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Katerina Zourou

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CHAPTER X

INSTRUMENT-MEDIATED COORDINATION AND MEANING MAKING THROUGH A DISTRIBUTED LEARNING ENVIRONMENT

KATERINA ZOUROU,
DEPARTMENT OF FOREIGN LANGUAGE TEACHING, UNIVERSITY OF
GRENOBLE III (FRANCE)

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Following the post-cognitivist theoretical tradition, which represents human agents and artefacts as a single entity in the analysis of an instrument-mediated activity, this paper reports on a study investigating socio-cognitive practices via a network-based learning environment. The key theoretical concept pertains to the distribution of cognition among individuals, tools¹ and the environment. The ways in which participants handled and shared resources, benefited from their colleagues' achievements and built knowledge while manipulating the digital environment are the core issues of this paper. In particular we intend to identify genuine cognitive processes that wouldn't take place without mediation by the specific tool (Stahl 2002, 1).

In regard to instrument-mediated activities, four main functions of the learning environment have been identified, namely as a meansto systematise individual representations, to regulate group work in pairs, to facilitate sharing and benefiting from the group's collective experience and to define one's relationship to other group-members. Beyond analysis of tool-supported activity in online environments, this paper contributes to the design of distance learning environments to enhance human interaction and collaboration.

¹ The terms “instrument” and “tool” will be used interchangeably and are opposed to “artefact”, following Rabardel (see 1.1). Due to space limitations, there will be no distinction between the terms “agent” (broadly used in HCI) and “user” (adopted by ergonomics scientists).

1. Post-cognitivist approaches to tool-mediated human activity

The material world provides opportunities to reorganize the distributed cognitive system to make use of a different set of internal and external processes (Hollan, Hutchins and Kirsch 2000, 176).

Under the generic term *post-cognitivist theoretical tradition*, Viktor Kaptelinin (2003), one of the most prominent researchers in the field of human-computer interaction (HCI), unites those theoretical approaches which treat the role of tools as mediators of human activity. The common characteristic of these approaches is that they attempt to overcome the cognitivist assumption, according to which human cognition is exclusively situated in the individual mind. According to Kaptelinin, there are four main theoretical frameworks that engage with the mediated nature of human cognition (especially by artefacts): cultural-historical psychology, activity theory, distributed cognition and the instrumental genesis approach. Due to space limitations, we propose only a short overview of these four approaches which move away from the traditional view of artefacts as simple add-ons to cognitive processes.

1.1. Key theoretical assumptions about tool mediation

Firstly, cultural-historical psychology should be considered as the epistemological foundation of all approaches investigating agent-tool dynamics. Initiated by Lev Vygotsky, it has been expanded by his disciples (Leont'ev, Luria and more recently Wertsch and Cole) under the term *sociocultural theory*. The theory claims that human action, on both the social and individual planes, is determined by the cultural, social and institutional context and is mediated by tools (“technical tools”) and signs (or “psychological tools”) (Wertsch 1991, 28). The term *mediation* has been adopted by sociocultural theory scientists to reflect the idea that all human action is *mediated*, either by humans, tools or signs (i.e. language).

Secondly, activity theory takes the concept of mediated action further by introducing the idea of systemic relations between an individual and his environment. Engeström (1987) and later on Kuutti (1995) attempted to define relations between elements of an activity and concluded that there are six fundamental items which mutually influence and dynamically configure one another in the framework of an activity. These six items are subject, object, tool, division of labour, rules and community. Briefly, activity theory can be seen as a serious attempt to provide both a systemic model of dynamic relations between components of an activity and corresponding methodological tools.

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A complement to the dynamic view of tool mediation is the *instrumental genesis approach* introduced by the French-speaking ergonomics scientist Pierre Rabardel (1995). First of all, Rabardel establishes a clear distinction between *artefact* and *instrument*. While the former refers to an entity not yet manipulated by users, the latter designates both the artefact and the subject's activity. Since an instrument is a “composite entity” made up of the subject (intentions, psychological implications) and the artefact (technical structure), the focus is on the “*dialectical transformation of artefacts and social schemes, during which the individual and his resources [...] develop*” (Beguin and Rabardel 2000, 186). Rabardel coins the term *instrumental genesis* to refer to the dynamic process that is mutually determined by individuals and instruments. Additionally, since users turn artefacts into instruments to give meaning to their everyday practices, the design of artefacts becomes a design-in-use process as users manipulate, adjust and configure tools according to their needs (cf. 1.2).

Finally, the distributed cognition paradigm is the fourth (and perhaps the most rigorous) epistemological framework to conceptualise the agent-tool dialectical relationship. According to Edward Hutchins, founder of this paradigm, and his colleagues, “*unlike traditional theories, [distributed cognition] extends the reach of what is considered cognitive beyond the individual to encompass interactions between people and with resources and materials in the environment*” (Hollan, Hutchins and Kirsch 2000, 175). The unit of analysis consists of small socio-technical systems (or *functional systems* in Hutchins' terminology) and especially the functional relationships between system elements. Another feature of the distributed cognition approach which is fundamental to our research is the need for instrument-mediated activity analysis to inform the design of tools, such as applications to support human-computer interaction.

1.2. Implications for interaction design

Linking theoretical assumptions about HCI to the design of human-computer interfaces is not a preoccupation shared by all cognitive theories treating the understanding of human interaction with the world. Hence, the question of artefact design based on people-in-action situations is mainly addressed by the distributed cognition paradigm, the instrumental genesis approach and activity theory. *In situ* observation of tool use offers a particularly insightful means of informing the design of computer interfaces for human learning and work. It also bridges the gap between “design-for-use” (by designers) and “design-in-use” (by users), according to Rabardel and Waern (2003). This idea is reflected in activity theorists Kaptelinin and Nardi's definition of interaction design as “[*comprising*] all efforts to understand human engagement with digital

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technology and all efforts to use that knowledge to design more useful and pleasing artefacts” (2006, 5). The development of computer interfaces to support human individual or collective activities is also addressed in the very promising interdisciplinary field of Computer Supported Collaborative Learning (CSCL, Suthers 2006).

For the purposes of our research the term *distributed learning environment* will be used to emphasise the social and material embeddedness of learning through a digital interface (Pea 1994). The principal research objective is to investigate the way in which tools facilitate human interaction, that is, how they support (or disrupt) instrument-mediated practices. Opportunities for the design of digital work materials will also be addressed (cf. 4).

2. The study

2.1. Context

Our study draws on the experimental project “Le français en (première) ligne”, initiated in 2002 and conceived to support the design and tutoring of online tasks for distance-learning students. This research project has a double goal: on the one hand to train Masters students in Teaching French as a Foreign Language in the creation of multimedia tasks for distance learners and on the other hand, to foster online communication between these two groups in relation to the tasks².

This article will draw on data from the year 2002-2003, when sixteen students enrolled in a Master of French as a Foreign Language at the University of Franche-Comté (Besançon) completed a 25-hour course on ICT for foreign language education. Divided into eight pairs and assisted by a lecturer and a PhD student, the French students designed multimedia activities for a group of Australian students from the University of Sydney studying beginner French. In this paper we will focus on the network-based multimedia creation practices undertaken by the French students.

² For a more detailed project description and research publications see the project website: <http://www.u-grenoble3.fr/fle-1-ligne>

2.2. The digital learning environment

With a view to supporting the creation of multimedia learning activities, a group learning support system (Lotus QuickPlace) was provided. This tool (or groupware) comprised the following spaces (fig. 1):

- Eight “workrooms”, designated by a letter from A to H, one for each pair (listed on the left banner page).
- A “shared materials” space, depository of common resources for the whole group (ideas and hints, links, sound and video files, texts, etc).



(Figure 1: Groupware home page).

When configuring the groupware, the project co-ordinators opted for free access to all spaces for all participating students. More specifically, all students had the right to navigate in all “rooms” (reader access), but to manage content (create, modify and erase content and folders) only in the space belonging to his/her pair (author access). This decision has been found to be crucial for the cognitive mechanisms triggered by this tool (cf. 3.2-3.4).

2.3 Methodology

Following a multi-method qualitative ethnomethodological approach, three classes of data will support our analysis: answers to a post-experiment questionnaire (eleven questionnaires collected), transcripts of eight semi-directed interviews of about half an hour’s duration (one interview per pair) and

all types of multimodal fragments deposited in the groupware, whether with a view to communication (posts and replies) or not (i.e. raw materials for multimedia creation)³. Our objective in combining multiple sources of data is to increase the reliability of results by examining a phenomenon from several perspectives, that is the “triangulation” approach (Van der Maren 1999). Interview extracts are followed by the interviewee’s name (e.g. “Bettina 1” for extract 1 from the interview with Bettina)⁴, while extracts from the questionnaires are denoted “quest” (for example “quest 1” for an extract of the first questionnaire).

3. Instrument-mediated activity through the distributed environment

In this section we will analyse the way in which the functional system is constructed from tool *affordances* (in terms of potential and constraints, Norman 1988) and users' intentions regarding knowledge construction and interaction. Four tool functions will be identified in relation to tool-mediated cognitive processes. The first three relate to meaning-making practices in the distributed environment, while the fourth is linked to the tool’s role in interpersonal relations. We will progress from individual-driven to collective and inter-individual practices.

3.1 The groupware as a tool for systematising and externalising cognitive processes

Throughout the semester, students uploaded materials to the groupware which they considered to be useful for the design of multimedia activities. These objects for re-use ultimately comprised sound and video clips, hyperlinks, ideas for further development in text format, drafts and preliminary forms of activities to be discussed with the other member of the pair, etc. We will call these resources *multimodal fragments*.

These raw resources (downloaded from the Internet or developed by the students) were stored in two spaces: in each pair's room and in the “shared materials” folder, common to all pairs. Symbolically speaking, the progressive uploading of raw and composite resources to the groupware allowed the “material” dimension of these heterogeneous objects to emerge fully. To borrow an expression that Christian Vandendorpe uses to stress the societal revolution

³ For a detailed description cf. Zourou 2006b.

⁴ Note that all names have been changed for privacy reasons.

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instigated by the invention of writing, “*the productions of the mind entered the objective space of the visible world*” (1999, our translation).

The externalisation of individual cognitive properties was thus made possible through mediation by the distributed learning environment. This idea draws back to Crook's concept of “points of shared reference” (cited by Lehtinen 2002, 115) as tool-driven anchors for the mutual sharing of information, as well as for the co-ordination of attention and action in a shared digital space (fig. 1). Appearing on the screen, multimodal fragments are “crystallised” on three levels: the individual, the pair (allowing partners to see, keep track of and coordinate their accomplishments over time) and the group level (facilitating the location of other pairs' work and being aware of their colleagues' progression and achievements, cf. 3.3). Hutchins (2005) also proposes the concept of *material anchors* to emphasise the role that objects play in stabilising mental structures. An example is given below: the contents of pair A's “ideas” folder.

Title▼	Author▼	Modified▼
Activity on French singers	XXXX	30/10/2002
We work on 4 different singers. For that reason we use singers' photos. Links towards bios of singers and lyrics of their songs. Cultural/civilizational aspect : matching exercise of four photos A to D...		
Working the plural form	XXXX	30/10/2002
Material : photos+ recordings of original dialogues: at the open air market (vendor and client), at the «citadelle»museum (guide and tourist) on the road (asking for directions to a policeman), faculty (professor and student), in a café.		
Expressing tastes	XXXX	04/11/2002
It's about a dialogue between a girl and a boy (for facilitating voice recognition). The two persons have a conversation on their personal tastes on different subjects such as music, cinema, cooking.		
Being lost	XXXX	04/11/2002
The aim of this exercise is to know how to ask information to someone (pedestrian, policeman...) when one is lost. Learners will exercise the «tu» and «vous» form while asking to a stranger. Exercise to be done in dyads.		
Greetings	XXXX	05/11/2002
Kissing is a way to say hello and often is a shocking experience for foreigners. Images of persons greeting each other		
Pages 1 - 5 of 6.		

Figure 2: the contents of pair A's “ideas” folder.

The idea expressed by Vandendorpe (1999, 20) that writing modifies not only an individual's relation to his thoughts but also to the thoughts of others, as far as cognitive processes are objectified by the text, is also valid for the distributed learning environment under examination. The groupware facilitates the externalisation and especially the interweaving of internal cognitive

Beyond the Brain: Embodied, Situated and Distributed Cognition processes, and their management through an external memory support (Sperber 2001).

The “crystallisation” of internal representations of a digital artefact is also related to cognitive systematisation and organisation. More importantly, not only is it possible to make individually located representations “visible”, but also to make them a source of conceptualisation, negotiation and transformation between partners, thus to collectively create and share knowledge.

3.2. The groupware as a tool to regulate pair functioning

Traditionally, shared learning environments are used to provide groups with co-ordination tools to achieve their working goals. This is the idea expressed in the following extract:

It is a pity that we don't use this groupware in more university courses; it is a database, every one adds his/her ideas; when we don't have time to brainstorm in class, it doesn't matter, we can find all that on the groupware [Bettina 1].

I think that [the groupware] was essential since everything was saved there; for us, it was a means of easily finding our resources and work, our ideas, and also it was a space where we could share ideas with everyone [Sylvie 1].

These examples stress the organisational aspect of the groupware, which is a basic functionality of the system. We will go further by investigating the impact of tool manipulation on the collective processes of work regulation afforded by the shared environment. Each pair was able to arrange its working room according to its needs. Creating folders to index and organise resources was the most widespread organisation process. Nevertheless, differences in arrangement of the working spaces (as they result from the creation and management of folders) occurred.

There were two main organisational modes. In the first mode, pairs created as many folders as the multimedia activities that they intended to design (this arrangement was by “by accomplished object”) while sorting materials in each activity folder. The second mode consisted in creating folders corresponding to the successive stages of their work⁵. The organisational principle here was progression in the project’s development on the diachronic level. As an example of the second mode, pair “D” started by creating a folder for the initial stage of brainstorming (“ideas”), passed to the “drafts of activities and tasks” folder, continued with the “exercises” and then the “finalised presentations” folder.

⁵ Due to lack of space, only an overview of the spatial management practices is provided. For a more detailed analysis and diagrams on this issue cf. Zourou (2006b).

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A general remark may be made, based on an overview of all pairs' folder menus: the attempt to separate drafts from finalised products. Extracts from the interviews and questionnaires also stress the need to control and regulate progressively the elaboration of the project:

The ability to separate drafts from finished work is a big advantage for accelerating our work (Quest 6).

The final public assessment session obliged us to have a good copy (Quest 4).

[The groupware] was just a depository for all materials. And was it nevertheless important? Euh... yes, we had a lot of "rubbish" [laughs] (*Claire I*).

Spatial organisation comprises an important cognitive dimension which is essential for sorting, understanding and organising objects. Differences in the instrumentation of pairs' workspaces (and by extension, differences in group functioning) are obviously related to different types of tool conceptualisation. In fact, modes of management of the working space resulted from the encounter between two structures: on the one hand, the symbolic system of the groupware (flexible enough, allowing users to add, change and remove materials and folders) and on the other hand, the pairs' cognitive processes (in their attempts to structure and take control of their work).

According to Beguin and Rabardel (2000, 179), these two types of structure, the psychological and the artefact, constitute the (composite) entity of the mediating instrument and are resources that the user jointly mobilises in the accomplishment of a tool-mediated task. In light of our analysis, the artefact composition (the pre-existing symbolic space that afforded action and tool manipulation), on the one hand, and user-driven attempts to arrange and manage individual workspaces, on the other hand, mutually determined the object-oriented activity (here, the organisation and regulation of modes of work).

3.3. The groupware as a tool reorganising collective work dynamics: the emulation effect

Up to this point we have identified instrument-mediated practices which relate to the organisation and spatial arrangement of cognitive resources in pairs. In this section, we will focus on the group level to discuss the effect of groupware manipulation on collective modes of functioning. We will focus, in particular, on the impact that free access to all spaces had on the relations that users established with computer-supported group functioning processes and meaning making practices.

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On a general level, the ability to have access to other pairs' progress, (in other words, materialisation on the screen of others' evolutionary trajectories over time) seems to have encouraged pairs to greater efforts in multimedia creation, as Candice explains in the extract below:

I also went there to see other groups' accomplishments (...) in fact; it was a kind of challenge: had they [other pairs] advanced more quickly than us? What had they done? When I saw that others had created four activities or that they had advanced a lot, while we still hadn't done anything, I thought "well, OK, it's now high time to start working" (Candice 1).

Candice affirms the influence of her colleagues' achievements on advancing her own work. She built an individual representation of the state of other pairs' collective work by navigating in her colleagues' workrooms. This cognitive effort functions as a stimulus for more commitment ("*It's now high time to start working*"), which determines organisational, planning and co-ordination practices within her pair.

To account for this computer-mediated practice, it is of benefit to invoke "emulation", the attempt to equal or surpass another. In our example, emulation has been facilitated, or even instrumented, by the appearance on the screen of each pair's accomplishments, as a kind of "materialisation" of their progress, or lack thereof (Mangenot and Zourou 2005, 65). For Candice, emulation was crucial since the appearance of pairs' achievements on a common digital tool enabled her to relate her pair's progress to that of her colleagues. In the following examples, Bettina and Alphonse attempt to compare other pairs' achievements to their own:

Yes, I had a look from time to time, so I wouldn't rest on my laurels, in fact, to see whether I was at the same level as everyone else and wasn't going down the wrong path. (Bettina 2)

Of course you took inspiration from the standard of work done by the others. Perhaps if we hadn't seen what the others had done, we wouldn't have achieved that standard ourselves. Because we were also inspired by what everyone else did after they saw that some of our colleagues already had for or five exercises. We wanted to do as well, if not better, than the others; thus, this way of seeing what the others had already done helped us a lot in improving our work. (Alphonse 1)

We could thus suggest that the groupware tool enabled self-positioning with respect to the achievements of other pairs. Designing multimedia activities resulted from a sociocognitive process within pairs, a process that was made visible and explicit by its appearance on the screen, and which then affected collective functioning between pairs.

Encounters between individual and collective representations, the back and forth movement between pairs' spaces and the group's common space, and the

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practice of striving for better results compared to the work-in-progress of other pairs are seen to be tool-enabled collective working processes. Readjustments upon consultation of others' accomplishments ("It's now high time to start working" [Candice 1], "I consulted their work to see whether I was at the same level as everyone" [Bettina 2], or even "seeing what our colleagues were doing was helpful in improving our work" [Alphonse]) show at what extent the free navigation of other pairs' workrooms influenced tool-mediated mechanisms like the co-ordination and management of collective action.

We thus turn to the individual-collective continuum which several researchers put forward (Salomon and Perkins 1998) in a move away from a strict distinction between the individual and collective poles. The two following extracts from questionnaires demonstrate this continuum:

The fact that work was public was motivating since you can always learn from the others (Quest 1).

[The fact that work was public] is a stimulating feature since we know that we're not just working for ourselves but as part of a group. (Quest 2).

At this stage we should mention the concept of *cognitive apprenticeship*, which, according to Brown, Collins and Duguid (1989), designates the way that knowledge is shared between pairs. By extension, users' attempts to conceptualise the evolution of other pairs' work and to build up meaning through heterogeneous sources of knowledge and fragmented information (since at that stage only drafts of activities were available) can be seen as a network-based type of *cognitive apprenticeship*. The endeavours to be "at the same level" as other pairs (Bettina) or "to be inspired by their activities" (Alphonse) constitute, in our view, intentional processes which were developed without recourse to verbal interaction between pairs. In this regard, we could invoke the process of *grounding*, which implies the attempt to create a common basis for mutual comprehension (Clark and Brennan 2001). In our view, the multimodal fragments created by the students were used as a common reference point in non-verbalised mutual regulation (Zourou 2006a).

3.4. The groupware as a tool redefining relationships to others

The majority of students confirm that using the groupware was beneficial in managing and regulating work in pairs, in sharing resources, as well as in viewing updates on their colleagues' accomplishments. However, Christelle, one of the students, views the groupware from a different perspective, expressing her doubts vis à vis free navigation through pair workrooms:

I know that [my partner] navigated much more in other pairs' rooms. I don't know why; I didn't look at all. I just looked at the audio files, or visual ones, from amongst the shared materials, that's all. I... Perhaps... out of respect for

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what the others were doing. I think that there should be something like that. To avoid... Well, after all, it is their own work, why should you stick your nose into something before it's finished? (Christelle 1).

Christelle's attitude of avoiding navigation in other working rooms out of politeness towards the other pairs' outcomes, does not result, in our interpretation, from an individualistic working method which is opposed to the potential exchanging and sharing of resources. On the contrary, it reflects a stance which considers the consultation of others' work as an intrusion of their personal space. According to Christelle, there is a clear boundary between "private" space (pair workrooms) and "public" space (rooms common to all students). Christelle's attitude, in that she wished to keep her pair's preliminary work apart from her colleagues' inspection, is directly related to interpersonal issues as mediated by tools.

From this point of view, isn't free access to pairs' work before finalisation equivalent to transgressing the limits of public and individual spaces enabled by the tool? Free access to pair and common rooms that resulted from tool affordances, as well from the coordinators' decision, is thus seen to be in opposition to fairly traditional representations of the private/public boundary in a digital environment. Although the collective working environment was designed to foster cognitive apprenticeship online (and mechanisms as emulation arose from open access), we cannot ignore differences in user attitudes to the question of knowledge distribution and the form of network-based interaction.

4. Conclusion

Identifying four functions of the groupware has been crucial for stressing the close relationship between tools' affordances and users' intentions: the basis of the functional system, which feeds interaction considerations into the design of digital learning environments.

First of all, our analysis allows us to confirm that the design and configuration of an artefact have consequences on the way the users (inter)act (with)in the technological environment. For example, the accessibility of all spaces within the groupware generated socio-cognitive processes which, on the one hand, were largely beneficial (as for example the mechanism of technology-enhanced emulation), but on the other hand, were also problematic (Christelle's reluctance to open access). Such different reactions to the same tool-mediated activity imply a need for holistic, qualitative studies focusing on collective, but also individually driven, tool manipulation practices. The processes by which users transform the artefact into an instrument (Rabardel and Waern 2003, 644) are particularly informative in relation to interaction design.

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In addition, a certain degree of openness of the distributed environment seems to be necessary to support collaboration beyond pair work. Students' right of access to all spaces modified their relationship to knowledge; more precisely, it encouraged them to invest more effort in their own projects (cf.3.3). Groupware modularity allowing workrooms to be configured depending on pairs' design needs has been found crucial in knowledge management, which is a key feature in the development of metacognitive processes (cf. 3.2). Taking into consideration issues like flexibility and modularity when designing human-machine interaction artefacts appears to be fundamental.

Nevertheless, we do not claim that free access to all spaces of the environment should be regarded as a panacea or as a recipe suited to all learning environments. Although externalisation of individual cognitive processes has been made possible by means of the groupware, understanding and meaning-making mechanisms require the activation of far more complex cognitive processes than merely displaying digital content on the screen. In our analysis, the processes of knowledge construction through multimodal fragments, of systematisation of individual cognition and of coordination of work stimulated by emulation appeared as collective mechanisms which wouldn't have occurred without the instrument's mediation.

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