as far as the subject is concerned, acquired either momentarily or more permanently. At the third level, the artifact can be permanently modified in terms of its structure so as to perform a new function.

Designing based on artifacts developed through instrumentalization

One way of handling the instrumentalization process that comes to mind is to propose flexible systems that users can adapt to their needs. Although it seems appealing, this solution throws up some specific problems. It is sometimes difficult to make users responsible for adaptation, especially because they do not always have the procedural resources to do so effectively. Also, the nature of the potential modifications may be very difficult to envisage. To illustrate this point, let us take a case of instrumentalization in working with a CAD system (Béguin, 1993).

We saw that in the electrical engineering research department described above, the software required a very precise format for entering data because the process was automated. At the same time, we also observed that the designers instrumentalized the computer files. This instrumentalization was based on the structural nature of the computer files. Unlike paper, the files allowed the designer to reuse all or part of their contents without altering the support. Thus the designers reused part of the data produced by their colleagues and displayed it on their screens. This recycling guaranteed a continuity between decisions being made by the designer in front of his screen and those made previously by his colleagues. Attributing this function to the files threw up new problems: a file can be organized in a wide variety of ways so that it can be reused in a given situation. Artifacts were developed to allow a shared organization of files and adapt them to the project at hand. In one research department, all of the designers printed out copies of their plans, which served as a base for recreating the structure of their shared file. In another department, the plotter was modified for each new project. In both cases, the artifacts were very different (a paper print-out or a plotter) but their functions were the same.

Could the software engineers have imagined that the systems they had developed would be used as groupware? [8] Clearly, it is when a system is implemented that its full potential is revealed. This is why we believe that many lessons for design can be learned from artifacts produced through instrumentalization.

An analysis of artifacts developed through intrumentalization does not provide immediate solutions that can be implemented blindly. The merits of such an analysis lie in its ability to indicate new needs. In our example of the reuse of files, it was necessary to develop computer environments that were equipped not only with file-organization tools, but also with tools geared to the management of electronic information.

DESIGNING TO PROMOTE INSTRUMENTAL GENESIS

One of the key points in our conceptualization of instruments is that the creativity and inventiveness of operators is an ontological feature of the design process (and not an indicator of user deviation or a defect in the designers' specifications).

This kind of creativity is a property that originates in the activity itself and through the implementation of the system. It can occur over long periods.

The traditional approach to engineering consists of viewing design as a change of state. This approach is inherently flawed given that man's living and working environments are dynamic systems. Design should therefore be understood as a cyclical process involving the use of, and search for, technical solutions. It should echo the inventiveness of its users and designers alike. In this context, several approaches can be considered.

The first consists of integrating instrumental geneses into the design process, so that formal design phases and design phases that occur during use alternate or are interwoven. We attempted to implement this approach in the design of an alarm for process control on chemical sites classified as SEVESO (Béguin & al., 1999). A prototype of the alarm was tested on a pilot site for 18 months. The results of the activity analysis, conducted at regular intervals, were transmitted to management and to the risk-handling specialists who had designed the alarm (after validation of the analyses by the operators). The aim was threefold: (i) to follow up on developments after the introduction of the artifact, (ii) based on that data, to achieve a shared understanding among designers, users, and management to form the basis of potential modifications, and (iii) to obtain feedback on the outcome of the modifications made during the testing period.

First, the analyses indicated that the operators were instrumenting the system, i.e. assimilating the artifact with preexisting social schemes. The design principles of the alarm were based on the risk of the product overheating. To ensure the alarm worked properly, the device supplied digital temperature readings. However, the operators conducted the process by keeping the product at the lowest possible temperature and the thermometers provided were not accurate enough. The alarm's temperature readings became an instrumental aid for process control in the users' activity. This led the designers to make modifications.

Our study also showed that the operators had little knowledge of the thermal kinetics of this chemical process in the upper temperature zones, where the risks are the greatest. In fact, this lack of knowledge and experience of the most dangerous situations has been a contributing factor to fatal accidents [9]. The technical system (which operates on the basis of the thermal kinetics of the product) was used to simulate the temporal conditions that would exist during a major accident, so that whatever actions might be needed to restore the process to its normal state could be tested. To implement this new function, the artifact was modified (instrumentalization) and the conditions under which the simulation could be conducted were defined (instrumentation). The use of the newly devised instrument led to drastic changes on site. First, organizational changes were made, since system utilization showed that the number of operators assigned to the site would be insufficient if a major emergency occurred. Second, architectural changes were made, as it turned out that the production room had to be adapted to cope with the most critical situations.

This is clearly a case of instrumental co-genesis, achieved jointly by users and designers. Experimental use of an artifact in sufficiently significant situations, over sufficiently long periods of time, is an excellent test of the principles underlying its design. This testing can reveal users' everyday needs and problems, and pave the way for new developments.

The organization of the design process becomes more efficient when it alternates between design and utilization. We feel that another complementary way of achieving more effective integration of instrumental genesis needs to be explored. This would consist of giving tools to user-designer exchanges. Our lack of experience in this area prevents us from expanding on this point, although we believe it is an important line of research. We will simply stress the importance of studies like that carried out on "cooperative prototyping" (Bødker & Grønbæk, 1991). One of the implications of providing tools in this way is the possibility it offers of organizing exchange based on weak hypotheses rather than on highly advanced developments, as in the computer aid example described above.

TOWARDS A DEVELOPMENTAL THEORY OF "INSTRU-MENT-MEDIATED ACTIVITY"

The activity theories initiated by the Soviet school of psychology are now internationally accepted (Engeström, 1987, 1993; Rabardel, 1995; Nardi, 1996; Cole, 1996; Clot, 1999). In a recent publication, Kaptelinin and Kuutti (1999) clearly described the advantages of considering the user's activity on today's technological systems from the mediational standpoint proposed by activity theory. The authors tell us :

> From a mediational perspective there is only one system to be seen: a human already equipped with many kinds of functional organs, developing against a cultural background and situated in a personal history of interactions with the world. Besides this one system there is nothing else to be seen. A place for a computer tool with a set of functionalities is there, but it is totally opaque. There is a possibility that some of the hidden functionality can be used to transform the human system in order to enable it to perform a task, but it is only a potential. To realize the potential, a situation has to be organized where the person interacting with the material can recognize a possibility and create a new functional organ or extend an old one for the new purpose. Hence, within the mediational perspective the focus is on the transformation.

The proposals set down in this chapter are clearly in line with this mediational and developmental approach to contemporary technologies. Kaptelinin (1996) and Cole (1999) both use specific terms to describe this approach: "computer mediated activity" or "tool mediated activity". One aspect we have stressed is the distinction the subject makes between the material or symbolic artifact and the instrument. We have attempted to demonstrate that instruments are composite in nature, in that they serve both as artifacts and utilization schemes. This is why we feel it is preferable to talk about mediation by the instrument, rather than by the artifact alone. From this perspective, the design process is about providing the user with an artifact, not an instrument. At best, these artifacts have potentials that the user may or may not develop. This potential will become apparent when the systems are implemented. This is when developments will be tried out, validated or rejected and artifacts will take on functions that will be temporary or permanent, following the diversity of the situations and projects the users set for themselves. Instruments come out of the specific form of activity that we call instrumental genesis. This is a process of dialectical transformation of artifacts and social schemes, during which the individual and his resources will develop.

The aim of this article was to indicate the directions we are developing, based on our conceptualization of instruments, in order to ground design in anthropocentric precepts. We advocate design based on instrumentation and instumentalization, and in particular, the organization of design around instrumental genesis. A more in-depth theoretical discussion would clearly be worth undertaking. Similar concepts have been explored in other studies, notably the "functional organ" defined by Kaptelinin (1996) following Leontiev, the notion of "affordance" put forward by Norman (1988), or Engeström's concept of the "secondary artifact" (1987), among others. However, such a discussion would have gone beyond the scope of this article, given that in our opinion, the theoretical reference frameworks necessary are psychological theories of development as well as activity theories. Studies by J. Piaget and his followers have made an important contribution by proposing the concept of the scheme and an understanding of the mechanisms of individual development. However, this approach must be linked to historical and cultural-oriented activity theory in order to conceptualize the cultural and social dimensions of the development of the human race based on experience gained historically. We feel that this is vital for the elaboration of a theory on activity mediated by the instrument.

Notes

[1] Electrical cabinets bring together in the same physical location all elements needed to run part of a factory, building, etc.

[2] A functional diagram defines the operating principles in the form of logical rules (and's and or's). In the final draft, the logical relationships are replaced by electrical relationships consisting of polarities, connections, and receivers carrying energy.

[3] The periods had the same basic structure, but with some variations across cycles. The main variation was the amount of time spent analyzing the functional diagram. The initial specifications were explored less and less from one period to the next, because the designer had an increasingly greater need to inspect his own new productions in order to perform the backtracking and assessment tasks.

[4] Lebahar (1986) showed that effective designers always maintain some degree of uncertainty in their work, without which they get trapped too soon into solutions that are too specific. Excessive precision at the onset can block the design process altogether.

[5] Mediation between the subject and others also exists, but this topic is beyond the scope of the present chapter.

[6] Such deviations sometimes cause problems, for example, because of the dangerous situations they may create. Distorted uses may not be compatible with the underlying principles of the technical process.

[7] We will focus on subjects' elaboration of their own instruments. The relevance of what they end up constructing is another question that will not be examined here.

[8] It has been shown that this setup provides an original and efficient way of solving some of the typical problems encountered with the newer design strategies (such as concurrent engineering), which stipulate that no decisions can be made without taking into account all other decisions made during the project (Béguin, 1997).

[9] Several studies on accidents have shown that in cases of reactor runaway, operators remain on the installation premises until the explosion.

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