

11

CHAPTER

Activity Theory

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11.1

MOTIVATION

Since the mid 1980s, activity theory has been explored as a basic perspective on human-computer interaction (HCI). In order to understand why this form of HCI came into being, let us consider the Scandinavian research on computer technology use and design of the early 1980s. The 1970s had been a period in which, in general, conventional theory had been challenged in the universities, at the same time that many new areas, such as computer science, evolved. In the Scandinavian context, this led to research projects that critically reconsidered the introduction of computer technology in the workplace. The projects developed an action research approach, emphasizing the active cooperation between researchers and “those being researched,” suggesting that researchers need to enter an active commitment with the workers of an organization to help improve their situation (Ehn & Kyng, 1987). In the early 1980s, concerns evolved for the maintenance and development of skills of the involved workers and for technological alternatives (e.g. Utopia; Bødker et al., 1987). These projects were situated in a context where insights from social psychology and industrial sociology were necessary—some of the inspiration came from activity theory through German work psychology and Scandinavian critical psychology.

11.1.1 Through the Interface—Artifacts Used in Context

The rise of the personal computer challenged the focus, in traditional-systems developments, on mainframe systems for automation of existing work routines. It furthermore brought forth a need to focus on how to work on materials and objects through the computer. In the search of theoretical and methodical

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perspectives suited to deal with issues of flexibility and more advanced mediation among human beings, material, and outcomes through the interface, it seemed promising to turn to the still-rather-young HCI research tradition that had emerged primarily in the United States (for further discussion, see Bannon & Bødker, 1991).

This tradition, however, already faced problems, as outlined by Norman (1980):

The problem seemed to be in the lack of consideration of other aspects of human behavior, of interaction with other people and with the environment, of the influence of the history of the person, or even the culture, and of the lack of consideration of the special problems and issues confronting an animate organism that must survive as both an individual and as a species (p. 2).

Specifically, the cognitive science–based theories lacked means of addressing a number of issues that came out of the empirical projects (see Bannon & Bødker, 1991):

- ◆ Many of the early advanced user interfaces assumed that the users were the designers themselves, and they accordingly built on an assumption of a generic user, without concern for qualifications, work environment, division of work, and so on.
- ◆ In particular, the role of the artifact as it stands between the user and her materials, objects, and outcomes was ill understood.
- ◆ In validating findings and designs, there was a heavy focus on novice users, whereas everyday use by experienced users and concerns for the development of expertise were hardly addressed.
- ◆ Detailed task analysis was seen as the starting point for most user-interface design, whereas much of the Scandinavian research had pointed out how limited explicit task descriptions were for capturing actual actions and conditions for those in use (Ehn & Kyng, 1984). The idealized models created through task analysis failed to capture the complexity and contingency of real-life action.
- ◆ Classical systems focused on automation of routines, and this perspective on qualifications was carried over to HCI. As an alternative, the tool perspective was formulated (Ehn & Kyng, 1984) to emphasize the anchoring of computer applications in classical tool use—the craftsman surrounded by his tools and materials with a historically created practice as his basis. However,

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this perspective was in dire need of a theoretical foundation that would make it applicable in the design and evaluation of computer applications; available HCI theory had no answer to this.

- ◆ From the point of view of complex work settings, it was striking how most HCI focused on one user/one computer in contrast to the ever-ongoing cooperation and coordination of real work situations (this problem later led to the development of computer-supported cooperative work, or CSCW).
- ◆ Users were seen mainly as objects of study. This was in striking contrast to the early Scandinavian experiences with active user participation, where users obviously were an active source of inspiration in design.

11.1.2 In Search of a New Theoretical Foundation

Because of these shortcomings, it was necessary to move outside cognitive science-based HCI to find or develop the necessary theoretical platform. European psychology had taken different paths than had American, with much inspiration from dialectical materialism (Hydén, 1981; Engeström, 1987). Philosophers such as Heidegger and Wittgenstein came to play an important role, primarily through discussions of the limitations of artificial intelligence (AI) (Winograd & Flores, 1986, Dreyfus & Dreyfus, 1986). Suchman (1987), who had a similar focus, introduced ethnomethodology into the discussions; and Ehn (1988) based his treatise of design of computer artifacts on Marx, Heidegger, and Wittgenstein.

The development of the activity-theoretical angle was carried out primarily by Bødker (1991, 1996) and by Kuutti (Bannon & Kuutti, 1993; Kuutti, 1991, 1996)—both with strong inspiration from Scandinavian activity-theory groups in psychology. Bannon (1990, 19991) and Grudin (1990a, 1990b) made significant contributions to the furthering of the approach by making it available to the HCI audience. The work of Kaptelinin (1996) has been important for connecting to the earlier development of activity theory in Russia. Nardi produced the most applicable collection of activity theoretical HCI literature up to that time (Nardi, 1996).

11.1.3 What Does It Offer?

As a consequence of this historical development, activity-theoretical HCI has come to focus on:

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- ◆ analysis and design for a particular work practice with concern for qualifications, work environment, division of work, and so on;
- ◆ analysis and design with focus on actual use and the complexity of multiuser activity. In particular, the notion of the artifact as mediator of human activity is essential;
- ◆ focus on the development of expertise and of use in general;
- ◆ active user participation in design, and focus on use as part of design.

Activity-theoretical HCI offers a set of conceptual tools, rather than a collection of tools and techniques ready for practical application. This chapter will demonstrate these concepts, along with some selected techniques that we have successfully applied ourselves.

11.1.4 How Is It like Other Theories?

Through numerous practical examples, Don Norman (1988, 1991) has pointed out how malfunction is more easily demonstrated than well-function, and how artifacts often stand in the way of human use rather than mediating it. Norman bases himself in part on Gibson's ecological psychology. This theory has been the starting point of several attempts (e.g. Carroll et al., 1991; Hutchins et al., 1996; Rasmussen, 1986, Rasmussen et al. 1994) to move away from the separation between human cognition on the one hand and human action on the other. Activity theory shares with these approaches an interest in actual material conditions of human acting. However, these approaches often lack a concern for motivation of actions, a level of analyses that activity theory adds through the notion of activity. Activity theory shares the idea that a hierarchical analysis of human action is valuable with means/ends analysis, task analysis, and alike. It insists, however, on flexible hierarchies, as we shall see later, rather than on static decomposition of wholes into parts. It further insists that activity takes place on all levels at the same time, and not in sequence (such as Norman's 7-stage model [1988]).

11.1.5 What Sets It Apart?

Because activity theory understands human conduct as anchored in collective/
shared practice, it addresses more than just individual skills, knowledge, and

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judgment, and it is not restricted to the “generic” human being. In other words, we can talk about the appropriateness of a certain tool for a certain practice, and we can study how the introduction of a particular artifact changes practice and how practice may change the use of the artifact. As practice develops over time, concern for the historical context of an artifact in use is essential to activity-theoretical HCI. Learning, accordingly, is not a matter of how the individual adapts, or gets adapted to the artifact; it is also a matter of how the collective practice develops, in small steps or larger leaps. To design an artifact means not only to design the “thing” or device, which can be used by human beings as artifacts in a specific kind of activity. As the use of artifacts is part of social activity, we design new conditions for collective activity, such as a new division of labor and new ways of coordination, control, and communication. In actual use, artifacts most often mediate several work activities, and the contradictions and conflicts arising from this multitude of use activities are essential for activity-theoretical artifact analysis and design.

11.2 OVERVIEW

In this chapter we will use a project that we have been involved with as an example to convey both the basic concepts of activity theory and their potentials in HCI analysis and design. The application developed was a graphical editor and simulator environment for Colored Petri Nets (CPNs). This editor is a (re-)design of a tool, Design/CPN, that is used by more than 600 organizations around the world, both in academia and industry. Design/CPN is a complex application that supports the construction and evaluation of complex CPNs. Typically these CPNs are used for verification of software protocols, such as in alarm systems; in such production applications, nets can contain thousands of places, transitions, and arcs, which are structured into hundreds of modules. Users are not individuals but (parts of) project groups cooperating around the nets, the protocols they model, and the design of the software and hardware on which these would run. Design/CPN has a traditional interface based on direct manipulation, menus, and dialog boxes.

The formal definition of CP nets goes like this: A Petri net is a bipartite graph with two kinds of nodes: *places* (depicted as circles or ellipses), and *transitions* (depicted as rectangles). Edges of the graph are called *arcs* and can only connect places to transitions and transitions to places. Places hold tokens, which represent the current state of the system. Simulating the net involves moving

tokens from place to place by firing transitions according to predefined rules. CPNs (Jensen, 1992–1997) are an extension of Petri Nets for modeling complex systems. CPNs can be hierarchical. Hierarchical nets make it possible to structure a complex net into smaller units that can be developed and tested separately.

The redesign of Design/CPN, called CPN2000 (Beaudouin-Lafon & Lassen, 2000), aimed to design an interface for the next 10 years, based on actual experiences with the existing tool. The project applied a participatory design process, involving users from the early stages of brainstorming all the way through the design process (see Mackay, et al. [2000] for details).

In order to study the practice and conditions of use, the process took as its starting point a number of studies-of-use situations involving videotaping novice as well as expert users. In parallel with this, to seek inspiration from advanced technology, a number of brainstorming sessions took place, including exploration of advanced interface ideas, such as tool glasses (Bier, et al, 1993). To provide hands-on exploration, prototypes were built and explored in workshops with users. A first version of CPN2000 was used by a small group of CPN designers for production work. This use was studied in order to inform the next round of the iterative design process.

Design/CPN is used both as a professional tool and as an educational tool, defining from the outset two different types of use activities to be understood as the basis of design. The educational activity is typically one where one to two students work in front of a computer, in a room with other students attending the same class (where the tools and nets have been introduced). In contrast, the professional users work in an environment where they share some nets with others and where the purpose of building the nets is mainly a tool for the design process as such—for example, when building an alarm system. The designers take over nets from one another; they take notes from reviews and meetings and adjust Webs accordingly; they redesign protocols based on earlier products; and they only rarely design new nets from scratch. When Design/CPN works well for a particular designer, it does not in the way of his attention on these other foci, which is why we talk about the computer application as *mediator*.

Design/CPN is a mediating artifact that allows the user to produce CPNs. However, such CPNs are in turn mediating how users verify alarm protocols; creating a CPN rarely has a purpose in itself. We can go on like this, illustrating how a particular artifact most often mediates a multitude of activities, and how what is sometimes the object of the activity is in other instances itself a mediator. To fully understand the use of an artifact such as Design/CPN, we must find out which activities the artifact is used in and how these are connected. This is why we talk about *webs of activities*.

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Accordingly, the webs of activities that Design/CPN is part of in the two situations (educational and professional) are rather different, the purposes of use differ, the qualifications and experiences of the users differ, and the focus of attention is different for the two groups: When students explore a new tool, their focus is primarily on the interface and its very narrow surroundings (how to create an arch, how to move a label, etc.); whereas the professional user may have her focus mainly on solving a tricky protocol problem or on remembering what her co-workers said in a meeting, at the same time that she works through a CPN to handle these issues. The professional user has developed a repertoire of operations that allows her to work through the artifact, whereas the student user still lacks this repertoire and needs to be conscious of how to handle the artifact. As an example, our user studies showed how an experienced user continuously reformatted a net on his screen while he was busy explaining some feature or other displayed on the screen to us.

The development of a repertoire of operations for handling Design/CPN is not the only difference between the student and the professional user, but it is a very important one for analysis and design of HCI. As a matter of fact, it happens to anyone even with the most mundane artifacts that they use everyday—somehow their attention is drawn toward the artifact, and they have to be conscious about the use of the device. For example, a small difference in layout of a key pad prevents the user from typing her PIN code, and she has to think and remember to reproduce it. Such halts are examples of what we call *focus shifts*, and they are essential for our analyses of HCI. An analysis of the foci of users in real work/use situations was important for the analysis of Design/CPN and design of CPN2000. This analysis technique will be presented in detail in Section 11.5.

There is no trivial move from the analysis of an existing artifact to the design of a new one. However, our analyses gave us reason to believe that we should get away from overlapping windows, and from traditional pull-down menus, and provide more direct tools for formatting nets. Furthermore, Beaudouin-Lafon (2000) developed a theoretical model regarding instrumental interaction on which the interaction design was based. This model reflects fundamental concepts of activity theory, as we shall illustrate later.

Accordingly, CPN2000 applies tool glasses, traditional tool palettes, contextual marking menus, and two-handed input. The idea was to move beyond WIMP (windows, icons, menus, and pointing devices) interfaces—specifically, that any entity in the interface should be accessible as a first-class object. Commands should apply to as many different types as possible. The CPN2000 interface requires a mouse and keyboard plus a trackball for the nondominant hand. A large window, the workspace, contains an index to the left, a set of floating palettes that can be turned into tool glasses, and a set of binders containing pages.

Floating palettes (Beaudouin-Lafon & Lassen 2000) are similar to those found in traditional interfaces: clicking a tool activates it. The tool is then held in the right hand and applied by clicking or dragging.

Tool glasses (Bier, et al., 1993) are positioned with the non-dominant hand and operated by a click-through of the dominant hand, typically the right hand.

Marking menus (Kurtenbach & Buxton, 1994) are available throughout the interface by clicking with the right mouse button. All the commands accessible through these contextual-marking menus are also available through palettes/tool glasses. The marking menus have at most eight entries per menu and at most one level of submenus.

An important characteristic of the interface is that it supports multiple working styles. Floating palettes are efficient when a single tool needs to be applied to multiple objects; a marking menu is more efficient when multiple commands are applied to the object in succession; tool glasses support a mix of these and are particularly efficient for editing the graphical attributes (color, thickness) of a set of related objects.

In the following, we use examples from CPN2000 and its design process to further illustrate *why* we apply activity theory to HCI, *what* we do, and *how* it is done (Figure 11.1 and color plate 10).

11.3 SCIENTIFIC FOUNDATIONS

Historically, activity theory originated as a dialectical materialist psychology developed by Vygotsky and his students in the Soviet Union in the beginning of the twentieth century. As a psychological theory, it was aimed at understanding the mental capacities of a single human being. Activity theory rejects the isolated human being as an adequate unit of analysis, insisting on cultural and technical mediation of human activity. The unit of analysis accordingly includes technical artifacts and the cultural organization that the human being is both determined by and actively creating.

Vygotsky and colleagues (1978) analyzes human activity as having three fundamental characteristics; first, it is directed toward a material or ideal object; second, it is mediated by artifacts; and third, it is socially constituted within a culture. Historically, activity theory is an answer to the problem of studying isolated individuals in the laboratory setting. Instead of dealing with the isolated relation between the subject (S) and an object (O), from which the subject is perfectly separated, Vygotsky introduced a mediating X, which is culturally con-

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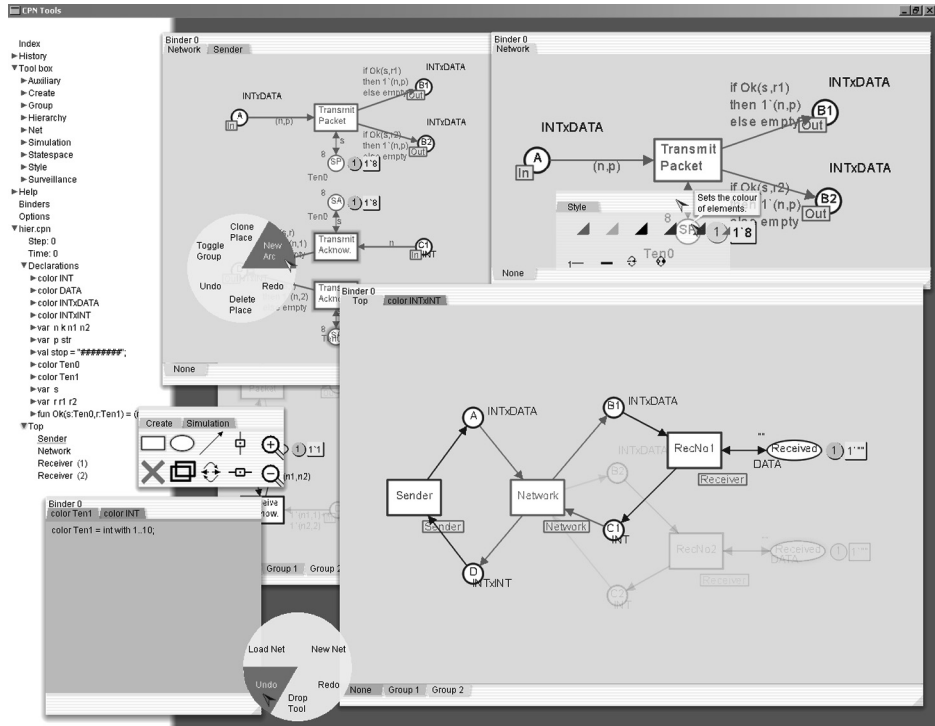


FIGURE 11.1 The redesigned CPN2000 binders, palette and marking menu. (See Plate 10 in the color insert for a color version of this figure.)

technical instruments (tools) or psychological instruments (signs). Psychological instruments like language and concepts are internalized during childhood development, following which it is not possible to experiment with or even to talk about a basic, universal, unmediated, cognitive apparatus; activity theory as such does not exist. Vygotsky distinguishes between meaning and sense in language. Meaning is stable and is what the sign points at or denotes, whereas sense is the fluctuating contents of the sign determined by the use of the sign in practice.

A. N. Leontiev (1978, 1981) was a student and co-worker of Vygotsky who, in the division of labor in Vygotsky’s group, was assigned the task of describing the development of natural history, from one-celled organisms to human beings. Leontiev’s work resulted in a slightly different basic model in the analysis of cognition. In describing this development, the hunt becomes an important laboratory for thought. In natural history, the first important step in the development

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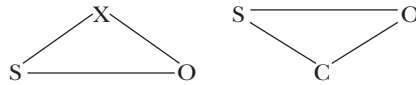


FIGURE
11.2

Triangles of activity. On the left is human activity mediated by artifacts (Vygotsky); on the right socially mediated activity (Leontiev).

from cell to human is when animals start to work together in fulfilling their needs. Thus for Leontiev the basic triangle is not S-X-O, but the pre-human S-C-O where C is community (Fig 11.2). At the level of animals it is possible to identify embryonic forms of mediation of S-O relations in form of *ad hoc* tools, mediation of the S-C relation as emerging rules and rituals, and mediation of the C-O as emerging division of labor, such as in the hunt.

At a point in the phylogenetic history, these embryonic mediations gradually become permanent parts of the systemic structure of human activity. According to Leontiev (1978), human activity can be analyzed into a three-level hierarchy of activity, action, and operation, each of which reflects the objective world. Activity is directed to satisfy a need through a material or ideal object. The subject's reflection of (including expectation to) this object is the motive of the activity. Human activity is carried out through actions, realizing objective results. These actions are governed by the conscious goals of the subject. Goals reflect the objective results of action. Actions are realized through series of operations, each "triggered" by the conditions and structure of the action. They are performed without conscious thinking but are oriented in the world by a nonconscious orienting basis, as described in Table 11.1. (See Bærentsen [1989] and Bærentsen & Trettvik [2002].) Goals that are different from the motive, but still realizing it, are possible only in human activity; in animals, goal and motive are always the same. According to Bærentsen & Trettvik (2002), operations may be cultural-historically developed or naturally evolved and ecologically determined. Accordingly, operations may realize internalized cultural-historical patterns of conduct or inborn species-specific patterns of behavior, and they may result from appropriated use of tools, educated manners toward other human beings, or movements in the physical world according to concrete physical conditions.

The three levels of activity are not fixed (Figure 11.3); an action can become an operation through automation/internalization, and an operation can become an action through conceptualization in breakdown situations (Bødker, 1991). A separately motivated activity in one context can be an operation in another. The focus of activity theory on how human acts transfer between the dif-

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Levels of activity	Mental representation	Realizes	Level of description	Analytical question
Activity	Motive (need)—not necessarily conscious, but may become conscious	Personality	The social and personal meaning of activity; its relation to motives and needs	Why?
Action	Goal—conscious	Activities (systems of actions organized to achieve goals)	Possible goals, critical goals, particularly relevant subgoals	What?
Operation	Condition of actions (structure of activity)—normally not conscious; only limited possibilities of consciousness	Actions (chains of operations organized by goals and concrete conditions)	The concrete way of executing an action in accordance with the specific conditions surrounding the goal.	How?

TABLE 11.1 Activity as hierarchically organized system, showing the relationship among the three levels.

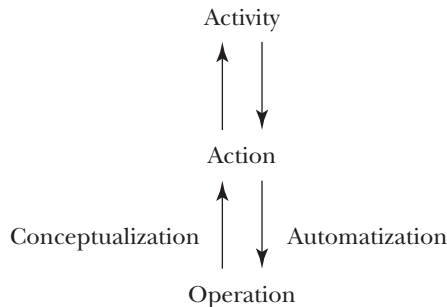


FIGURE 11.3 The dynamic relationship among levels of human activity.

from the mainstream of cognitive theories, for example, Card and colleagues’ (1983) engineering psychology, where acts are classified as belonging to static categories such as time bands. In short, development is a basic feature in the framework of activity theory.

Leontiev’s notion of human activity can be depicted as embedded triangles (Figure 11.4)—the Subject-Object-Community triangle of prehuman activity expanded with societally constituted forms of mediation: instruments, rules, and division of labor (Engeström, 1987). The specific form of the triangular figure is

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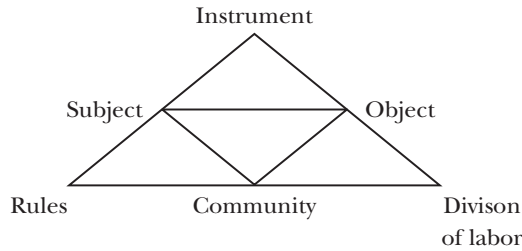


FIGURE 11.4 Leontiev's theory of human activity as depicted by Engeström (1987).

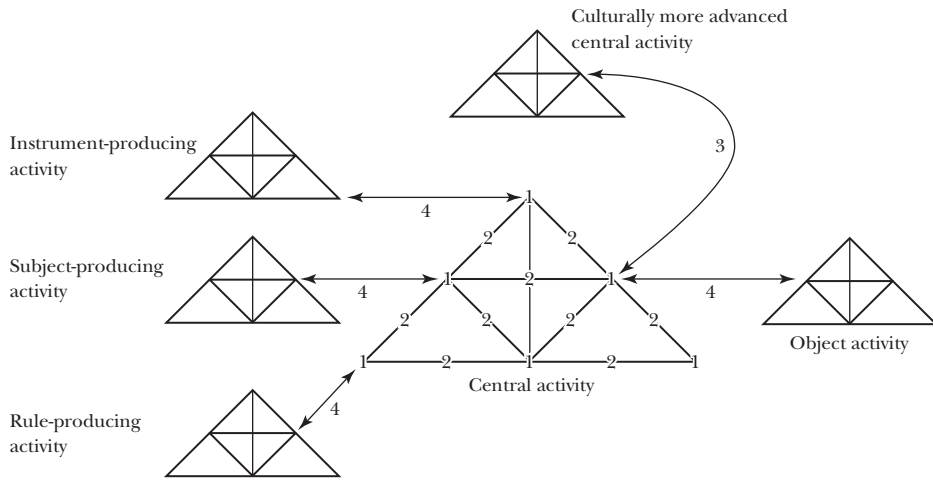


FIGURE 11.5 The relation between activity systems in terms of classes of contradictions. (1 = primary, 2 = secondary, 3 = tertiary, 4 = quaternary)

not very important. The important thing is that activity is an intertwined system; if one corner changes, the system becomes unstable and must develop to obtain renewed stability.

Activity systems are fundamentally marked by contradictions. In dialectical thinking (Hegel, Marx, etc.) dynamics are understood as the eternal resolving of inner antagonist contradictions. Engeström (1987) classifies contradictions within and between activity systems as the driving forces in human learning and development (Fig 11.5). The *primary contradiction* is the contradiction of commodity between use and exchange value. This double nature is a basic feature of

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the capitalist economy, penetrating each corner of the activity system as an eternal source of instability and development. Though an example from CPN2000 may be a bit farfetched, there is, in this project as in any design project, the tension between the best possible solution and what may be designed with the time and resources available. *Secondary contradictions* are between the corners of the activity system—between the students’ understanding of CP nets and assumptions about distributed systems underlying Design/CPN, between documentation standards of the alarm company and flexibility of documenting with CPN2000, between early graphics editors and the need for support for production of CP nets, and so on. *Quaternary contradictions* are contradictions between the activity looked at and the neighboring activities. Examples include contradictions between the institution educating the alarm engineers to become natural scientists and the need for skills in cooperation and decision making in the alarm company, and contradictions between the producers of Design/CPN wanting a conceptually clean tool and engineers needing support for discussion and documentation. *Tertiary contradictions* are contradictions between the considered activity and the activity (existing or nonexisting) it potentially could become. Such tertiary contradictions can be generated deliberately by finding examples and developing visions in the process of developing a community of practice to a new stage. The use of bimanual input in advanced 3D animation environments can be seen as generating a tertiary contradiction in the CPN2000 project.

Activity is constantly developing as a result of contradictions and instability, and as a result of the development of new needs. Activity theory understands human beings as dialectically re-creating their own environment. Subjects are not merely choosing from possibilities in the environment, but they are actively creating the environment through activity.

The historical development of activity implies a development of artifacts and environments. Modes of acting within an activity system are historically crystallized into artifacts; in this sense, the historical development of activity can be read from the development of artifacts mediating the practice, to some degree (Bærentsen, 1989; Bannon and Bødker, 1991).

Artifacts can be characterized as crystallized knowledge, which means that operations that are developed in the use of one generation of technology are later incorporated into the artifact itself in the next (Bannon & Bødker, 1991, p. 243).

Activity is crystallized into artifacts in two ways. First, they are externalizations of operations with earlier artifacts; second, they are representations of modes of acting in the given activity. Artifacts mediating human activity are not

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just more-or-less suitable attachments to human practice; they also constitute activity.

Vygotsky's theory has a strong focus on developmental psychology and pedagogy. In understanding learning and development, the concept of the zone of proximal development is central. Originally it was aimed at changing the focus of developmental psychology (which is, in practice, a foundation for teaching strategies) from already acquired skills to potential skills "waiting" to mature in the individual. Learning is seen as a voyage through the zone of proximal development. Inherent in the concept is an emphasis in activity theory treating potentiality and development as basic aspects of human activity and stating that learning and development are socially mediated. People are understood not in terms of what they are but in terms of what they are becoming.

The concept of *the zone of proximal development* has been widely applied outside the areas of pedagogy and developmental psychology. It is central in Engeström's (1987) framework of expansive learning, as well as in approaches to the design and use of computer artifacts. In such contexts, the zone of proximal development has come to mean the possible future practices, or developmental potentials, spanned out in confronting existing practice with other ways of doing similar things. In other words, development takes place in the meeting of what is in one way or another different from what the learners already are capable of doing.

11.4 DETAILED DESCRIPTION

We outline here a series of key principles of activity theory, formulated with emphasis on HCI.

Activity theory takes motivated activity as its basic, irreducible unit of analysis. This unity implies that human conduct cannot be understood as the mere aggregation of behavioral atoms, and that consciousness is rooted in practical engagement in the world. Computer artifacts are looked at in use and not in isolation. Looking at computer artifacts in use sometimes means focusing on the narrow-use activity and the handling of the computer artifact, typically in HCI studies. In other cases, the context is much wider, such as focusing on the web of activities of use and design. One of the forces of activity theory is, however, that it allows for studies of all these levels of activity to be combined, applying one and the same set of concepts.

In the CPN2000 case, we studied the activity of alarm-protocol design, _____S
 where Design/CPN mediated cooperation between designers and the actual _____R

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validation of a protocol, to mention a couple of the distinct activities identified. In both cases, the CPN tool mediates a designer's work on a CPN. In one instance, the designer's purpose is to capture all the changes to the protocol agreed upon in a meeting; in the other, it is to see if the designed protocol works.

Human activity is mediated by socially produced artifacts, such as tools, language, and representations. This means that, in their immediate relation with their surroundings, human beings extend themselves with artifacts that are both augmentations of and external to the person.

The particular Colored Petri Nets are fundamental artifacts to the group of designers. The Design/CPN supports construction and validation of nets, but the formalism is also independent of the tool and used for such activities as scribbling notes from a meeting.

Activity can be understood as a systemic structure. Activity is object oriented: It is a (possibly collective) subject's active engagement directed toward an object. This engagement is socially mediated by the community in which the activity is embedded or constituted. Changing parts of the systemic structure disturbs the balance or the entire structure.

As illustrated here, designers used Design/CPN in order to build alarm systems. Only some people who were part of this activity used Design/CPN or CPN. Others worked on hardware or management, for example. In this particular case, we do not know if changing the hardware platform or management strategy (e.g., division of work in the project) would have influenced the use of Design/CPN, though we suspect it would.

Activity is realized through conscious actions directed to relevant goals. Actions are realized through unconscious operations triggered by the structure of the activity and conditions in the environment.

In our studies, we have seen how users construct CPNs using the Design/CPN tools to create places, transitions, annotations and so on. The same act can change among the three levels in the course of learning and due to changed condition.

The expert user keeps reformatting the net through operations, whereas the students we studied had their point of focus on the formatting, when they carried this out.

When the guidance for an act is transformed from conscious interaction with external objects into an unconscious internal plan of action, internalization takes place. Externalization takes place when activity with one generation of an artifact is crystallized into the next generation of the same artifact.

CPN2000 is ultimately a crystallization based on the operations, actions, and activities of using Design/CPN.

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Before the existence of CPN tools, the formalism was used by drawing nets by hand or by using general-purpose drawing programs. In such manual construction of nets, the person constructing the net spends time checking the syntax of the net as she draws it. Also different styles in laying out the nets were developed. In Design/CPN as well as in CPN2000, this checking of syntax as well as elements of layout is crystallized into the tool. However, in the redesign from Design/CPN to CPN2000, the introduction of two-handed input is an example of development by design that cannot be understood in terms of crystallization. This is because it transcends the existing ways of working with CPN in an abrupt manner.

11.4.1 Mediation

Computers mediate our daily activities, whether these are in relation to things or other human beings. Activity theory has been concerned with this kind of mediation by a variety of mundane tools (see Kaptelinin, 1996) and by information technology (Bannon & Bødker, 1991; Bannon & Kuutti, 1993; Bertelsen, 1996; Bødker 1991, 1999). Activity theory gives a useful handle for understanding the mediators, and how they are shaped, in a dialectical relationship with the changing practice of use.

Because activity theory takes purposeful acts as the basic unit of analysis, we have to study what happens when users focus on their job (or other purposeful act) while applying the computer artifact. With the hierarchical structure of activity, this means that the routine situation tends to be when the object of the user's (conscious) action is the same as the object of work, whereas the user directs unconscious operations to the mediating artifact. The computer artifact becomes a transparent tool.

In studying the CPN tools, we may identify the activity of the protocol designers as shown in Table 11.2.

In the further analysis of mediation, the next step is to look at the actual objects of focus in this work and the various possible locations of the objects (things or persons), as they are present inside or outside the computer or both. These "real" objects of our activity—our objects of interest (Shneiderman, 1983) or domain objects (Beaudouin-Lafon 1990)—constitute the anchoring of the further analysis. Each location of the object has its own characteristics, with regard to how directly it can be accessed by the user. The syntax shown in Figure 11.6 is used to map the interaction of a particular artifact.

If we look at the CPN example, we see that the actual objects are alarm protocols (Fig. 11.7). The CPNs are examples of objects that exist both outside and

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Why?	Making good alarm systems (and ultimately building and selling alarm systems)
What?	Building and verifying alarm system protocols by constructing CP nets using Design/CPN (various subgoals of this process)
How?	Adding new places and transitions, moving arcs, changing arc curvature, changing markings, pulling down menus, etc.

TABLE 11.2 Applying the analytical questions from Table 11.1 to CPN use.

11.2

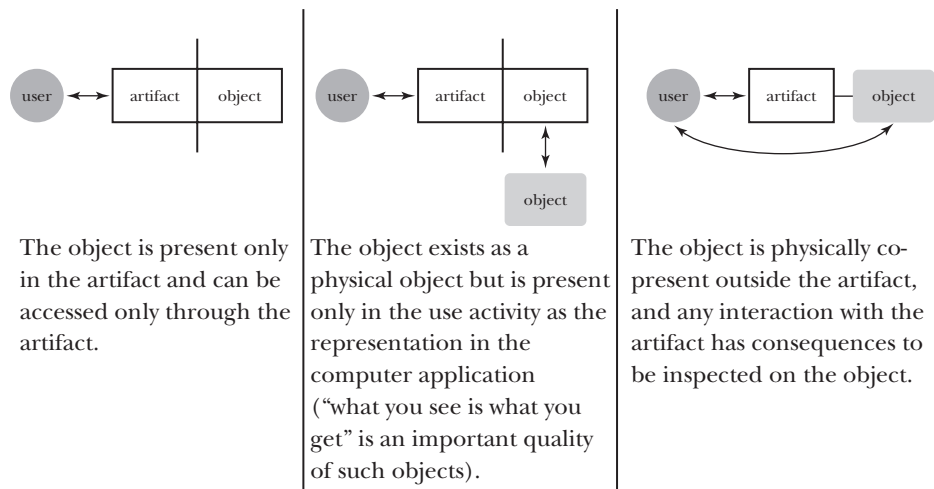


FIGURE 11.6 Objects as they are encountered in or through the artifact—a graphical syntax.

11.6

inside the computer. Printouts are used for discussions and annotations in meetings with the remaining project group, and the changes are later entered into Design/CPN by a protocol designer. Accordingly, these printouts mediate the cooperation in the design group in ways that Design/CPN does not. At the same time, the CPN “in the computer” has numerous capabilities for simulation, and so forth, that the printout does not. In this manner, most computer applications are most appropriately seen as clusters of artifacts rather than singular ones. Beaudouin-Lafon (2000) mention some of these artifacts, namely what they call meta-instruments. Meta-instruments are, in their understanding, instruments to create instruments. In activity theoretical terms, meta-instruments belong

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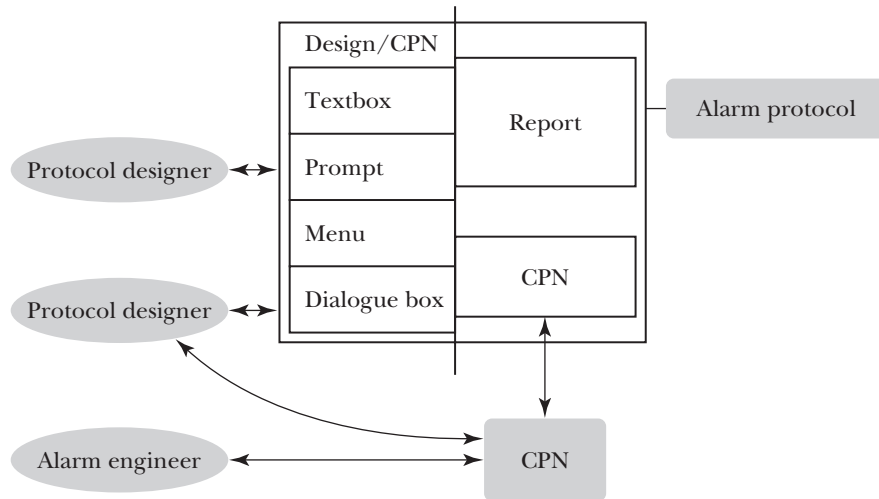


FIGURE
11.7

The ultimate object of Design/CPN is the alarm protocol. While using Design/CPN, other objects are in focus, such as the net (CPN) that exists in the computer as well as a printout, and the simulation report in the computer. Meanwhile, the users focus on many objects (textbox, prompt, etc.) that belong to the handling, as meta-instruments, or because they attract the attention of the users. Some users—the alarm engineers—use only the printed-out net, while others—the protocol designers—interact with the alarm protocol through Design/CPN and perhaps through a printout.

differentiated analytically and designwise when necessary. The instruments created or modified through meta-instruments are, at the same time, examples of objects that are objects exactly while modifying them (but preferably not otherwise), and objects that exist only in the artifact.

We further (Bødker 1991) analyzed the levels of mediation in computer-mediated work as follows:

- ◆ The physical aspects support operations toward the computer application as a physical object. Pushing keys and mouse buttons, as well as movements of pointing devices, are the physical aspects; Mackenzie's (Chapter 3, this volume) discussion of mouse degrees-of-freedom and dimensions are concerns that belong mainly with the physical aspects.
- ◆ The handling aspects support operations toward the computer application. The handling aspects are the conditions that allow the user to focus on the "real" objects and subjects of the activity. A typical example of a concern at

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this level is the scroll bar and how scrolling affects the window on which it has effect.

- ◆ The subject/object-directed aspects constitute the conditions for operations directed toward objects or subjects that we deal with “in” the artifact or through the artifact (see Figure 11.6).

In Design/CPN, the *handling aspects* are about creating places and transitions, adding new places and transitions, moving arcs, changing arc curvature, changing markings, pulling down menus, and so on. The *physical aspects* are related to the use of the mouse to move and place things, and the use of parameters to change curvature. As a matter of fact, changing the physical aspects of the tools was a major concern in CPN2000 and an important reason to choose bimanual interaction. The choice of a different set of physical aspects gave new possibilities for the handling of the CPNs, such as through the two-handed click-through of tool glasses. The *subject/object directed aspects* are about how pieces of nets may be reused in other configurations, for example, and how a hierarchical structuring of complex nets may be carried out.

Computer artifacts not only mediate in a toollike transparent way. A great deal of learning takes place before and during normal use, as will be illustrated in the example in section 11.5.1 where we analyze the use of Design/CPN by novice users.

It is possible to use the questions of why, what, and how to capture important stereotypes of computer artifacts. We use the terms *system*, *tool*, and *media* to capture these stereotypes, as shown in Table 11.3.

A system mediates between the individual contributors of actions and operations and their object. At the same time, the system is the instrument of the acting subject, who is not directly contributing to the production of the outcome. A tool mediates the relationship between the subject and the material object being worked on. And a medium mediates the relationship between the acting subject and the practice surrounding the subject and the activity.

Almost no real-life computer application can be understood in terms of only one of these stereotypes. Accordingly, the stereotypes can be used analytically by tracing and characterizing the use of the artifact in the historical development of use, or in the web of different activities that takes place around the computer artifact. It is particularly interesting to understand the contradictions among the different use activities.

Design/CPN is used by individual users to construct and analyze CPNs. It is intended as a tool mediating this work, although, as we shall see, there are situations where the users do not find themselves in control.

	<i>system</i>	<i>tool</i>	<i>medium</i>
<i>why?</i>	planning/control	material production	communication
<i>what?</i>	data entry + extraction	shaping material	creating and interpreting signs
<i>how?</i>	“low risk” data entry	transparency: good access to material	transparency: undisturbed interpretation

TABLE 11.3 Characteristics of the system, tool, and media perspectives.

11.3

11.4.2 Internalization—Externalization

Activity theory does not assume a fixed separation between mental representations and external representations, as in cognitivist approaches to human cognition. In contrast, the unity of consciousness and activity is taken as a basic feature of human cognition. Cognition cannot be separated from the outward acts in which the individual engages. The principle of internalization and externalization deals with the development of mediation. When learning addition of natural numbers, the child first uses external representations like fingers, pebbles, or an abacus, but gradually these artifacts are internalized and the child is able to perform addition without external props. Externalization, on the other hand, may take place in a situation of a need for repair, such as when the numbers are too large to add by mental arithmetic, in which case an abacus or a piece of paper may be used for external representation. Likewise, externalization is needed when two or more persons work together; speaking aloud or using the abacus are means supporting this type of externalization as well. When internalized acts take place, they enable simulation and rehearsing as well as monitoring of the invisible.

CPN tools are examples of rather massive externalization. Not only are CP nets externalized means for making sense of distributed systems, but making automated simulations is a further externalization of the process of checking the behavior of the system under various conditions.

Considering the three types of use situations—editing a net, modifying a net to do something else, and constructing a net from scratch—the user studies strongly indicated that the three situations required increasing competency. Students had no problems editing nets, whereas modification was harder for them, and creating a net from scratch was very difficult because it also involved

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wrestling with the tool, the formalism, and the idea of modeling a system. In dealing with such complex situations, it is important to have internalized handling of the tool, the CPN formalism, as well as concepts of the domain to be modeled. However, users rarely work from a blank page; more often they modify and change layout of existing nets in a sort of bricolage. Thus, earlier nets are used as externalized experience with making nets.

11.4.3 Computer Artifacts in a Web of Activities

In much activity-theoretical research, the unit of analysis is, in one way or another, a particular work or educational activity, with its community of practice, actors, rules, division of work, and tools. In particular instances, this analysis is expanded to several interlinked activities—be these interlinked historically, in what Engeström (1987) calls activity systems, or in what we call *webs of activity*. When moving the focus from activities to computer artifacts as mediators of activities, we are faced with certain theoretical possibilities. First of all, what allows us to generalize our investigations beyond sheer individual use of technology is practice. By anchoring an analysis in practice, the historically developed ways and means by which groups of people undertake a particular activity, we are able to balance the analysis between the general and the particular. Furthermore, as is often the case with interface design, we need to explore an artifact that is not yet there; the existing practice is a valuable starting point for that, as illustrated by the CPN2000 example (Bødker & Grønbaek, 1996).

Studies of computer artifacts in use need to focus on the narrow-use activity and the handling of the computer artifact, as well as on the wider context of use and design. One of the forces of activity theory is that it allows studies of all these levels of activity to be combined. It allows us to change scale and to study connections on multiple levels of activities where computer artifacts are used and designed, without establishing a permanent hierarchy in the analysis (Bardram, 1998; Raithel, 1992, 1996).

Bødker (1999) summarizes how a computer application may have positions in a variety of activities in the web of design/use activities. As discussed by Engeström (1987), as well as by Mathiassen (1981), it is the tensions or contradictions between these positions that are the source of change. In Engeström's model of work development, he sees contradictions in the activity system as the major driving force of such change: He bases his analysis on contradictions within the activity and between this activity and surrounding activities, because they constitute the basis for learning and change; he looks at contradictions in

how tools, objects, and subjects are seen. An interesting contradiction that we shall return to is whether the CPN tool always works on a valid CPN or whether it is all right to work on sketches that are incomplete.

Engeström suggests studying contradictions between, for example, the tools currently used and the object created, or the norms that are part of practice and the division of work. Looking at things from the point of view of the artifact, which is shaped and used in several different activities, makes it very difficult to identify and delimit the activity system that is of interest for the analysis. This would potentially include all use activities, all teaching and artifact production activities, as well as ideals for the change of all of the use activities. Despite this, *awareness toward contradictions is an important component in our analysis.*

The CPN2000 case identified two distinctly different use activities—that of alarm-protocol design, and that of learning about distributed systems. As indicated by the example analyses that we present here, the difference between these two transcends all levels of use, including the handling of the CPN tool. Furthermore, the analysis indicates that Design/CPN has many users who do not understand CPN well enough to design a CPN from scratch, whereas they are able to make changes and adjustments to nets created by others.

As indicated by the example, activity theory allows for a focus of attention to technical solutions that crosses boundaries between activities, or supports several coexisting activities simultaneously (Engeström & Escalante, 1996). Heterogeneity as a conceptual frame of analysis has come out of actor-network theory. In the context of human-computer interaction, heterogeneity has been emphasized not least in the work by Star (1996). However, it is also profoundly embedded in many studies of webs of activities. One early example is Engeström & Engeström's (1989) joint work with doctor-patient construction of a patient diagnosis, where they point to the profoundly different understandings and models that the two persons carry of the particular disease. Another example is Bødker & Grønbaek's (1996) analysis of cooperative prototyping. The focus on heterogeneity points to the profoundly different conditions that various groups (and individuals) have for participating in activities of design and use of information technology.

11.4.4 Development

The most distinct feature of activity theory, when compared to other materialist accounts in computer science, is the emphasis on development. Because human activity is historically constituted and constantly developing, human use

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of technology cannot be meaningfully understood in terms of stable entities. Rather than labeling levels of consciousness, activity theory offers concepts like automation, conceptualization, internalization, and externalization as handles for understanding the dynamics between levels of the hierarchical structure of activity and of computer use (Bannon & Kuutti, 1993).

Activity-theoretical analyses have served as a basis for studying how people operationalize their use of artifacts of various sorts. Bærentsen's (1989) analysis of the development of hand weapons goes beyond that in presenting an analysis of the historical development of hand weapons interlinked with the development of their use as well as their context in terms of conditions of use. Existing practice is historically shaped, and activity-theoretical analyses help create links between the past, the present, and the future, which are important for the design of interaction artifacts. Bertelsen (1996) has analyzed how practice is crystallized and transformed in the case of a checklist used in planning a music festival. Bødker (1993) used the tool, systems, and media metaphor to characterize different stages in the development of a particular computer artifact. This makes it possible to focus on how the purpose of the use of the artifact changes along with changes in actual objects and in ways of handling the artifact (why, what, and how).

Engeström's seminal work (1987) points to activity theory as a basis for development of work as such, and it points to a number of instruments for this that make sure that we look to the past as well as to the future throughout the design process. As regards the specific design of computer artifacts, these instruments have been crystallized and developed in

- ◆ User interface styles
- ◆ Theory-informed checklists
- ◆ Extreme (plus/minus) scenarios (Bødker, Christiansen, & Thüring, 1995; Bødker, Graves Petersen, & Nielsen, 2000).

Bardram & Bertelsen (1995) used the concept of the zone of proximal development in the context of developing transparent interaction. At first sight, this appears to contradict the concept, as there does not seem to be any social mediation going on in the one man–one computer situation. However, computer artifacts are not only tools mediating users' relations to their object of work; they are, at the same time, media mediating the relation between designers or culture and users. Computer artifacts are social mediation in the same sense as books, and accordingly the designer leaves traces that help her to be present as a more capable peer, guiding the user through the zone of proximal development.

Design—Use

As illustrated by Gasser (1986) and Bødker (1999), the use of rather rigid computer applications develops beyond pure adaptation by the users; as such, the computer application (even when built) is a source of changing practice. From this perspective, design never seems to stop (Floyd, 1987).

The interlinking between design and use, however, goes further than that. The design activity is constrained by the computer in various ways, through the actual, available materials as such, and through the past experiences of designers and users (Bødker, et al., 1987). The introduction of two-handed interaction in CPN2000 depended on the availability of trackballs for PCs, and it gave rise to many concerns regarding how one could support two-handed interaction as well as alternative and more traditional one mouse—one hand interaction. The choice of two input devices opened up a new design space because it made it possible for designers to focus on new possibilities, such as tool glasses. The iterative design process set up for CPN2000 aimed to make active use of experiences from use in the continued design. Hence, experimental use of prototypes by experienced CPN designers was introduced to inform the iterative design process.

Designers and users are, in general, parties in a number of interlinked and partly overlapping activities that we need to understand in order to make better design, and ultimately to create better computer artifacts. In these multi-practical design situations, the experiences, resources, tools, and so forth, of designers meet and sometimes clash with those of the users and others involved. The CPN2000 project involved a number of designers and implementers of different backgrounds—some with primary experience in and concern for the programming tools, some with a background in Petri Nets, and some with an interest in advanced interface design. The PN people were also designers and users of the old tool, whereas most of the rest of the group had no or little experience with Design/CPN. This introduced many conflicting interests into the process. These differences, however, in the end added to the creative design that resulted. But it was indeed necessary to create a process where these conflicts were elaborated and turned around to something positive through such springboards as scenarios from use and through video prototypes (Mackay, 2002). In Bertelsen & Bødker (2002), we have discussed such differences in terms of general discontinuities in design and pointed out that it is vitally important for innovation and dynamics of design to mediate and explicate the discontinuities rather than to eliminate them. In the CPN2000 project, the divergent perspectives enabled the group as a whole to go beyond established conceptions of what tool support for CP nets could be.

Summary—A checklist for situating computer applications in use

To situate the computer application in use, one should

- ◆ situate work and computer application historically,
- ◆ situate the computer application in a web of activities where it is used,
- ◆ characterize the use according to the stereotypes of systems, tools and media,
- ◆ consider the support needed for the various activities going on around the computer application, and the historical circumstances of the computer application,
- ◆ identify the objects worked on, in or through the computer application,
- ◆ consider the web of activities and the contradictions in and between activities.

FIGURE 11.8 Situating the computer application in use.

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11.4.5 Activity Theory in Practical Design and Evaluation

Bødker (1996) summarizes how to make an analysis situating a computer application in use, followed by a focus shift analysis of an actual use activity. This summary is outlined in Figure 11.8. Though these analyses are outlined as having a certain order among them, the analyses have really been taking place in interaction and iteration.

A similar kind of checklist can be found in Korpela, et al. (2000), as shown in Figure 11.9.

Yet another similar example, however based in abstract considerations, is the activity checklist (Kaptelinin, Nardi, & Macaulay, 1999), which is based on the formulation of the five basic principles of activity theory: object-orientedness, hierarchical structure of activity, internalization and externalization, mediation, and development. Mediation is “folded in” with each of the other four principles, resulting in the four categories of concerns: means/ends, environment, learning/cognition/articulation, and development. For each category, a series of questions are asked with the purpose of understanding the use-context that the artifact is intended to support. The main problem with respect to that list is

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The checklist included the following questions to identify the main constituents of the central activity:

- ◆ 1a. **Outcome:** What services or products do we produce?
- ◆ 2a. **Object and process:** What raw materials or prerequisites do we start from? How do we produce the services or products from the inputs we have?
- ◆ 3a. **Instruments:** What kinds of physical tools and knowledge, skills etc. do we need for this work?
- ◆ 4a. **Subjects:** Who are we—what different kinds of people are needed to produce these services or products?
- ◆ 5a. **Social relations and means:** When we work to produce the services or products, what kinds of rules, division of labour, communication etc. apply between us?

The following questions were included to identify the network of activities:

- ◆ 1b. **Outcome:** Who needs our services or products? For what do they need that—to produce some services or products to some others?
- ◆ 2b. **Object:** From whom do we get our “raw materials”? How do they produce what we need?
- ◆ 3b. **Instruments:** From whom do we get the tools and knowledge we need? How do they produce that?
- ◆ 4b. **Subjects:** Where do we come from—who educates and raises the kinds of people needed here? How does that happen?
- ◆ 5b. **Social relations and means:** Who sets the rules for us? How are the rules generated?

FIGURE 11.9 Situating the computer application, part 2.

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that it leaves out concerns for contradictions, thus disabling the theoretical framework’s analytical power.

11.5 CASE STUDY

According to Engeström (1987), activity theory does not offer ready-made techniques and procedures for research, rather its conceptual tools must be

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Summary—A checklist for HCI analysis through focus shifts

For each specific focus, ask:

- ◆ what is the purpose of the activity/actions for the user?
- ◆ which object, is focused upon by the user? where is this object located (in, through, or outside the computer application)
- ◆ what is the instrument? where is it located (in, through, or outside the computer application)

When more users are co-operating, ask:

- ◆ are the purposes, objects and instruments in accordance or conflicting (between the individuals, as well between the group and individuals)?

For each focus shift, ask:

- ◆ from what focus/object to what?
- ◆ breakdown or deliberate shift?
- ◆ what causes the shift? in particular whether it is the physical, handling or subject/object directed aspects of the computer application that is involved.

FIGURE 11.10 HCI analysis through focus shifts.

11.10

concretized according to the specific nature of the object under scrutiny. However, we do see several crystallized techniques emerge, such as the checklists shown in Figures 11.8 and 11.9 and the focus-shift analysis that follows. The second example in this section is concerned with the design implications of activity theory-based concepts.

11.5.1 Focus and Focus Shifts

The objects of work identify the points of focus from which the analysis starts. The focus shifts that indicate the dynamics of the situation are, however, the main points of concern in the analysis. This is summarized in Figure 11.10.

In making this analysis, we apply a mapping technique that creates an overview of the answers to these questions. This will be illustrated through the later example from our analysis of Design/CPN, and we start by summarizing the situation and artifact:

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Mary and Sue are students of computer science, using the Design/CPN tool for the first time after seeing it demonstrated in a lecture. They are generally well acquainted with the Unix environment, opening and closing windows, menus, and so on. They take a class in distributed systems, in which CPN is used for analysis and verification.

They have particular assignments to do in order to explore the tool. The teacher who has designed the assignments is well acquainted with the tool.

The objects that they focus on are primarily the CPNs, though these are parts of something wider—learning about distributed systems, doing exercises, or, as in industrial settings, modeling network protocols so as to analyze them.

They sit next to each other, each doing the assignments on a computer. The camera is on Mary and the computer screen she works on. The camera-person also acts as interviewer, but has no knowledge of the tool and cannot give advice.

The timer on the camera shows 14.50 when this example starts. The actual events last for about 30 seconds.

By carefully reviewing the tape, we see that it contains nine focus points and eight focus shifts. The focus points are identified through looking at the actions on the screen and identifying what gets talked about.

Three objects of focus are concerned with the actual activity and accordingly supported by the subject/object directed aspect of Design/CPN: the exercise, the Petri Net, and a report that is generated as part of the exercise. The user shifts between focuses of solving the problem outlined in the exercise, creating the net, and creating a report as part of the exercise. Of these objects, only the exercise is outside Design/CPN because it lives on a sheet of paper. The remaining objects are inside the Design/CPN. In the remaining four categories of focus points, the Design/CPN tool imposes itself on the user, and accordingly they are, more or less sufficiently, supported by the handling aspects of Design/CPN. The four focus points are: a textbox, a menu, a dialogue box, and a prompt. In actual fact, we are dealing with more than one menu, more than one prompt, and so on.

The exercise sheet is the only object accessible through tools other than the computer application; that is, it can be written on with a pen.

In the analysis, we use a form where the objects of focus are outlined in one dimension, and a time/progression of the interaction is outlined in the other. In this dimension, we also place the transcript of the conversation taking place and the screen images used to identify foci. An asterisk * is used to indicate the point of focus, and the trace left by the series of asterisks is accordingly a trace of focus shifts—as shown in Figure 11.11.

The immediate observations that we make from this analysis are that novices _____S
 in this type of training situation have much of their focus on the tool. This is not _____R
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		Subject/object directed aspects			Handling aspects			
Transcript	Picture	exercise	Petri net	report	text box	menu	dialogue box	prompt
(14.50.00)	S14							
M: It says that I have to make a textbox, that's what I'm trying to do so that I can see the report S: I did (. . .), that's what he said in the lecture								
	S15							
M: why doesn't it show up?								
	S16							
	S17							
S: it is gigantic M: well, if I can close it, I should be able to . . .								
	S18							
(14.50.37)	S19							

FIGURE 11.11 Tracing focus shifts.

surprising. What is more surprising is that they have severe difficulties orienting and remembering where functions are located in the many long menus. As shown in Figure 11.12, things pop up as very large windows on top of others, adding to the problem of orientation. Error boxes and other elements pop up S on top of nets, disturbing the focus on the net. Some elements of the nets, such R as arcs, are, however, small and difficult to grasp, move, and annotate. L

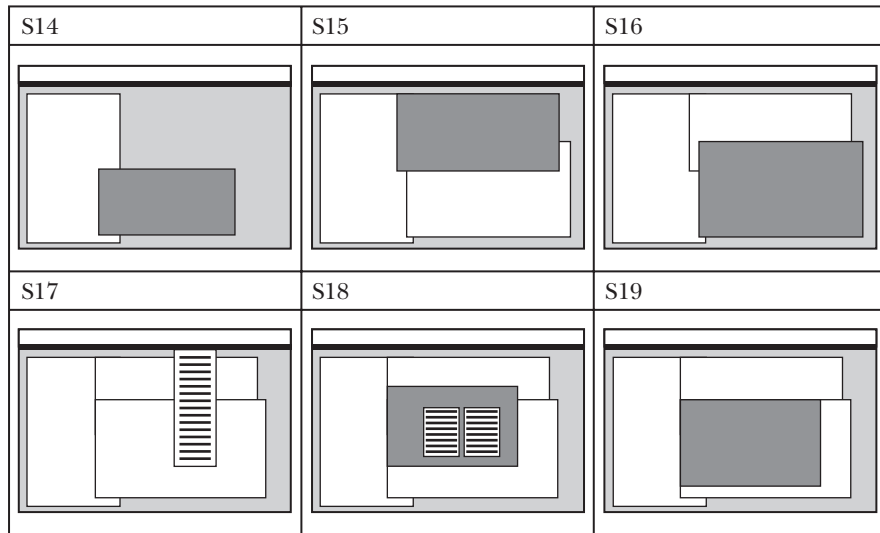


FIGURE
11.12

Sketches illustrating which window or menu the user focuses on. The numbers refer to the transcript in Figure 11.11. The shaded window indicates which window or menu is in focus of use.

11.5.2 The Concept of Artifacts in Use as a Tool in the Redesign of the CPN Tool

Many ways of bringing activity theory to design have not yet crystallized into formalized techniques or methodical prescriptions. Thus, the influence of activity theory often seems indirect, taking effect only through the way designers understand the situation at hand. An example of this “application” of activity theory in the CPN2000 project is the influence of the concept of artifacts in user in the initial discussions in the CPN2000 HCI group.

A concern early in the design process was to determine what the basic data structure for the tool should be. This was important because the basic data structure would be determining the overall architecture of the tool. The textbook definition of a CP net states that it is a “bipartite graph with places and transitions. . . .” Thus, the obvious and consistent solution would be to have representations of nets according to the formal definition as the basic data structure in the tool. This was the approach taken in the old tool as well. The formal, presentation-independent net was the basis for the editor as well as the validator and simulator.

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In a historical perspective, the tools used in working with CP nets have developed from pen and paper through general-purpose graphics editors (only supporting presentation of the nets) to tools like DesignCPN directly based on the formal semantics and syntax of the nets, enabling automatic verification and so forth. Whereas this development is an obvious advantage for construction of nets, it is also striking that the need for additional data structures in the tool related to the presentation of nets became a source of inconsistency.

This dilemma between basic data structures based on formal definitions and practical use of the tool was not new. In syntax-directed source-code editors, it is a well-known problem that editing tools cannot determine which parts of the syntactical structure that comments belong to, thus marginalizing the use of comments and jeopardizing the maintainability of the code. Similarly, in an earlier study an object-oriented source code debugger (Bertelsen & Bødker, 1998), we observed a discrepancy between the strictly object-oriented principles that the tool was built on and the programming practice that the tool was intended to support. The general emphasis in activity theory on understanding artifacts in use, rather than in isolation, in this case becomes operational in the analysis, through the concept of the debugger-in-use (not as container for principles).

The concept of Petri-nets-in-use was formative in setting up the user studies. The focus was not only on how the existing tool was used and what limitations it had. Focus was as much on understanding the kind of work the tools and the CP nets were going to support. In addition, the concept of Petri-nets-in-use was a possible handle for transforming studies of use into considerations for the system architecture.

Focusing on CP nets in use implies that not only is the CPN tool seen as a means for working with the nets *per se*, but that the nets are seen as means for doing something else purposefully. In this respect, a CP net is not only a well-defined formal description of some phenomena, but it is also a means for communicating design ideas, for documentation, and so on. Thus, the layout of nets became a first-order aspect in the concept of Petri nets in use. In the CPN2000 tools, this is reflected, for example, in the use of tool glasses for reapplying the styling of one part of a net to other parts of the net.

The concern for artifacts in use moves the focus of HCI from being mainly at the interface, to the whole work arrangement, as well as inward to concerns for system functionality and system architecture.

11.5.3 The User Interface

As mentioned earlier, Beaudouin-Lafon (2000) has developed an interaction model for CPN2000 and for computer applications in general. In line with the

framework of activity theory, his idea is to understand user-interface elements such as scroll bars and windows as mediators/artifacts, and hence to view the entire user interface as a cluster of artifacts where interaction with domain objects, as well as with the artifacts themselves through meta-instruments, take place.

He develops ways of describing the relationships among the physical, the handling, and the subject/object-directed aspects of the interface through the following:

- ◆ The degree of indirectness—the temporal and spatial distance between the object on the screen and the instrument that operates on it.
- ◆ The degree of integration—the relationship between the degrees-of-freedom of the physical pointing device and the logical device (e.g., scroll-bar) on which it operates.
- ◆ And the degree of compatibility—the relationship between the movement of the physical device and the domain object; for example, the relationship between the direction of the mouse and the direction of the object when dragging an object.

This model is used to characterize and compare standard interface components, and to discuss the notion of direct manipulation in general. It strongly supports the idea, in activity-theoretical HCI, that mediation is essential rather than directness as such, and it points to a number of ways in which user interfaces may be designed to mediate better.

11.6 CURRENT STATUS

In her collection of papers regarding the application of activity theory to human-computer interaction, Nardi (1996) suggests that activity theory is a powerful descriptive tool rather than a predictive theory. It offers a set of perspectives on human activity and a set of concepts describing this. In this chapter, we have explained the descriptive concepts of activity theory, but we have also presented a number of concrete techniques used to focus on computer-mediated activity, more commonly known as HCI.

A recent issue of *Scandinavian Journal of Information Systems* (volume 12, 2000) presents a series of studies of activity-theoretical HCI as well as of the wider activity of use, such as the changing character of work influenced by information technology, distribution of activities, and the emergence of interorganizational communities. Not least does the volume deal with design of these technologies

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so as to accommodate for use in the narrow as well as in the wide. As with the rest of HCI, activity-theoretical HCI must be concerned with wider activities because of the changing application of computer technology in society in general and in work in particular. As an example of this, the use and design of one piece of software running on one hardware platform rarely takes place in isolation. People switch between many computer applications, running on many pieces of hardware, including handhelds and electronic whiteboards. As a consequence, Nielsen & Søndergaard (2000) explore webs-of-technologies to be considered in use and in design. These webs-of-technologies, together with the webs-of-activities, make us focus on contradictory demands and needs, and make us see these contradictions as important driving forces of change.

HCI is increasingly becoming an interdisciplinary science. Engeström & Miettinen (1999) map out the relationships of activity theory to most recent theoretical trends in the social sciences, including pragmatism, symbolic interactionism, actor-network theory, Wittgensteinian approaches, situated learning, and semiotics. It is largely these same theories that have found their way into HCI. Nardi (1996) as well as Plowman and colleagues (1995) combine activity theory and ethnomethodology. Star (1996) has worked to combine symbolic interactionism and activity theory in CSCW and in information systems design, and Engeström & Escalante (1996) have combined activity theory and actor-network theory in their study of design and use of a public-information system. Activity theory has become a theoretical tool for ethnographical studies (e.g., Nardi, 1996; Spasser, 2000), for participatory design (Beguin & Rabardel, 2000; Bødker & Grønbaek, 1996; Bødker & Petersen, 2000; Timpka & Sjöberg, 1994), as well as for psychological approaches (Bærentsen, 2000; Greif, 1991).

Activity theory has served well to inform analyses of computer artifacts in use, in particular in work. A wide array of methods and tools support this perspective, from historical analyses and ethnographical studies to schemes for focus-shift analyses. Similarly, activity theory is getting a foothold for understanding design activities, structurally and processually (Bødker 1999; Koistinen, & Kangajosa 1997; Korpela, 1994). The change-oriented perspective on computer applications in use implies direct demands on how we do design, so as to accommodate further change. And it needs to address further the technical constitution of the artifact. Bertelsen (1997, 1998) has started to address issues of why object-oriented technology seems appropriate for an activity theoretically inspired design process. It seems to be one of the really big challenges for an activity theory-informed design—how far one may actually be able to go? How close to technology? How design oriented?

The Finnish developmental work-research tradition (Engeström, et al., 1996) offers, for the time being, the most complete methodological approach to

activity-theoretical work analyses and design, emphasizing the continuous development of work. In the developmental-work tradition, computer artifacts may be one instrument of such development, as described by Helle (2000). However, Helle's paper is in a sense an exception within a tradition where very few examples, thus far, have addressed the issues of IT in use and design. This forces practitioners such as Korpela and colleagues (2000) to seek their own approaches based on the theoretical frame of developmental work research.

Two interesting issues in activity theory-based HCI approaches to study in the future is the crystallization of activity theory-based design instruments, like the activity checklist and the focus shift analysis, and the development of technical concepts based on activity theory. For the latter concern, we have seen that the concept of artifacts in use is leading to considerations of basic system architecture and data formats.

11.7 FURTHER READING

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