In Search of a Unit of Analysis for Designing Instruments

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A welcome topic of the new journal *Artifact* is to promote as a distinct academic field the transdisciplinary approaches centered on design research. One of the conditions for such a transdisciplinary approach is that the different actors recognize the specificity of the contributions of other actors and the complementary nature of their respective productions. In this essay, I will argue that the different contributions of experts in design must be completed by users' constructive activity. More particularly, my focus is to search for a unit of analysis that helps to build shared references between users and designers. I will proceed in two steps. In the first, I will suggest that an instrument cannot be confused with an artifact, and that it is the user or the worker who gives to an artifact the status of an instrument. In a second step I will describe the design process as a dialogical process in the Bakhtinien sense. I will conclude with comments on "*what is an artifact?*"

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ARTIFACT AND INSTRUMENT

Work initially developed by L. S. Vygotsky and others in Soviet psychology supplies a rich and fertile approach to apprehend activities with artifacts. As an activity consists in acting "through" an instrument (Bødker, 1989), artifacts must not only be analyzed as things but in the manner in which they mediate usage. We have Vygotsky to thank for emphasizing the importance of mediation, which he considers as the central fact of psychology.

The basic structure of human cognition that results from mediation is often pictured as a triangle, as in Figure 1. So artifacts must not only be analyzed as things, but in the manner in which they mediate action.

But, in this well-known picture, the terms "computer", "tool", "artifact" are used interchangeably. And apparently, no particular ontological or epistemological problems exist. Yet if the purpose is to make a contribution to the design of technical devices, we need to be able to describe more accurately what allows mediation to take place. I will suggest that we have to make a distinction between artifacts and instruments.

From artifact to instrument

An instrument cannot be reduced to a physical or symbolic artifact, nor can it be confused with one. For example, a hammer is not an instrument in itself. A hammer is an artifact. To be an instrument, the subject (the users or the workers) must associate an organized form of psychological and motor operations with the artifact. So, we can define an instrument as a mixed entity (Béguin & Rabardel, 2000; Rabardel & Béguin, 2005), made up of two types of components. First, a psychological and motor one that comes from the subject, and which has individual, social and cultural dimensions. Second, an artifactual part (an artifact, part of an artifact, or a set of artifacts), which may be material or symbolic (Figure 2).

Each side of the instrument is a conceptual minefield. Rabardel (1995) proposed to conceptualize the subject side of the instrument as a "scheme", in the sense of Piaget (Piaget & Beth, 1961), and more accurately as a "utilization scheme". A "utilization scheme" 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 scheme is a structure with a history, one that changes as it is adapted to an expanding range of situations and is contingent upon the meanings
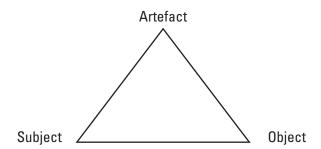
Figure 1.
The basic structure of human cognition.

Figure 2.
An instrument is a composite entity made up of subject and artifact components.

granted to the situations by the individual. However, and because it is not possible to fully discuss these points, I will use the terms "*subject side*" and "*artifact side*" of an instrument (see Figure 2), and I will come back later on the status of the artifact side. An important consequence of such an approach is that an artifact is not an instrumental component in itself (even when it was initially designed as such). The instrumental position of the artifact is relative to its status within the action. More extensively, the artifact part of an instrument is any stuff one associates with the action in order to perform a task, to reach a goal, or to realize a motive. We all have examples in mind such as the association of the scheme "striking" with a wrench, which turns the wrench into an instrument that has the same function as a hammer. In this small example it is the subject who gives to the artifact the status of resource to achieve the goals of his/her finalized action, who institutes an artifact as an instrument.

From instrument to instrumental genesis
To continue the previous example, using a wrench as part of a hammer is a catachresis. The term "catachresis" is borrowed from linguistics. It refers to the use of a word in place of another. For example, using the word "arm" for speaking about the "arm" of a chair is a catachresis. This term can be extended to the field of instrumentation. Catachresis is a way to name things without an available word, or to do something without technical resources at hand. In this sense, it is testimony to the inventiveness of users or workers who seek to exploit their environment and enroll it in the service of action, in order to increase the capacity to act in the environment. One must not think that catachresis would be in decline in the presence
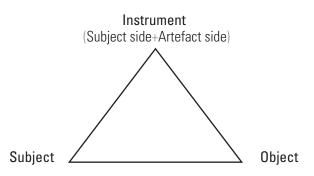
of modern technology. It is not the case. During preparation for landing for example, we have observed that aircraft pilots who are not satisfied with the descent speed proposed by the on-board computer may enter false information (for instance, they may specify that there is a tail wind when no such 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 may attempt to regain control as long they have an entry point into the system (in our example, the entry point is the input data the pilot must supply because the computer cannot acquire it on its own).

Catachresis results from a process that may be relatively elementary (as in using the artifact "wrench" as a hammer), or from largescale processes that develop over a longer period on "the floor" or in fieldwork. In order to grasp this process, we speak of "*instrumental genesis*". Because the instrument is a mixed entity, instrumental genesis is a process that encompasses the evolution of both the artifact and subject sides. Let us call these two processes "instrumentation" and "instrumentalization".

Instrumentalization is the attribution of a function to an artifact, which extends the artifact's initial design and enriches the properties of the artifact. It is based on the artifact's initial attributes and properties, and confers on them a status in accordance with the current action and situation (in the example of the wrench that replaces the hammer, the initial properties are its heaviness, hardness, and graspable-ness). At the lowest level, instrumentalization is local; it is related to a single action and to the specific circumstances under

which that action occurred. At the highest level, the artifact is modified physically. The constituted functions become an integral part of the artifact itself, by way of a modification in how it works or is structured.

Instrumentation concerns the genesis of the human side of the instrument. At the lower level it concerns the "utilization scheme". When a person uses a wrench as part of a hammer, there is a direct assimilation of the artifact in the constituted scheme. But more often there is an adaptation of the scheme (for an example of such a process with an automatic truck gearbox see Rabardel & Béguin, 2005). In the larger case, the development of the human side leads to a deeper reorganization of the human side of the instrument. For example, introducing CAD in a new setting leads to the development of new utilization schemes, but also to a new conceptualization and new forms of collective action.

Instrumentation and instrumentalization help to analyze a particular instrumental genesis. But they are intertwined in the same constructive process. Indeed, instrumental genesis may have sources that are external to the subject. For example, an insufficiently elaborated design that does not sufficiently consider the user's requirement or practice causes a "gap" (Thomas & Kellogg, 1989) for which the user must compensate. But even if the artifact is well designed, an instrument is not finished when an artifact is specified. The argument there is that the development of an instrument requires the users or workers to develop their own resources for action. Therefore both designers and users contribute to the design of an instrument, based on their diversity.

Designing an instrument
One way to resume what was previously said is that an instrument is a "coupling" between the subject and the artifact. But this coupling is far from what is described by the concept of "*affordance*", where it is argued that anyone immediately and directly perceives the signification and function of an object. These concepts create difficulty when used to clarify relations between the given and the created (Béguin & Clot, 2004). During design this coupling is not tuneful. And behind the artifact there is a designer. The term "catachresis" I evoked
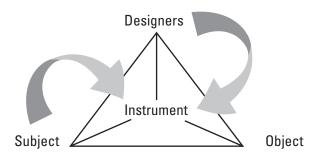

Figure 3.
The "instrumental proposal" and the "instrumental genesis"in dialogue.

previously is traditionally regarded as using a word to denote something radically different from its "normal" meaning, and by extension the "deviant" uses of an object. Such a meaning takes for granted the functions intended or imagined by the designers, and institutes them as the norm or the reference. But, an interpretation in terms of deviation is not the only one, and not even a desirable one. Instrumental genesis is the user's contribution to the development of an instrument.

However, we have to take into account the fact that in designing an artifact the designers imagine a function, with the objective of orienting the worker's activity (see for example Vicente, 1999, for a theoretical argumentation on this position). But this is at best an instrumental proposal made by the designers. There will be a response during instrumental genesis. Consequently, the unit of analysis must be extended in order to give greater importance to the collective.

If we agree with the idea that the aim of the design process is to design an instrument (and not only an artifact), and if we consider instrumental genesis as a contribution made by the user to the design of an instrument, then we can define the design process as a dialogical process in the Bakhtinian sense. By dialogicality, Bakhtin refers to a process where someone takes something that belongs to others, and makes it his/her own. "Because words are half-ours and half-someone else's . . . one is invited to take the internal word as a 'thinking device', or as a starting point for a response that may incorporate and change the form or meaning of what was originally said" (Wertsch, 1998, p. 67). In the design process, the "someone else's half" (the artifact for the user) is associated with "one's

own-half" to bring about instrumental genesis, producing a response that changes the form and meaning of what was originally said. Typically, instrumental genesis is a response that changes the form and meaning of the artifact initially proposed by the designers. But note that the reverse is also true: instrumentalization made by users can lead to a response by the designers. So, the challenge is to organize a cyclical and dialogical process (Figure 3), where the result of one person's activity, designer and worker, constitutes a source and a resource for the activity of others (Béguin, 2003).

In speaking of a dialogical process, my goal is not to argue that there is no difference between design and communication, or between sign and artifact. I do not think that artifacts are like books we have to read (Tilley, 1990). My argument is that language is simply one of the possible dialogical forms, but not the only one. Design is another: we have to grasp in its specificity. Let me give some brief arguments.

One feature of a dialogical design process is that it must articulate a cyclical process, between nomos and praxis. On one hand the design is initially a concept, an intention, a will relative to the future, or an order to happen. On the other hand, these orders and intentions have to be concretely realized to occur in action. But action will meet resistances, setting the initial ideas in motion. We have to inscribe instrumental genesis in this cycle, in order to bring back into play the result of the designer's activity after having confronted it with the workers' or users' activity or practices.

To design is to use media (technical or digital drawing, scale models, mock-ups, etc.) for projecting a representation and reflecting on it. But these media play a role in the context of exchange between actors (Vinck, 2001). In a dialogical process, the media must support these individual and collective dimensions. And due to the necessity to articulate the relationship between theoretical concepts and practice, a prototype is probably the best medium. However, it is only at the end of the design process that designers can produce a prototype, after numerous decisions have been made. So, it is often too late: changes can appear much too expensive. What are the projective methods that can be used, and the benefit and risks of using one medium or another?

In using the medium as vehicle for dialogue, divergence surfaces legitimately. These disagreements are the real source and the engine of dialogicality. But during the design process they can be solved in two extreme ways. The first is design: modifying the characteristics of the object currently being designed, changing the criteria for attaining the goal, etc. The second is conflict, for example authority or the exclusion of certain actors whose goals appear too contradictory. What is specific to design is that the disagreements are solved at the level of the object of the design process, the intention or the solution. During conflict, on the other hand, the purpose of the design process loses its centrality, leaving the actors in a situation of face-to-face contention where the difficulties are ascribed to others. So, it is of the utmost importance to verbalize and to legitimize the rationales and possible consequences in regard to the users or workers' perspectives. Otherwise, exchange between users and designers would easily become "conflict-ridden", with the risk of leading to poorer and lower quality outcomes.

Users and designers have their own points of view, their own criteria, their own concepts, and finally different ways of grasping the same situation. But, simultaneously, the actors are engaged in an interdependent process. So what is specific to one actor, and what needs to be shared? Instrumental genesis can appear as nonsense for the designers. But, as outlined by Leont'ev (1978), that which does not have meaning may still have a signification. Something may be a non-sense, but it is not without signification. During dialogical design, an important amount of time must be spent on building the signification of the events: we have observed something. What lessons can be drawn from it; what decisions should we make accordingly?

What is an artifact?

In this essay, I argue that the aim of the design process is to design an instrument, and not only an artifact. But asking "*what is an artifact?*" is a useful question. In defining the design process as a dialogical process, I argue that an artifact could be defined as a sort of bridge laid down between heterogeneous actors, with different points of view and perspectives. But based on what has been said previously, I would suggest two additional criteria that go over a dialogical design process.

First, an artifact can be defined by its structural properties (and not its materiality – a symbolic artifact can also be defined by its structural constraints), which are also constraints. In Rabardel & Béguin (2005) we distinguish three types of constraints. One can use a wrench as part of a hammer due to its graspable-ness and heaviness. It is the "*existence modality constraint*". The artifact also carries constraints concerning the nature of the objects of activity (in the sense of activity theory). A metal lathe, for instance, can only perform transformations of matter through the removal of turnings. We call these constraints "*finalization constraints*". Finally, the artifact carries more or less explicit "*action pre-structuring constraints*". De Terssac (1992) stressed for example that expert systems involve a positioning of the operator and a more or less explicit form of regulation of his actions and activity, which tend to reduce his own regulating possibilities. Probably other constraints could appear, for example at the collective level. The general idea is that an instrumental proposal made by the designers "crystallizes" in the artifact a representation of the activity of the user, and conveys it in a setting. But when this crystallization is of bad quality, it is a source of problem for users or workers. This is why the designer must be able to apprehend the subject's (or subjects') construction that is already available in a situation.

Second, an artifact can be defined by its plasticity. I have argued previously that instrumental genesis is testimony to the inventiveness of users or workers who seek to exploit their environment and enroll it in the service of action, in order to increase the capacity to act in the environment. From my point of view, it is particularly important to give a status to instrumental genesis during design. But instrumental genesis is a living movement, which goes beyond the fixed chronology of one design process. Plasticity consists in designing artifacts that allow or facilitate the constructive and developmental process of instrumental genesis. It can be, for example, that the artifact can be modifiable (Henderson & Kyng, 1991). But identifying the properties that allow plasticity remains a requirement of future research attention.

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