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The Complexity of Distributed Collaborative Learning: Unit of Analysis

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Abstract

The problem area of this paper is manifested in the new conditions that characterise distributed collaborative learning. The core argument is that distributed collaborative learning implies an interconnected complexity that can only be properly understood by extending the *unit of analysis* from technology and pedagogy themselves to real-life social contexts in which networked computers are being used. Experiments and small-scale field trials are only steps towards a deeper understanding of how complex relationships create conditions for learning. The argumentation is built on three elements; (1) activity theory as a powerful framework that informs analysis, (2) empirical studies of distributed collaborative learning, and (3) how the theoretical foundation and the practical experiences should be integrated into new designs.

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Keywords: Activity theory, unit of analysis, collaborative learning, tele-learning.

Introduction

Research within CSCL has focused on instruction and learning that takes place within classrooms (Roschelle 1996; Neuwirth & Wojahn 1996) and across classrooms (Pea 1996), and in some cases across distances between geographically dispersed individuals (Kaye 1992; Sorensen 1997; Fjuk 1998). These different types of studies could be categorised in terms of Crook's (1996) distinction between interaction around and through computers. When learners are interacting around the computer they use various computer-based applications as shared resources in their collaborative knowledge construction. When learners are interacting through computers the learners must create a common ground within a virtual space as the point of reference. This latter, but increasingly important, issue of CSCL is termed distributed collaborative learning (Fjuk 1998; Wasson, Guribye and Mørch, 2000). Distributed collaborative learning is used to designate new forms of learning 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 information- and communication technologies (such as traditional internet services, Web-based groupware, multimedia shared spaces, videoconferencing technology, interactive 3D applications, etc.) with appropriate pedagogical approaches to collaboration and social interactions. The problem area of this paper is manifested in the new conditions that characterise distributed collaborative learning as a phenomenon.

Based on a number of case studies Sorensen (1997) and Fjuk (1998) arrive at the conclusion that distributed collaborative learning is a product of complex interconnections between several aspects, such as: theories of learning and instruction, subject domains, teacher's roles, delivery institution's educational praxis and tradition, organisational and administrative arrangements, costs, properties of ICT (information- and communication technology) and available software, geographical distances between co-learners, etc. Any changes associated with one of these aspects will inevitably *influence* and *change* the others. The problem area of past CSCL research is, however, that they mirror a partial thinking with respect to these aspects (Sorensen 1997). Such approaches though do not provide inspiration for distributed collaborative learning as a new phenomenon relying on its *own specific conditions*. We argue that the profound changes in the area of collaborative learning caused by ICT and networked computers can only be properly understood by extending the *unit of analysis* from technology and pedagogy themselves to real-life social contexts in which ICT is used. This core argument throughout the paper is outlined by first presenting activity theory as a powerful framework that informs analysis and designs associated with distributed collaborative learning. Thereafter the paper presents findings from exploratory studies to illustrate the link between the unit of analysis (based in theory) and real-life experiences. Finally, the paper presents issues for further work to exemplify how the combination of theory and practice should inform *new designs* of distributed collaborative learning situations.

Adequate Unit of Analysis

The problem area within most CSCL research in general, and in distributed collaborative learning in particular, is that their ecological validity could be considered low, since most studies are experiments or small-scale field trials (Ludvigsen 2000). Studies that build on perspectives from language sciences and the cultural-historical activity theory (Baker et al 1999) are limited to experimental settings, or field trials where the time span of the learning activities is of short duration (Dillenbourg & Traum 1999). Such

studies provide with supplements to prior experiences and knowledge, but do not in any strong sense provide insights into how real-life use situations develop over a certain period of time. Contingencies and unforeseen happenings as a result of novelty may constrain the learners' collaborative processes unrealistically, and thus the total experiences of the new situations. In contrast, established deliveries of distributed learning, ideally combined with long-term studies that are aimed at understanding the processes from the participants' viewpoint, provide more realistic insights into the new area of learning.

Moreover, the research tendency is that the activities, mediated by ICT, constitute the unit of analysis themselves, rather than additional and interconnected aspects that are manifested in the distributed situations (Fjuk & Dirckinck-Holmfeld 1997; Ludvigsen 2000). This issue is nicely illustrated by the work conducted by Muukkonen et al (1999). The authors studied how university students participated in a learning environment where intensive progressive inquiry was the purpose of the instructional activities. The authors found that the students' participation was partly influenced by other but interconnected activity systems. They argue that the students are part of a large number of small courses, which means that they are not used to carrying out intensive in-depth research to improve their knowledge.

The additional unit of analysis in a study conducted by Wasson, Guribye & Mørch (2000) is a scenario in which the educational purpose was that the students should create a shared product. The students did so, however, without sharing information and concepts. The three groups of students that took part in the scenario were constrained in various ways for fulfilling the requirements for their courses, which implies different motives for taking part in the scenario. This resulted in lack of motivation associated with collaboration and joint production. Thus, if we view a student's collaboration in the activity system, we actually see how important it is to understand how this activity system is related to *other* activity systems the student participates in.

Both studies indicate that there are tensions between how to prioritise activities in different activity systems, and that broader aspects related to the *curriculum design* influenced the learners' activities. This leads us to the core issue throughout the paper, that is, distributed collaborative learning must be understood and considered in terms of a complex mix of various interconnected activity systems.

Sociocultural Perspectives

In recent years a series of alternatives to standard cognitivist approaches to learning and cognition have evolved. These approaches are situated action (Suchman 1987), situated learning (Lave & Wenger 1991; Greeno 1998), distributed cognition (Hutchins 1995), cultural psychology (Cole 1996), mediated action (Wertsch 1991), and activity theory (Engeström 1987; Engeström & Miettinen 1999). In spite of different terminologies, research traditions, and methodological preferences, the approaches share the assumption that learning has to be understood as actions and activities integrated in a complexity of social, institutional, cultural and historical practices. The unit of analysis is widened *from* viewing the individual as a "solo learner" *to* including the learner's practice in relation to activities in communities of practice.

Activity theory constitutes a rich framework for studying different forms of practices as developmental processes, with individual and social issues interlinked at the same time (Kuutti 1996). An important feature of activity theory is that the system is driven by a collective motive that extends beyond the level of individual intentions. Activity systems are not reducible to a sum of individual actions, they have "...cyclic rhythms and long historical half-lives" (Engeström *et al*, 1995). In other words, activity theory affords analyses of social phenomena on different levels; *activity* – at the level of social systems; *action* – at the level of the individual learner acting intentionally; and *operation* – at the level of the concrete operation, procedure or behaviour. To fully understand an activity, its history and development should be taken into consideration. This expands the unit of analysis even beyond the context of one given *activity system*.

In an activity system there are potential *contradictions* or tensions between all components of the systems (Engeström 1987). Contradictions are used to indicate 'misfit' within elements of an activity, and between different developmental phases of a single activity. Contradictions manifest themselves as problems, breakdowns, clashes, etc., within the system itself or in relation to other systems (Kuutti 1996). An individual's actions will be affected by three major factors: the tools used, the community she/he belongs to and its explicitly or implicitly expressed rules, and the division of labour within that community. These factors interact in the creation of the social practice, and contradictions within the system influence the whole collaborative situation. When the unit of analysis expands to the interaction

between different activity systems, the complexity that we are dealing with increases. Figure 1 illustrates these issues, with the focus on distributed collaborative learning.

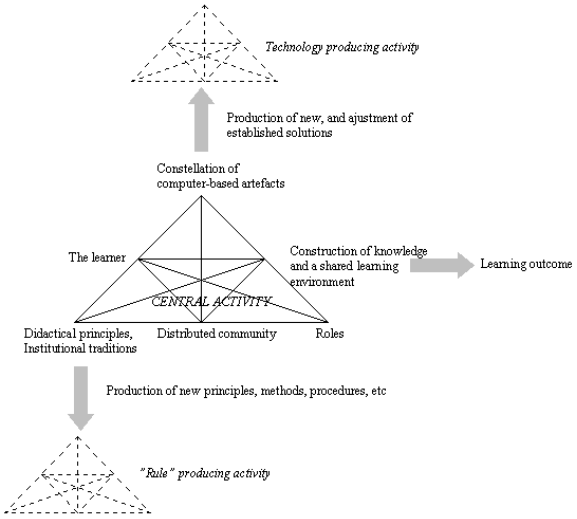

Figure 1: Activity analysis of distributed collaborative learning and some levels of contradictions (Inspired by Engeström (1987))

Using activity analysis on distributed collaborative learning would include all use activities, ICT and tool producing activities, all teaching and knowledge construction activities, as well as changes and contradictions in the use activities. This complexity makes it difficult to identify and delimit the activity systems that are of interest for the analysis (Bødker 1996). As such, we do not need to analyse *all the systems*, but to be aware of contradictions between the activities a learner is influenced by in her/his collaboration. Figure 1 illustrates how a learner's relationship to the distributed community is mediated by certain didactical principles, institutional traditions as well as the community's collection of computer-based artefacts. Furthermore, the community's commitment to the development of a shared learning environment and individual knowledge is mediated by the roles embedded in the collaboration (e.g, the power each yields, tasks each is responsible for, etc.). The figure also illustrates how contradictions associated with didactical principles and ICT solutions are leading to production of new didactical principles and ICT solutions, respectively. In analysis, and in designs also, this complexity can be operationalised in terms of questions like: How do the constellation of artefacts serve as mediators for the learner's actions directed towards cognition, and the development of a shared learning community? How do the didactical principles mediate the learner's collaboration in the distributed community? How do established institutional traditions mediate the community's distributed work and progress? The next section focuses on these areas of tensions aimed at giving guidance for further designs.

Experiences from real-life situations

This section provides real-life experiences provided through an exploratory study of distributed collaborative learning situations that are designed, organised and delivered by two Scandinavian educational institutions. The study, conducted by (Fjuk 1998), is particularly interesting because of the following issues:

- The target group is part-time adult learners that are committed to work and family. They are separated by physical distance during the majority of their collaborative learning processes and are linked by *text-based and asynchronous communications systems* and *some shared interest* in achieving knowledge on a specific subject domain. The areas of text-based, asynchronous communication systems are still the most active (Lehtinen et al 1999).

- The institutions have delivered various distance and open learning approaches since the late 1980s. As such, the experiences provided through their long-term deliveries differ from research results gathered from experiments or small-scale field trials.

Fjuk's (1998) studies clearly indicate that designs of distributed collaborative learning situations must be sensitive to potential contradictions within and between various activity systems. The learners' collaboratively oriented processes were constrained by aspects found in triadic relationships between pedagogy, technology and organisation. The *technological aspects* concern properties of the available computer applications (Web-applications, text processor, painting programs, spreadsheets, etc.). Examples of *pedagogical aspects* are: theories of learning and instruction, potential learning goals with respect to interaction, subject domains, teacher's roles, etc. *Organisational aspects* concern the delivery institution's educational practice and tradition. Typical dimensions include: course structures, presentation of subject matters, organisational and administrative arrangements, institutional history and philosophy, costs, etc. Because of the interwoven relationships between the aspects, it is complicated, sometimes even impossible to consider what aspects that are *most critical* with respect to distributed collaboration. In what follows, we point out some issues of this triadic complexity.

Several researchers emphasise a dynamic interaction between individual and collective activities, since the embedded actions are in interaction and reciprocally affect each other (Hutchins 1995; Perkins 1993; Salomon 1993). This necessary interaction, however, constitutes a possible area of tension when it comes to use of the artefacts. Since the first reported experiments with usage of asynchronous and text-based communications systems in distance learning (Harasim 1990; Kaye 1992), the literature has been rich in emphasising this interaction. In contrast to pre-printed material, text elaboration is not based on a static text, as in textbooks, but on something dynamic and modifiable created by the learners. The textual dialogues persist in a linear record whose history can be examined during the subsequent course of social interaction. This introduces a new dimension of reflection, allowing the learners to examine the ongoing discussion in a way that is impossible in oral discussions. As such, an individual's understanding, presented in written contributions to a discourse, act as stimulants or mediators for the co-learners' reflection and understanding. However, the ICTs used implied *breakdowns* when it comes to an operationalisation of opposed alternatives in argumentation, joint construction of problems and negotiation of meaning. Collaborating learners in Fjuk's (1998) study experienced this challenge in the following way:

"We did not do a good job of (...) digging deeply into our studies. It was only superficial digging, where we did not succeed in coming to grips with the subject. Possibly because our basic knowledge was not certain enough, but also because the mutual challenge did not come off in CMC [Computer-mediated communication] (...) Then it later became evident (...) that we had not been able to discuss our way to arrive at a conclusion about a common understanding [and this] created a lot of problems in the project organisation." (Translated in Fjuk & Dirckinck-Holmfeld (1997))

In order to challenge each other's understanding, to negotiate meanings and to make the interactions innovative, good internal and external conditions with respect to collaboration are particularly important. The artefacts hampered the mutual dependent interactions of individually and collectively oriented action, since they did not become *integrated parts* of operationalising the didactical principles that include negotiation and argumentation.

These studies clearly indicate that distributed collaboration is mediated by the embedded conditions found in the ICT used. However, pedagogical and organisational practices surrounding their use are *as important as* mediators of human activities as are the technological ones. Institutional traditions may impose frames for social interactions in terms of specific pedagogical and didactical conditions, and in terms of economy and technological requirements and selections. Concerning the latter, the institutions' technological profile logically creates an expectation in the learners that the selected solution implies a functionality that can operationalise the actions found crucial with respect to the pedagogical method. If this is not the case, it clearly constitutes obstacles for fulfilling their role as responsible co-learners of a shared collaborative environment. Moreover, Fjuk & Sorensen (1997) show how the institutional tradition, with respect to pedagogical profile and course design, implicitly guides new designs in directions other than planned. This was manifested in the choice of language used to describe the expected roles and actions of the learners. If the course guide described expected collectively oriented activities (like negotiation of meaning, brainstorming, etc.) in the distributed context as 'reading' and 'writing' activities, this may imply a contradiction to the necessary dynamic and spontaneous processes that many collectively oriented activities require.

Concerning pedagogical and didactical conditions, they did not seem to be spawned and rethought with respect to the creation of a fertile, technological and *distributed* ground for the specific needs of social interaction. In contrast to rather traditional forms of collaborative learning, the collaborating learners are situated in and are committed to various but sometimesdifferent social contexts, like work organisation, family, neighbourhood, technological infrastructure, etc. The individual learner's commitment to the shared distributed learning environment is thus constrained by the conditions manifested in the individual's social contexts. These conditions may have significant bearing on the learner's perspectives and beliefs, coordination of time, commitment and responsibility to the co-learners and their shared task. It thus seems that the more interdependence there is between the individuals' activities, resources and ICT uses, the complexity of distributed collaboration increases. The *distributed nature* of learning and the *interdependent activities* (such as negotiations and opposed perspectives in argumentation) constitute a contradiction and require intensive meta-communicative interactions like planning and explicit articulation of individual and collective activities. This is in resonance with Wasson et al's findings (2000), that conclude that distributed environments result in *new* and other collaborations patterns compared to traditional forms of collaboration. According to Wasson et al (2000), collaboration patterns define sequences of interaction among collaborating learners. One example is what the authors term *coordinated desynchronisation* which describes how coordination of activities between collaborating learners changes after they have identified a common goal. The study shows that the learners gradually shift from communicating synchronously to asynchronously. By having simulated real-time meetings, the collaborating learners agree upon a goal to pursue, divide their work and then work more or less asynchronously to accomplish it. Another collaboration pattern is *constructive commenting* (Wasson et al 2000) which describes commenting and feedback behaviour. Feedback is required to keep each other up to speed and moving in the right direction towards a common goal. The learners of Fjuk's (1998) study claimed that they had progressed too far in their own process of knowledge construction before they received feedback on ideas and thoughts. A major effect of this was a reduced sense of responsibility since it appeared as if there was no one to commit oneself to. If feedback from co-learners represented a contradiction to prior knowledge and thought, the learners often did not have *the capacity* to follow it up and to negotiate upon their own thoughts. The learners of the study concluded:

"In some cases it is difficult to solve problems and if this happens too often or if we come to a standstill or do not understand each other, then the energy disappears" (translated in Fjuk & Dirckinck-Holmfeld (1997))

In conclusion, past designs concerning distributed collaborative learning seems to have been marked by an approach of using networked computers as add-ons to existing pedagogical and organisational practice. However, we need to know the principles of educational traditions in order to change them with respect to new technologies and concepts. Creative and new ways of thinking that will work in practice are dependent on prior understanding of the knowledge, experience and principles that underpin that tradition of praxis. This reality of new distributed learning situations clearly indicates that the learners' social interactions towards a shared learning environment must be viewed in terms of interconnected activity systems. It is therefore crucial to explore which conditions the distributed environment imposes on the social interactions that are found crucial for developing a common learning environment.

Further Work: New Designs

Based on activity theory and past exploratory studies, we have discussed how distributed collaborative learning develops contradictions that lead to *new production activities*. Figure 1 illustrates this issue regarding rules (e.g., associated with didactical principles and institutional traditions) and constellation of technological artefacts. This section provides some first steps and suggestions towards new designs associated with these two interrelated activities.

We argue that an awareness of contradictions becomes important to approach design of distributed collaborative learning environments, that is, designers must think in terms of both *interdependencies* and possible *conflicts* in order to understand, explain and control changes associated with distributed collaborative learning environments. Thinking in contradictions, eliminates the borders between pedagogical, technological and institutional aspects (Fjuk 1998). Our central issue with respect to designs is to view networked computers as *incorporated parts* of the individually and collectively oriented actions (Fjuk & Smørdal 2000). This means that the constellation of artefacts must serve as tools for thinking, reflection and interpretation, as well as for social interaction and collaboration. Concerning

the former, the cognitive artefacts, examples are word processing programs, drawing and painting programs. These types of artefacts may in turn serve as powerful mediators for social interaction since they are basic for planning and monitoring collective progress. The *operational* aspects of these actions are mediated by e-mail systems, chat systems, videoconferencing solutions, web-based groupware, text-books, etc. The learner's focus in one particular situation is of vital importance for framing the use of the artefact and meaning making process. The artifacts serve as tools within an activity system, but they are potentially part of several activity systems (or collective activities). Artefacts are only temporarily bound to one activity system.

Based on this interwoven and dialectical relationship between individual and collective actions, and its mediating artefacts, designs should then consider which *artefacts* that serve as potential mediators of given *didactical principles*, and what new ones that are needed to be developed to support them. But, available artefacts may impose a rethinking of the collaborative learning method and corresponding principles. To organise good interactional conditions, we suggest that a mix of various artefacts must be available for the distributed learning environment. It is necessary to offer the learners various ways of *combining* synchronous and asynchronous modes of interactions, in terms of text, audio and video, to allow them to use the artefact that serves as mediator in the web of human actions. This combination has a twofold effect: First, by offering the learners opportunities to take part in synchronous interactions, they will be better able to incorporate these interactions into their own reflections and thoughts through an asynchronous mode. Furthermore, the reflective dimension of asynchronicity will stimulate the learners to actively take part in the synchronous interactions. Being a part of such a technological environment, the learner may create her/his own portfolios of reflections and thoughts (mediated by e.g., text-processing or drawing programs), as well as formulate comments and questions to co-learners and tutor (through e.g., e-mail, chat, discussion groups etc.) while participating in socially oriented activities mediated by various synchronous videoconferencing solutions. Through constituting a personal entrance to the learning scene, it enhances the overview of learning expectations, learning content, learning goals, learning methods as well as the individual and collective activities (Sorensen 1999). Second, the learners may use the artefacts they are familiar and/or confident with, associated with the situated object of the interactions. As such, the use of artefacts is conducted automatically, due to internalisation of the artefact's properties and behaviour. This is arguably an ideal use situation, because the tool is transparent in collaboration, and hence does not hamper the focus of the object of collaboration.

How the activities towards new productions should be *organised in practice* is dependent on aspects like subject matter, pedagogical method and approaches, levels of interdependencies between learners and resources, study location, time, history and tradition of the institutions, etc. This will in turn influence how combination of technological artefacts will be used and mediate the planned learning activity.

Concluding remarks

The core issue throughout the paper is that distributed collaborative learning is a complex phenomenon that must be sensitive to aspects found in triadic relationships of pedagogy, technology and delivery institution. This complexity must be integrated both as unit of analysis and in design of new situations. Furthermore, experimental settings are too limited, as a unit of analysis as well as to understand learning in complex multidimensional environments. We clarify this argument by relying on perspectives from activity theory, combined with experiences gained from real-life practices of designing and delivering distributed collaborative learning.

Activity theory has its strengths as analytical tools describing complex relationships, and the relation between objects, participants and different aspects of social organisations. This approach needs to be developed further to be able to give more detailed accounts of learning activities especially related to the understanding of *learning in discourse*. We need approaches that are sensitive to different levels of analyses and give reasonable accounts for how these levels are related to each other.

How the theoretical foundation and practical experiences should be integrated into new designs is shown in suggestions for further work. We do not believe that a specific design of learning environments can predict how learners will collaborate and what they will learn. Rather, we do think that the insight which is demonstrated by the sociocultural perspectives gives reasonable directions for understanding the complexity of distributed learning processes. By understanding this complexity we can create more robust and valid learning environments where higher order processes could be realised.

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