Re-contextualization of Teaching and Learning in Videoconference-based Environments: An Empirical Study

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ABSTRACT

The paper reports an empirical study of the use of videoconferences in decentralized university education. The study focuses on breakdowns that occur during the transition of educational practices from regular classrooms to videoconference-based environments. It was found that the main cause of breakdowns was discoordinations of teaching and learning resulting from physical and organizational distribution of decentralized education. The paper concludes that implementation of educational activities in new types of learning environments requires both downwards contextualization, an adaptation to the limitations and affordances of the environment, and upwards contextualization, locating the activity in a larger-scale context.

Keywords

Decentralized education, learning environments, videoconference settings, breakdowns, activity theory

INTRODUCTION

One of the main ideas behind the current trend towards "virtual universities" (Cunningham et al., 1998) is a possibility to make a better use of educational expertise of university teachers. It is assumed that information and communication technologies (ICT) allow for extending educational activities of a university to include students who cannot participate in traditional on-campus education. Such an extension, which takes various forms (Lau, 2000), presents a challenge to CSCL research. Traditional university education has been shaped by centuries of historical development. Moving from traditional classrooms to “new communication environments” (Mantovani, 1996) cannot be accomplished by a direct translation of existing educational practices into a new setting. Instead, it requires a *re-contextualization* of teaching and learning and development of new social organization within the setting. This notion, which is widely accepted in the field of CSCL (Koschmann, 1996), has, unfortunately, not influenced much of practical developments in distance education, web-based learning, and so forth.

The study presented in this paper addresses the problem of re-contextualization of teaching and learning in ICT-based environments by focusing on coordination breakdowns of educational activities under new conditions and the emerging practices of coping with such breakdowns in everyday educational use of technology. The object of our study was decentralized education at a Swedish university (thereafter, “the University”). More specifically, we were interested in the use of videoconferences within decentralized courses delivered by the University to students living in other towns. The reason behind choosing this specific form of technology-based education was that videoconferences could be considered the closest match to traditional classroom settings. One of the reasons behind the widespread use of videoconferences at the University has been an assumption that practically any teacher can successfully use his or her experience with delivering traditional courses in a videoconference setting. In a pilot study by Esbjörnsson (1997) it was shown that this assumption was not correct. Successful teaching and learning in a videoconference setting was found to be associated with special types of arrangements and expertise, which could be rather complex and difficult to accomplish. The lack of such arrangements and expertise resulted in various problems and breakdowns. In the present study we specifically focus on breakdowns in videoconference settings to identify potential problems related to attempts to deliver traditional courses in the new environment.

The rest of the paper is organized as follows. Immediately follows a brief overview of conceptual frameworks that can be used in studies of coordination breakdowns and the reasons why activity theory has been selected as the main theoretical approach employed in the study. Then a background information about the University is provided, as well as a description of videoconference-based learning environments analyzed in the paper. After that the method and the findings of the study are presented. Finally, implications of the findings for analysis and design of ICT-based learning environments are discussed.

POTENTIAL CONCEPTUAL FRAMEWORKS FOR STUDYING COORDINATION BREAKDOWNS

A variety of approaches seem to be plausible frameworks for studying coordination breakdowns in videoconference-based learning environments. They include, among others, coordination theory, distributed cognition, situated actions, and activity theory. Each of these approaches, from out point of view, has its strengths and weaknesses.

Coordination theory (Malone and Crowston, 1992, 1994; Crowston and Osborn, 1998) focuses on various types of dependencies between actors and activities within one coherent system. It provides powerful generalized representations that can be used for capturing and re-designing a wide range of processes, such as business processes. In case of videoconference-based learning environments the main problem is, however, not to optimize and streamline dependencies between activities but rather to discover what these activities are and what they could be. Coordination theory appears to be a useful analytical tool at a later stage of analysis, when the basic components and structures of teaching and learning in the setting are identified and understood.

Distributed cognition can be characterized in a similar way, despite all the differences between this approach and coordination theory. The distributed cognition framework makes it possible to create detailed and insightful representations of how people and artifacts are coordinated within a coherent system. According to Hutchins, "One important aspect of the social distribution […] is that the knowledge required to carry out the coordinating actions is not discretely contained inside the various individuals. Rather, much of the knowledge is intersubjectively shared among the members of the team" (Hutchins, 1995, p. 219) Such sharing can only be possible if a common ground for intersubjectivity has been established through evolutionary development of a settings. It is often not the case when it comes to videoconference-based learning environments. In fact, in our earlier work we found a very different phenomenon. Successful functioning of a videoconference as a setting critically depended on the expertise of one concrete individual, the facilitator. Ironically, the importance of this "invisible" expertise was not recognized by the managers responsible for the setting (Hedestig, 2000).

The situated actions approach (Suchman, 1987), which is partly based on conversation analysis, provides a number of useful insights into coordination mechanisms necessary to make videoconference environments work. In particular, it emphasizes that communication is "not so much as alternating series of actions and reactions between individuals as it is a joint action accomplished through the participants' continuous engagement in speaking and listening." (Suchman, 1987, p. 71) Therefore, flexibility, coherence, and resources necessary to remedy communicative troubles should be important concerns in design of learning environments. However, the potential of situated actions as a guiding approach in addressing the above issues appears to be limited. Even though the importance of communicative resources can be clearly identified, the ways to provide such resources given the constraints of a specific setting may remain an open issue. Besides, the notion of plans as a weak resource of an action (Suchman, 1987) is hardly applicable to many learning environments, since actions in environments of this kind are often strictly determined by a number of plans, such as course schedules.

Finally, activity theory that focuses on hierarchically organized, mediated, and developing individual and collective activities can help formulate some key questions and provide conceptual tools helping to address these questions (Kaptelinin, 1996)[*]. Formulating key issues for a systematic empirical analysis, based on activity theory, appears to be a promising starting point for understanding the differences between traditional on-campus courses and their videoconference-based versions. Representations of these two types of learning as activities can help identify goals specific for each setting, as well as essentially common goals, that are being accomplished in different settings through different operations. A useful concept that can be utilized in the above analysis is the notion of mutual transformations between individual and collective activities (Kaptelinin, Cole, 1997). The main limitation of activity theory is that this approach is rather abstract and needs to be made more concrete by developing concepts and representations specific for a domain in question (cf. Kaptelinin, Nardi, Macaulay, 1999).

Therefore, even though a theoretical framework that can be directly used for analysis of coordination and re-coordination in videoconference-based learning environments does not exist yet, a number of frameworks can provide useful insights (c.f. Nardi, 1996). In our study we relied mostly on activity theory. Following the principles of this approach, we focused on actors participating in the setting, their goals and sub-goals, with special attention to conflicts between various goals, mediating artifacts, and developmental transformations of individual and collective activities.

THE USE OF VIDEOCONFERENCES AT THE UNIVERSITY: A SETTING IN A CONTEXT

The University has a strong history of distance and decentralized education. Decentralized education, which combines traditional classroom activities with distance learning, has become the main form of off-campus education at the University. Over 5000 students located outside the University campus (the distance is ranging from 100 km to 700 km) are currently

[*] Space limitations do not allow for an extensive discussion of activity theory in this paper. A detailed exposition of this approach can be found elsewhere (e.g., Leontiev, 1978).

participating in various courses and programs. The University is the major educational and research center in Northern Sweden, and to meet current demands it is more and more involved in decentralized education, gradually transforming itself into a "virtual" university. The gradual character of the transition is important, because it provides a possibility for the University to try various forms of decentralization without radical changes of the whole system and to capitalize upon existing expertise of the teachers. As mentioned above, that was one of the main reasons why videoconferences have been so widely used at the University.

Videoconference-based learning settings at the University are composed of two main types of components: (a) the *teacher's site*, or video studio, located on campus, and (b) the *students' site* (or sites), a videoconference classroom at a so-called "study center" located off campus. A typical arrangement of these sites is shown in Figure 1.

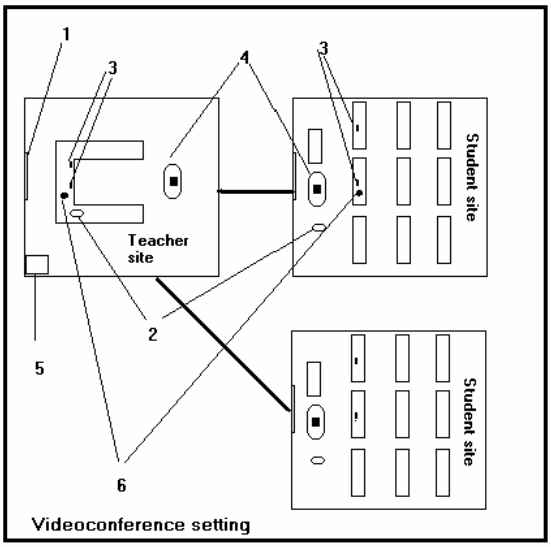

Figure 1. **A typical structure of a videoconference setting. At the teacher's site the teacher can use a whiteboard or an electronic whiteboard (1); at all sites there are document cameras for slides (2), two or more stationary microphones (3), TV-monitor(s), a video recorder and camera (4), and remote controls (6). At the teacher's site there is also a computer connected to the videoconference system (5).**

The teacher's site. When teachers use videoconference settings at the university they follow the same teaching styles as in traditional classroom teaching, that is, traditional lectures, seminars, and tutoring sessions (Hedestig, Kaptelinin, 2001). The studios are relatively small but include seating arrangements for groups up to 10-15 persons. The equipment consists of a document camera, an electronic whiteboard, a computer, a projector, TV-monitors, and hands-free microphones. The most common types of activity at video studios are lectures delivered by teachers to one or more student sites.

The students' site. The videoconference equipment at the students' site is usually installed in a traditional classroom at a local study center, that is, a room with rows of tables and chairs. Such an arrangement directs students' attention towards the monitor, that is, towards the teacher. Devices, such as cameras and microphones, can vary depending on how much a study center can afford to invest in equipment. Most study centers provide a camera, a document camera, a TV-monitor for incoming and outgoing images and one or two microphones (see Figure 1). Usually there is a student at the students' site, who is responsible for the remote control connected to the equipment. At students' sites there are usually no technicians or facilitators to provide support during sessions.

VIDEOCONFERENCE-BASED LEARNING – A WEB OF POTENTIAL BREAKDOWNS

The findings reported in this section are based on (a) field observation of videoconference sessions (about 100 hours in total), (b) interviews with teachers, students, and technicians/facilitators, and (c) a one-year ethnographic study of the work of a videoconference facilitator. The field observations have been conducted both at students' sites and teacher's sites. During these sessions we also recorded certain events, such as turn taking and breakdowns. The interviews were both unstructured and semi-structured. Most of unstructured interviews were first interviews with new informants. Semi-structured interviews were based on the Activity Checklist (Kaptelinin, Nardi, Macaulay, 1999). In the ethnographic study of facilitator's work one of us had been closely observing the facilitator almost every day for over a year and interviewing him both before and after each session.

In our field observations we have identified different types of coordination breakdowns. It should be noted that this paper does not deal with technical breakdowns, which are left beyond the scope of the present study (analysis of them can be found in, e.g., Dallat et al, 1992; Abbot et al, 1993; Rosengren 1993). Our findings, which are presented below, are divided into two main groups. When dealing with coordination breakdowns identified in the study the first and the most basic distinction was between (a) breakdowns caused by certain aspects of the settings and (b) breakdowns caused by factors existing in the larger context, outside the videoconference setting. These groups of breakdowns can be interpreted as indicators of two types of contextualization of activities, introduced by Engeström (1990): downward contextualization, that is, an adaptation of activities to the limitations and affordances of the environment, and upwards contextualization, that is, locating activities in a larger-scale organizational and inter-organizational context.

Downwards contextualization: Breakdowns originating from within the setting

Coordination breakdowns at students' sites

Most of the students' sites had the traditional classroom arrangement with few cameras and microphones. At sites where each student had an opportunity to control the camera and audio there were more spontaneous questions than at sites where students had to share a microphone and a remote control (see Table 1). Students from sites with only one camera and one or two microphones often commented on the difficulty of asking questions:

> *"It's impossible to ask spontaneous or short questions during a video session. It takes too much time. First I have to ask someone to give me the microphone. Then I have to ask the student who has the remote control to push the mute-button, so the teacher can hear me. At the same time the student also has to direct the camera towards me. This process takes too much time, and many of us do not bother to even think of asking a question"*

> *"Since it is necessary for us to push the mute-button at our site, it takes too long time to ask the teacher a question. Instead many of us so to speak seat back and watch the 'show'. We see it more as a TV-broadcast program, and a TV-program that you never interrupt! If there is something unclear we prefer to ask questions afterwards, if at all."*

Interactions are further complicated by the fact that students are looking at the same direction, so they do not face each other and cannot use nonverbal cues. Instead of talking to each other they mostly address the student(s) who has the microphone and the remote control.

A way of handling the coordinated use of equipment by the students was to move the student in charge of the technology in front of the room so that he or she could face the group. A common problem with this type of seating arrangement was a role conflict experienced by the student in charge of technology. The student had to choose whether to pay attention to the teacher and take notes or watch for any cues from the students and work with the cameras and microphones.

The role of a technician seldom shifted from student to student. A student who was a "designated technician" in the beginning of a course usually remained in this role during the rest of the course. The result was that the whole class became very dependent on this student, and when he or she was absent (for instance, due to illness) there were problems with finding a replacement. Typically nobody wanted to volunteer and someone was forced to take the responsibility. This person often lacked the skills of using the equipment, which affected the quality of interaction.

Coordination breakdowns at the teacher's site

In face-to-face classrooms instructors develop skills of coordinating and delivering a lecture with the use of familiar artifacts. In a videoconference studio these skills are often not applicable. Teachers have to change their practices to adjust them to a different context featuring different kinds of technical artifacts. Empirical data obtained in our study allow to differentiate between three types of coordination activities in a video session: (1) coordination related to course content, (2) coordination related to teacher's presentation (the outgoing image), and (3) coordination related to students' activities (the incoming image) (Hedestig, Kaptelinin, 2001).

Coordination related to course content. Teachers had to prepare to videoconference sessions much more carefully than to traditional classes. Most of the teachers we interviewed were aware that videoconference-based teaching is much more intensive and it was impossible to just copy a two-hour face-to-face lecture to a two-hour videoconference session. In their preparation teachers produced special materials suitable for the media: slides of different style, handouts to be distributed in advance, time schedules, storyboards, etc. Teachers' preparation phase was based on a very structured plan of a session. During a session teachers would often realize that their plans did not take into consideration the complexity and heterogeneity in the setting. Videoconference sessions are very situated because the frequency of technological breakdowns is still rather high and time schedule is rarely followed. It is not unusual that starting time and estimated breaks were delayed by 5-20 minutes (see Table 1). For a teacher the consequence of those delays could imply significant changes of the original plan of a lecture.

Video-session	Planned starting time	Real starting time	Planned break, min	Real break. min	Difference. min
1	10.15	10.23	15	21	+14 (8+6)
2	9.00	9.11	15	22	+18 (11+7)
3	13.15	13.20	10	18	+13 (5+8)
4	8.15	8.16	15	25	+11 (1+10)
5	10.00	10.10	15	19	+14 (10+4)
6	10.15	10.25	-	-	+10

Table 1. Examples of differences between planned and actual timing of videoconference sessions

Coordination of the outgoing image. When teachers act according to pre-planned content they have to concentrate on monitor(s) showing the outgoing image. Since the setting requires high concentration of both students and teachers it is common that the view is being changed from time to time, so that students do not look at slides only during the whole session. Actions involved in this sequence include zooming documents or images on document camera, showing slides or computer applications, showing the teacher or an area of the whiteboard, etc. These actions take place rather often, up to once in every second minute (see Tables 2 and 3). Usually technicians are responsible for those actions, but sometimes the responsibility lies solely on the teacher.

Descrption	S1	S2	S3	S4	S5
Lecture time (min)	56	83	84	69	91
Change video source	0	0	0	0	0
Zooming	5	10	8	5	10
Camera movements	10	34	55	51	67
Audio adjustments	2	0	0	2	2

Table 2. Examples of sessions (S1-S5) when the teacher uses a regular whiteboard

Description	S1	S2	S3	S4	S5	S6
Lecture time (min)	73	45	44	47	47	103
Change video source	43	29	26	23	13	80
Zooming	2	0	0	0	4	11
Camera movements	0	0	0	0	0	1
Audio adjustments	0	1	1	1	2	9

Table 3. Example of sessions (S1-S6) when the teacher uses slides on the document camera

Coordination of the incoming image. Sessions become even more difficult to coordinate when the teacher has to concentrate on reactions and responses of the students. The teacher has to discover verbal and non-verbal cues from students by viewing the monitor for the incoming image, which often resulted in communication breakdowns (see Table 4).

User-User breakdown	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10
Turntaking breakdowns	0	3	2	12	6	7	4	2	3	18
Lack of feedback	17	2	2	0	0	6	1	5	4	0
Understanding problems	1	4	1	1	0	1	1	0	2	3

Table 4. Examples of sessions (S1-S10) with communication breakdowns.

A consequence of the above problems was that coordination of a session became very complicated, especially in cases of "multipoint" sessions, when more than two studios were involved. It was not uncommon that teachers focused exclusively on the content, paying no attention to the audience and leaving most of coordination to the facilitator.

Coordination among actors at teacher's sites: interaction between the teacher and the facilitator

Teachers were usually helped by a technician/facilitator, whose role greatly depended on the format of a session. In situations when lectures was delivered from a video studio[*], the goal of the facilitator was to help the teacher and control incoming and outgoing images. Actions carried out by the facilitator included changing camera angles, zooming, switching between different sources, and adjustment of the audio.

Most interactions between the teacher and the facilitator were based on non-verbal cues, such as eye contact, gestures, and other kinds of signs. The facilitator had also an eye on the students' site and could give signals to the teacher if something would go wrong. In fact, the facilitator became more of a teacher assistant by sharing the responsibility of coordinating activities among the participants. This support was especially important for the teachers because for many of them teaching in a videoconference environment was a new experience and they had to develop new work practices (Hedestig, 2000).

Upwards contextualization: Breakdowns originating from outside the setting

Activities within a videoconference session could also be affected by external factors. In our study we have focussed on some interdependencies between videoconference settings and the broader context, which affected teaching and learning in the setting.

Coordination breakdowns across intra-organizational boundaries

A three-year program at the University can consist of up to 15-20 courses involving departments across different faculties. Different departments have different work practices, different competencies in technology use, and different organizational

[*] Lectures typically fell into one of the following categories: (a) lectures based on the use of the whiteboard, (b) lectures based on PowerPoint slides, and (c) "technology intensive" lectures, in which the whole range of available technology was used, including electronic whiteboards and various computer applications.

structures, which are difficult to integrate. Coordination of these organizational units of the University is often problematic, which can be illustrated by following examples:

1. *Teacher X planned a videoconference session to take place two weeks after his course started. The day before the session students contacted him and informed that it was impossible for them to participate in the session because another teacher (Y), who taught the previous course, scheduled an examination on the same day. Teacher X called the department in charge of the previous course but none there could help him. Teacher X got the name of teacher Y from the students and tried to contact him, but teacher X was out of town. The video session had to be cancelled.*
2. *A teacher was planning a discussion seminar during a video session. He asked the course administrator (who was also a webmaster) to put a list of questions on the web, so that students could prepare for the discussion. The administrator made a mistake and placed the questions to the 'Exercises", not the "Discussions" section. The students misinterpreted the aim of the session and when the teacher tried to initiate a discussion they refused to participate, claiming they were unprepared. The teacher had to cancel the discussion and deliver a lecture instead.*

Decentralized education courses at the University are usually conducted by teacher teams working with both on-campus and distant students. For many departments functioning of teacher teams is associated with serious coordination problems since participating teachers are always on the road. They become a "virtual team" and have difficulties in coordinating their activities within the group, as well. Constantly traveling to off-campus sites teachers cannot easily meet and keep each other updated on a day-to-day basis. Besides, they experience coordination problems with students. For instance, they have difficulties with answering students' questions when these questions refer to lectures given by other teachers.

Coordination breakdowns across inter-organizational boundaries

Distance and decentralized education usually involve several organizations, which often have different structures, cultures, communication patterns etc. Collaboration and communication between those actors can be easily disrupted by actors who do not share the same common ground or perspectives. The complicated nature of coordination required to solve the most trivial problems when an inter-organizational cooperation is involved, can be illustrated with a simple example of room reservation. When teachers planned a videoconference session, they had to make reservation for a room/studio both in a study center and on campus. This reservation procedure could take days to accomplish. The problem was caused by the need to coordinate several organizational actors, each working with its own reservation system. Reservation systems were not integrated with each other and nobody had a full control over the status of all video studios. If a site were occupied during the time a teacher planned to use it, a negotiation procedure would occur were either the teacher or administrative personal would try to find a solution. Coordination breakdowns resulted from this included the following ones:

- *Students occasionally did not turn up because they were not notified of changes. Also, students would arrive to a site when the videoconference classroom was closed because study center personnel were not informed about the reservation.*
- *Sometimes teachers made reservations with "wrong" people, that is, those who were not actually responsible for reservations. At some study center reservations was made by an administrator, at others by a technician. In our interviews with teachers it turned out that some of them made reservations with technicians and these reservations were later on cancelled by administrators, who did not even inform the teachers on the grounds that the teachers did not follow the correct procedure.*
- *When teachers made room reservations they did not know exactly what equipment was available in the room. Sometimes they would discover that crucial equipment did not exist there and it was impossible to conduct a lecture as planned.*
- *Study center personnel could not make any reservation for an external organization wanting to rent a video studio (which could potentially be very profitable for the center) because teachers always made reservations in short notice.*

A distinctive feature of decentralized education in our study was a complicated system of dependencies between different organizations: the University with its faculties and departments, local authorities, and companies running local educational facilities.

This lack of coordination between the above stakeholders was a major source of actual and potential breakdowns. Videoconference settings for decentralized education can be considered boundary objects that create new challenges for all institutional actors. In particular, they make especially evident the obstacles to coordination that still exist in organizations. For instance, most information and decision support systems at the University had been developed and implemented within the University, which means that external actors cannot access this information. To make inter-organizational cooperation work, new informal ways of coordination and communication between organizations have emerged, and these new communication patterns evolved on an operational level and often exist without being noticed by those working on strategic levels. The complex interactions between various "players", which compose organizational context influencing teaching and learning in videoconference settings at the University, are summarized in Figure 2.

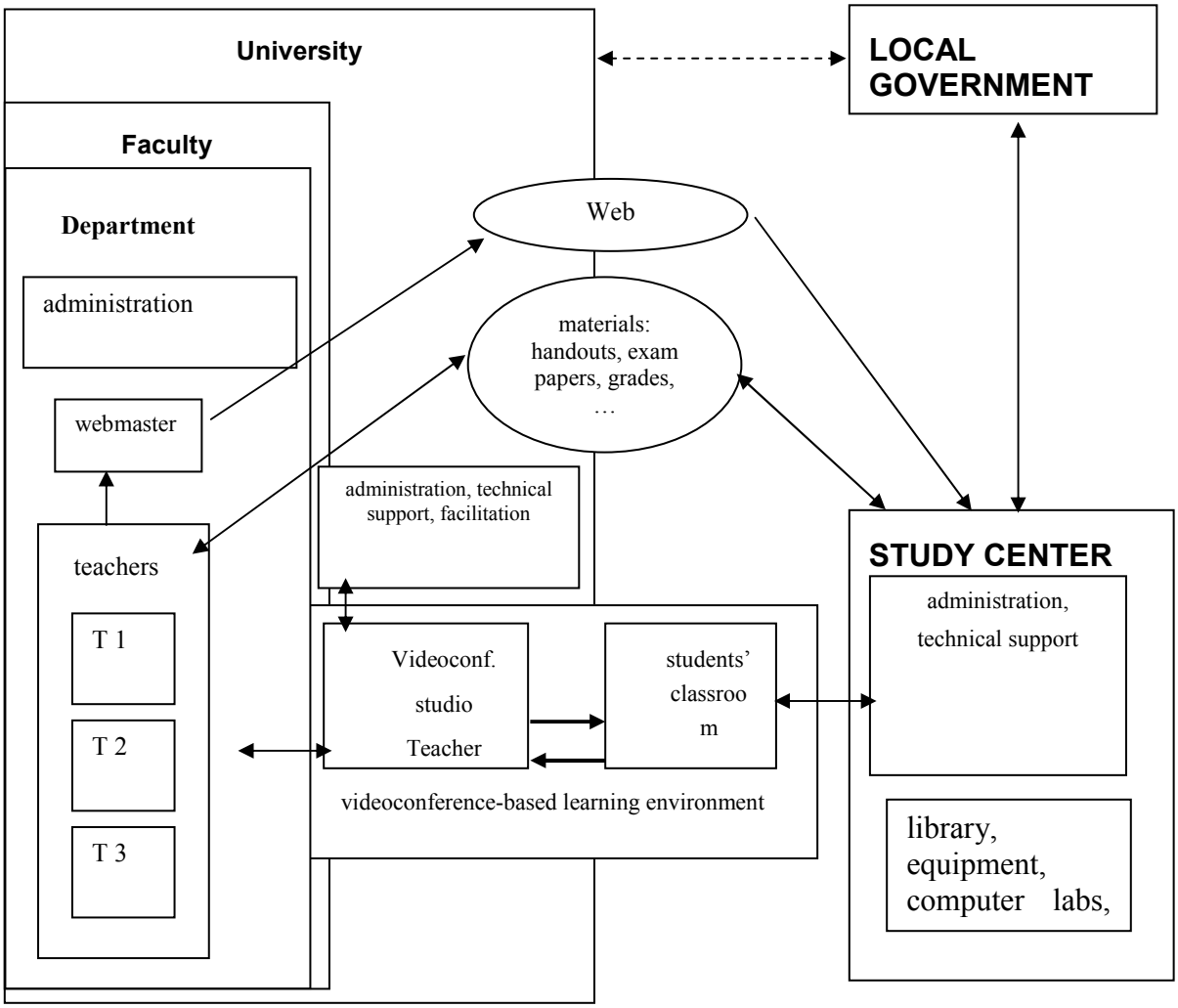

Figure 2. A simplified model of the organizational context of videoconference-based learning environment at the University

GENERAL DISCUSSION

Traditional classroom education is a well-established genre with a long history that goes back for centuries. The evolution of this genre has resulted in strategies, tools, and environments that provide a basis for smooth functioning of the system as a whole. Decentralized education implemented through videoconferences is a relatively new genre. As a result, the participants may have conflicting expectations, such as teachers considering it as something very similar to regular classrooms and students seeing it as a type of TV-broadcast.

Strategies and methods developed within traditional education are not necessarily applicable to videoconference settings. While in regular classrooms teachers can draw students' attention to key contents by using subtle cues, perhaps even without being aware of that, in videoconference settings teachers and facilitators should carry out special, sometimes complex actions to direct students' attention to relevant information. In a way, teachers should acquire competences similar to those of film directors. Interaction with students is also quite different in videoconference settings; it requires new communication skills. Besides, in videoconference settings teachers have more limited possibilities to monitor the audience and they have to develop the ability to use available cues for getting appropriate feedback. Finally, the possibility to monitor the outgoing image (that is, to observe himself or herself "from the outside"), time management, and the need to coordinate activities in the setting with the technician/facilitator also present new challenges to the teacher.

Success or failure of videoconference sessions critically depend on appropriate infrastructure, that is whether the students are informed about the schedule and assignments, whether a room and equipment are available, etc. During a

videoconference session the teacher and students may look like being together in a "virtual classroom" but in fact they are separated not only by physical distance but by institutional boundaries, as well. Facilities used by the teacher and the students are often provided and maintained by different organizations. An extensive coordination work carried out by various actors from different organizations (such as teachers, managers, technical support people, webmasters, secretaries, etc.) is needed to combine the above facilities into integrated learning environments. In decentralized education teachers and students have to deal with multiple and not always compatible organizational policies, routines, and requirements. Therefore, educational practices need to be contextualized in a larger organizational and inter-organizational context.

To sum up, coordination mechanisms and structures developed at various levels of traditional education often fail in new learning environments. Spatial and organizational boundaries cause communication breakdowns both in information exchange between the sites and inter-organizational cooperation necessary to create and maintain a setting. There is a need for "re-contextualization", that is, development and implementation of new coordination structures and mechanisms appropriate for new learning environments.

The study reported in this paper was primarily informed by activity theory. Following the basic principles of this approach, we focused on actors and their goals, conflicts, mediation, and development. This approach provided support in discovering breakdowns in activities we observed, and it can be concluded that activity theory can be a fruitful approach at an early exploratory phase for identifying key issues and concerns. In our future research we plan to use activity theory for developing more detailed representations of actual activities in videoconference settings. Representations of that kind could help take a next step in our analysis and provide a basis for understanding emerging practices that deal with the breakdowns described in this paper. Besides, such representations can potentially reveal new and advanced uses of technology that go beyond traditional education and allow accomplishing new goals.

Finally, even though in this paper we do not discuss design implications of our findings, we believe the findings do have direct implications for design of videoconference-based environments. This issue, however, requires a special treatment. In our view, there is a need to go beyond tool-centered perspective to a practice/activity-centered perspective not only in analysis but in design, as well. *System design* should be embedded into and subordinated to *interaction design*, which, in turn, should be embedded into *design of educational activities* mediated by technology. Such an arrangement could provide a meta-framework for interdisciplinary cooperation between, respectively, software engineering, Human-Computer Interaction, and Computer Support for Collaborative Learning, and assure the most efficient use of social science insights in supporting education with new tools, systems, and environments.

ACKNOWLEDGEMENTS

The study reported in this paper has been conducted within a research project funded by The Bank of Sweden Tercentenary Foundation.

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