# Networked Computers' Incorporated Role in Collaborative Learning

Annita Fjuk, Ole Smørdal

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Annita Fjuk* and Ole Smørdal**
*Telenor R & D/INTERMEDIA, University of Oslo
**Department of Informatics/INTERMEDIA, University of Oslo

**Abstract**
Networked computers are increasingly being used in collaborative learning. To understand what roles networked computers have in collaborative learning over distances, systems developers need conceptual frameworks that address the triadic complexity of knowledge construction, social interaction and technical issues. Some theoretical accounts of this relationship exits, but in terms of usefulness for systems design and how the role of networked is regarded, they have shortcomings. Based on activity theory, this paper presents a conceptual framework for understanding computer applications as incorporated into collaborative learning. This is operationalised by focusing on the applications as mediators for reflection and thought as well as for the social exchange processes and the learners' role-taking process.

**Keywords:** Activity theory, conceptual frameworks, collaborative learning, networked computers.

## 1. Introduction

The rapid development and expansion of networked computers and corresponding applications have had a strong influence on the tools and methods of CSCL. Networked computers facilitate distributed learning, i.e., learning situations where the distance is not only distance in space or time as in traditional distance education (Holmberg 1995), but includes the mediation of learning activities by a constellation of various tools (such as traditional internet services, Web-based groupware, multimedia shared spaces, videoconferencing technology, combined with text processing programs, drawing and painting programs, spreadsheet applications) with appropriate pedagogical approaches to collaboration and social interactions. These tools have become much more than value neutral instruments supporting individual actions. They shape the goals and courses of actions, increasingly taken place in collaboratively based learning environments free from time and place constraints.

These new learning environments cause a situation in which thought and meaning are articulated by the personal tools of the individuals. The core argument throughout this paper is that a computer-based instrument (together with other mediating instruments like e.g., paper and pencils) should ideally mediate the web of human actions, without hampering the alternation between them. Schmidt (1994) illustrates this point in the following way:

*"(...) the user should not be required to shift to a special editor and leave the world processor normally used for composing letter, writing report, etc. The same applies to CSCW facilities supporting cooperative authoring, conferencing, etc. " (Schmidt 1994, p. 68)*

If this is not the case, the operational conditions of the personal tools may hamper the mediation of individual and collective actions taking place in the collaborative environment.

Several researchers place emphasis on an understanding of collaboration for the purpose of systems designs (e.g., Schmidt & Bannon 1992, Pea 1996). This emphasis is based on theories and practice related to rather conventional ways of collaborating and interacting, i.e., situations that assume co-presence of collaborating actors. This is not sufficient for providing insights into design of CSCL applications. Rather, we argue, distributed collaborative learning must be understood in terms of its own conditions, and hence in terms of the interdependencies and possible contradictions between technological and non-technological aspects.

There are some theoretical frameworks that can offer particular insights into this. Actor-network theory (Latour 1991) explores the roles of human and non-human elements as equals in an interactional network. Hanseth (1996) uses this theory to analyse information infrastructure development and use practices. Interactionist theory of action (Strauss 1993), originated as a critical approach to the main line sociological literature, offers a rich understanding of the structural conditions of technology (among other factors) to actions embedded in collaboratively based learning arrangements. Fitzpatrick et. al. (1995) use this theory as a bridging link between the social and the technical to provide insights into how to design computer systems. An activity-oriented approach of psychology, widely known as activity theory (Vygotsky 1978; Leontjev 1983; Engeström 1987), offers a rich understanding of socially based human development in which artefacts have an essential meaning to actions. Kuutti (1994) uses the theory to classify the types of work supported by information technology.

## 2. An activity theoretical account of incorporation

Quality with respect to distributed collaborative learning, we argue, is facilitated by *incorporating* good didactical principles with technological advances, into a new practice resting on *its own conditions*. If a computer application hampers the web of human actions, the level of incorporation is low and thus quality. Activity theory is a powerful framework for considering this core issue of our work. In what follows, we outline the principles that we find useful regarding this issue.

Vygotsky (1978) recognised the inseparable aspects of human development and the societal dimension of the educative process. He sought to define those aspects of social engagement that concern the development of mental processing. A key issue of his research was that internalisation is social by its very nature, and that intellectual development takes place on two levels. First it appears on a social level, through interpersonal processes. Then it appears on an individual level through intrapersonal processes. Mental processes and human development are derived from actions performed by a person in cooperation with others. These range of actions compromise the so-called zone of proximal development.

A basic feature of an activity-oriented approach is the principle of mediation. Human activity is always mediated by a number of instruments, both external (such as hammers, computers, etc) and internal (such as language, concepts, etc.). Herein, are the goal-oriented actions that are characterized as by having a communicative as well as an operational aspect (Christiansen 1990).

### 2.1. The hierarchical structure of activity

Leontjev (1983) developed a hierarchical structure of activity, with inner dynamics, transformations and its own development. The driving force behind activity, action and operation is different, as can be seen in figure 1:

*Figure 1. The internal side of an activity, along with corresponding driving forces).*

An activity is realized through goal-oriented processes, termed actions. An action can realize different activities as the given action may fulfil different motives. Before an action is performed, it is planned consciously. Actions are realized through operations that face conditions in the external world. Operations are typically initiated unconsciously—often even the collection of operations that accomplish the action is selected without explicit decision. The 'automatic' choice and routinesed performance are possible only for a knowledgeable and experienced person (subject). But once acquired, this ability appears as a competence for situated action. Human development is thus a process moving actions to operations, and operations into actions (e.g., instances of breakdowns). As the degree of routinisation increases, the action is moving towards operation.

According to Leontjev (1983), actions are usually polymotivated; two or more activities can temporarily merge, motivating the same action.

### 2.2. Instrument-mediated action

Central to Vygotsky's activity-oriented approach is the instrument-mediated action, and which enrich the issue of integrating networked computers and human action. Any instrument can be understood only within the context of human activity by identifying the ways people use the instrument, the needs it serves and the history of its development (Kaptelinin 1996a). Vygotsky distinguished between two interrelated types of instruments: tools and signs. According to Vygotsky, the function of a tool

*"(...) is to serve as the conductor of human influence on the object of activity; it is external oriented; it must lead to changes in objects." (Vygotsky 1978, p. 55).*

Examples of tools are text-processing programs, drawing and painting programs, paper and pencil, description techniques, etc. The signs have a different character and are means of thought, and reflective and conscious actions. A sign

*"(...) is a means of internal activity aimed at mastering oneself; the sign is internally oriented." (Vygotsky 1978, p. 55).*

Examples of signs are language, writing, drawings, schemes, diagrams, all sets of conventional signs, etc. The essence of signs is that they are basic instruments for intrapersonal processes that necessarily have a communicative form. However, it is the internalisation of social dialogues into an inner dialogue that allows one to plan and monitor cognitive progress and further actions in interpersonal and communicative processes. The communicative aspect of an action is the way knowledge is constructed about the phenomenon of question, while the operational aspect of the same action is

mediated by the chosen tools (e.g., paper and pencil). The outcome of the action is framed by the embedded conditions of the tools.

All signs reflect the tools and aid available for use in carrying out action. Following the instrument-mediation perspective of human activity, we can point out two interrelated roles of a computer-based instrument:

- The mediator of the communicative aspect of action (sign)
- The mediator of the operational aspect of action (tool).

To develop computer-based instruments mediating actions within activity, we argue that systems design has to be aimed at understanding the communicative aspect of action (the sign-part) in order to offer good solutions for the operational aspect.

### 2.3. Operationalising collective aspects

Although activity theory almost exclusively has dealt with individuals, approaches have been developed to expand and operationalise the concept of activity to socially organized arrangements. The concept of collective subject has been introduced to account collaboration amongst individuals, dealing with a joint activity. The collective subject can then be considered as a 'total subject' of the joint activity, and

*"the interrelations with the individual subjects can be comprehended through a psychological analysis of the joint activity" (A. A. Leontjev, cited in Engeström 1987, p. 70).*

Such an interpretation may be problematic if the various subjects have different motives for their actions, but also with respect to analysing inter-personal processes (such as negotiation of meaning, development of shared understanding, joint production, etc.)

An essential problem with Leontjev's general structure of activity is that the instrumental and communicative aspect of activity was not brought into a unified model (Engeström 1987). These features have certain importance to the topic of incorporating networked computers into the total arc of collaboratively based learning environments. Engeström (1987) has taken these features into consideration, and as such we will apply Engeström's interpretation as a theoretical foundation for understanding the problem area.

Engeström's interpretation has been widely adopted in the computer-science field. Bødker (1991), who introduced activity theory to the HCI-field, uses Engeström's interpretation to study computer-based instruments in use. Bellamy (1996) uses the interpretation as a framework to study the relationship between technology and educational change. And finally, Kuutti (1994)—who introduced activity theory to the CSCW community—applies the structure of activity to classify the types of (cooperative) work supported by information technology. Kuutti (1994) recognizes the incorporated role of the computer. He is rather engaged in considering the different aspects of cooperative work separately, and to identify the capabilities of computer applications to support pre-defined aspects of collaborative arrangements.

### Development of meaning, exchange processes and role-taking processes

The objective of Engeström's systemic model is to consider the socially based nature of human activity by including rules of communication and division of labour. In agreement with the model, we introduce three aspects that together constitute a useful basis for understanding the nature of distributed collaborative learning. The interconnected aspects are: Development of meaning and knowledge construction, exchange processes and role-taking processes. These aspects are illustrated in figure 1. The upper triangle of the model illustrates Leontjev's basic interpretation of human activity, and concerns the individual learner's actions directed towards knowledge construction and thought, - mediated by a constellation of instruments.

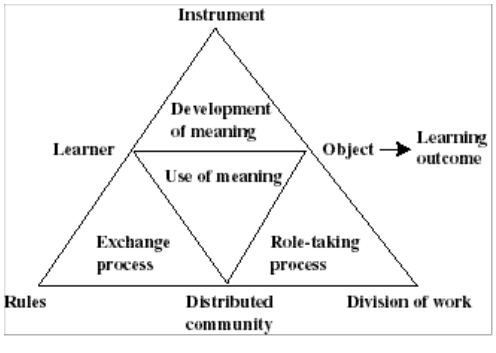

*Figure 1. The aspects of collective activity*

The model shows that a learner is not isolated but is a part of a distributed learning community, represented by the aspects of exchange and role-taking processes. The exchange processes concern the learner's actions directed towards the shared learning community, -mediated by the embedded rules of that community (laws, traditions, physical distances, etc.). The role-taking processes concern mediation of actions directed towards the shared community's division of tasks and responsibility. The last aspect, *use of meaning*, concerns the *situated use* of achieved knowledge. This aspect advocates at least two interconnected issues: First, the lasting changes where the learner's solo-capabilities are improved through a community of practice. Second, the constellation of instruments needs to be studied in use, with a focus on their role as mediators. Many computer applications are generic, and their use is shaped very differently by different communities of practice.

**2.4. The problem of computer-mediated collective action**

In order to analyse the incorporated nature of networked computers and actions, we find some problems by applying Engeström's model as an analytical approach: The first problem is connected to a weak recognition of the dynamic structure of activity presented by Leontjev (1983). Leontjev's structure is to some extent presented through the concept of inner contradictions. An activity itself is not only mediated by, but also develops rules, instruments and division of labour. However, the processes by which a community of individuals articulates actions and operations, and handle and develop them in the face of situated actions and contingencies, are not clearly elaborated. The evolution of collaboratively based arrangements involves actions to negotiate on perspectives and beliefs, and to handle contingencies and situated actions.

The second problem is related to the instrument-mediation, that is, to the duality between sign and tool. Collaborativecommunities are created and maintained by activities conducted through actions of individuals. As such, the duality of sign- and tool-mediation has to be present in the aspect of `Development of meaning`. However, the model is exclusively focusing on this particular duality. The aspects of 'Rules' and 'Division of work` may be viewed as structures of the communicative aspect of action. To guide systems design, the duality of sign- and tool has also to be considered with respect to the two collective aspects of human activity. Let us for a moment use asynchronous text-based e-mail systems as examples to illustrate this: These systems are well known for being obstacles for negotiations and consensus seeking. The lack of immediate feedback, the written communication style and the dominating non-verbal situations, make these types of actions both time-consuming and problematic to fulfil especially when deadlines are near. The role of an e-mail system is thus not limited to transmission of operational aspects of communication. The e-mail system also shapes the goals of the people using it, as well as the style of communication and communication rules3. A conceptual framework for understanding the role of networked computers in distributed collaborative learning

Engeström (1987) regards contradictions as the driving force in any human activity. Contradictions manifest themselves as problems, breakdowns, clashes, etc., within the activity system itself or in relation to other systems. We have adopted this view, and analyse the quality of incorporation with respect to various contradictions. That is, contradictions concerning the instruments' incorporated role into development of meaning and, in exchange and role-taking processes. In addition we address the contradictions due to the duality of instruments. The dialectics between the aspects (c.f figure 1) is crucial in understanding collaborative learning. In any collaborative community, neither of these aspects can be considered separately, because they all influence each other continuously. Rules-mediated exchange processes influence the course of individual and collective actions. Moreover, individual and collective actions may influence and change the whole collaborative community. The collaborative community also influences what kind of instruments that are used in the web of actions, and the instruments may in turn influence the division of tasks and responsibility. In what follows we operationalise these considerations of incorporation in terms of various categories of contradictions.

**5.2. The main contradictions**

Although many instruments may act both as a tool and a sign, we regard this an essential property

of computer applications. The framework consists of two categories or contradictions:

- The tools and sign duality in the levels of action.
- The role of computers in collective action.

We distinguish between the tool and sign duality within the levels of actions. Hence, the following categories should be considered:

| | **Activity <-> Action** | **Action <-> Operation** |
|---|---|---|
| Tools | Use of tools involves thought and is targeted toward the object of the activity. The involvement of thought may stem from problems of using the tool, due to breakdowns, or due to unfamiliarity with the tool. | Use of tools is conducted automatic, due to internalisation of the tool's properties and behaviour. This is an ideal use situation, because the tool is transparent, and hence not hampers the focus on the object of collaborative knowledge construction. |
| Signs | Signs are an aid for thought and reflection. They are targeted toward the activity itself. | Signs are unconsciously guiding the course of actions. |

*Table 1: The tool and sign duality in the levels of actions*

It may be difficult, even impossible or unnatural, to make a clear distinction between tool and sign related to a given action. This is however not the main clue of the framework. Rather, focus should be put on the duality within the instrument.

The computer applications' incorporated role into a collective action is related to the tool - sign duality. Hence, the following categories should be considered (Examples are included):

| | **The role of computers in collective action** |
|---|---|
| Development of meaning | Tools and signs are targeted toward the object of the activity. Tools are means of changes upon the object, while signs are aiding thought and reflection upon the object. Examples:<br>Tools: Applications for: text processing, spreadsheets, and calendars. Database management systems.<br>Signs: Texts, spreadsheets, paintings, databases, calendars. |
| Exchange processes | Signs mediate thought, knowledge and perspectives among individuals in the community. Tools are means of changes upon the object, but the interpersonal aspects involved are also focused.<br>Signs: e-mails, group decisions, shared meaning, joint productions (e.g., project report)<br>Tools: e-mail applications, video conferencing systems, workflow systems, shared databases, co-authoring tools. |
| Role-taking processes | Signs mediate the division of tasks and responsibility in the activity, like common decisions, commitments, and work arrangements. Shared tools are means for a community to collectively make changes upon the object. Signs: Group decision, common plans (e.g., activity responsible charts), access rights, calendars<br>Tools: Project management, etc. |

*Table 2: The role of computers in collective action*

### 5.3. What to look for?

This section outlines some possible contradictions that may guide the analysis and designs.

**Contradictions due to the duality of instruments**

These categories of contradictions relate to the duality within instruments (Vygotsky 1978), i.e., the double function of computers as tools and signs. We have observed that the tool function may hamper the sign function, and vice versa. An example is: A multiple user database may be designed so that the individual users cannot know of, and cannot interfere with, each other's actions. (This is common, and is enforced by serialisability protocols in shared databases.) The problem occurs due to the missing

mediation of the other users' actions. Hence, situations where collaboration would be appropriate are hidden by the computer system (Sørgaard 1988).

**Contradictions between different instruments**

These categories of contradictions relate to the constellation of instruments used. A large number of computer based and non-computer based instruments are present in any collaborative situation. These may be designed with different modes, paces, heuristics, etc. in mind. Table 2 gives an example where *activity responsibility charts* function as signs for making joint plans regarding *who* is doing *what* and *when*. Berge (1997) developed a Web-based groupware aimed at supporting distributed project-based learning. The learners' joint activity of filling in the charts was considered a central part of the collaborative processes. The original layout and format found in the paper-based forms were emphasised by the course designers. However, the implementation of these forms in Web implied problems. The charts include circles to be filled in, and this was complicated to implement by the technology used (CGI scripts). The result was that the learners used the original paper-based forms. To make common plans, the learners faxed the forms back and forth. This implied extra work for the individual as well as it constrained effective communication amongst the distance learners. Thus, the constellation of instruments used hampered the collaborative processes, and the level of incorporation was rather low when it came to *use*.

Another example associated with this category of contradiction is: Cf. the quote in the introduction (Schmidt 1994).

**Contradictions due to the levels of action**

These categories of contradictions relate to the hierarchical structure of activity (Leontjev 1983). We have observed that computer applications have been designed with one particular level in mind, not taking into consideration the dynamic interplay between them. An example is: A MOO/MUD application is fundamentally based on a room metaphor, and may as such help novice users to engage in interaction with limited training. However, this can be an obstacle for an experienced user.

**Contradictions between the aspects of collective actions**

These categories of contradictions relate to the dynamic relationship between development of meaning and, the exchange and role-taking processes (Engeström 1987). We have observed that individual computer applications hamper the actions directed towards exchanging materials in collaborative learning (Fjuk 1998). A word processing program is a potential tool for linking thought and articulation of it into writings. Using a word processor is shortly routinesed, and works as mediators for individual knowledge construction and development of meaning. Fjuk (1998) shows that routine actions become problematic ones, when a special function is to be used, like integrating a picture. The produced text may not appear as appropriate signs in communication. The level of incorporation is then low, since the individual learner's needs might conflict the collectively oriented processes. This category of contradiction is associated with the previous one, that is, the operation is not conducted automatically, - thoughts are directed towards the *tool* itself.

A second example is: If versions managements and remote editing are considered as important for making a common project report, the designer's role is to find *co-authoring tools* that keep track of this. A brilliant Web-based solution that keep track of co-production, does not necessarily guarantee that it supports our arguments of incorporation. The level of incorporation is high, first if these exchange processes do not hamper the mediation of the other aspects.

A final example is: Consider a video conferencing system with a shared workspace. Seeing the collaborators' facial and bodily expression may be used to control access to the shared workspace. However, bad image quality may hamper this important aspect of awareness of the others' intentions and views (Kuzuoka et al. 1995).

**Contradictions between multiple activities**

These categories of contradictions relate to Leontjev's (1983) view on polymotivated actions, i.e., two or more activities can temporarily merge, motivating the same action, thus creating a contradiction between the involved activities. An example is: A secretary is involved in different activities. The mediating instruments in these activities may be different (Framemaker, Word and LaTex/UNIX, Mac, PC), and thus constituting a hamper in collaboration because of the weak incompatibility between the instruments.

## 4. Concluding Remarks

This paper has proposed a framework for systems developers in their process of structuring their understanding and analysis of a problem situation, in which computer-based instruments are incorporated into distributed collaborative learning. An essential feature of the framework is the duality between tool and sign. This two-sided role differs from situation to situation, and what role a computer application occupies has to be considered with the situation at hand.

The computer-based instrument occupies the interrelated roles as a sign for thought and reflection and as a tool for operationalising the same action. The fundamental issue is to first consider computer applications in connection with signs, since these types of instruments have a fundamental meaning to a collaboratively based learning environments in which mediation of thought, perspectives and common decisions have a central and shared position.

The framework has shown to be powerful in analysis and designs. First: It focuses on the social and instrumental dimensions of learning. This focus goes beyond an interpretation of collaboration anchored in physical worlds, upon which many computer systems for collaborative learning are being developed. In line with traditional school-education, systems design is often driven by an understanding of transforming collaborative instruction in physical domains into computer-based equivalents. Simulating classrooms, course rooms and the like manifests this. There is no clear correspondence between such thinking in systems design and what impact it has on social interaction and learning. What counts for a learner, is not associations to classroom education, but pedagogical and technological instruments that effectively support their interactional needs. Second: The framework is particularly useful for learning situations that builds on the Web as technological platform. Web offers its users instruments for simple interactions such as searching, browsing and exchanging information. Instruments like e-mail, news and hyperlinks, are integrated parts of most browsers and thus of human interaction. When extending the functionality of Web, the established patterns of how Web is used must be incorporated into systems design. This is an important factor for motivating the use of it in learning situations.

Concluding, although activity theory views interpersonal processes and cooperative activities as the foundation for human development, the concept of collective action is not thoroughly developed. The interrelation between individual and collective oriented action is important when it comes to understand and analyse the complexity of distributed collaborative learning. With basis in Engeström (1987) model of collective activity, the collective action has to be enriched with other theories on action and interaction. This is an issue for further work.

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*Annita Fjuk, annita.fjuk@telenor.com, (Dr. Scient.)* is the leader of the eLearning group at Telenor FoU, and has been involved in the area of collaborative tele-learning and distance education since the late 1980s. Her main interests throughout her research are the interwoven relationship between learning and technology in designs and development. *Ole Smørdal, ole.smordal@ifi.uio.no, (Dr. Scient.)* is scientific programmer in the systems development group at the Department of Informatics, University of Oslo. His research interests include the interwoven relationship between human work and technology in systems analysis and design. *Full address:* INTERMEDIA at University of Oslo, Box 1161, Blindern 0318 Oslo, Norway.

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