Baker, M., de Vries, E., Lund, K., & Quignard, M. (2001). Computer-mediated epistemic interactions for co-constructing scientific notions: Lessons learned from a five-year research programme. In P. Dillenbourg, A. Eurelings, & K. Hakkarainen (Eds.), *European perspectives on computer-supported collaborative learning : proceedings of the first European conference on computer-supported collaborative learning* (pp. 89-96). Maastricht : Unigraphic.

Computer-mediated epistemic interactions for co-constructing scientific notions: Lessons learned from a five-year research programme

Michael Baker[a], *Erica de Vries*[b], *Kristine Lund*[a], *Matthieu Quignard*[a]

[a] UMR 5612 GRIC, Research Group on Communicative Interactions, CNRS & Université Lumière Lyon 2, 5, av. Pierre Mendès-France, 69676 Bron Cedex, France. `{mbaker, lund, mquignar}@univ-lyon2.fr`
[b] Laboratory for Educational Sciences, University of Grenoble II, BP 47, F-38040 Grenoble cedex 9, France. `Erica.deVries@upmf-grenoble.fr`

Abstract. This paper reports on a five-year collaborative research programme, the aim of which was to create Computer-Supported Collaborative Learning Environments that favoured and supported the production of epistemic interactions for the co-construction of scientific notions. Three systems (C-CHENE, CONNECT and DAMOCLES) were developed and experimented with science problem-solving tasks within constraints of the French secondary school curriculum. A number of issues were explored in relation to our research goals, including: structuring the communication interface, statistically or automatically constituting dyads to favour conceptual confrontation, summarising points to be debated, and studying/defining the teacher's multiple roles in CSCL contexts. We discuss limitations of our research and bring out lessons that have been learned from this research programme, concerning notably: freedom and constraint in the communication interface, structuring collaborative problem-solving sequences, richness and negotiability of environments, interrelations between cognitive, epistemic and social dimensions of interaction, and evolution of new educational practices.

Keywords : interaction, argumentation, explanation, conceptual learning in science, CMC

Introduction

Interactive linguistic exchanges between people play an essential role in the elaboration and perpetuation of scientific concepts. This is so for several reasons on different levels. Firstly, scientific concepts are not to be found in nature, they are cultural products; and this cultural heritage, despite being largely expressed in written language, is kept alive in situations that involve social linguistic interaction (VYGOTSKY). Secondly, although conceptual acquisition and change may occur in children as a result of interaction with objects of the inanimate world, the use of objects is usually situated within larger social interactions (*pace* PIAGET), in which case the objects are termed tools. Although tools in didactic situations can be designed to give appropriate feedback, the meaning of feedback depends on explanations and negotiations mediated by language. Thirdly, concepts are intimately associated with signs, of which they constitute the signifiers (SAUSSURE) within sign-systems such as languages, the primary use and mechanism of acquisition of which is social interaction (BAKHTINE). Notwithstanding Vygotsky's analyses of the processes by which children elaborate scientific concepts, their processes of interactive elaboration remain largely to be elucidated.

Our working hypothesis is that certain types of interactions are conducive to the elaboration of scientific concepts in teaching-learning situations. Particularly, we postulate that explanatory and argumentative interactions play a role in the co-construction of scientific notions. Following Ohlsson (1995), we term these *epistemic interactions*, since they are potentially concerned with the expression and critical examination of foundations for proposals. They can involve several interactive processes (Baker, 1999) ; for example, under the pressure to defend their views and to critically evaluate those of their partners, students may be led to explain (Webb, 1989; Renkl, 1997), to produce a more articulated discourse (Crook, 1996), to elaborate meanings, to clarify views and to change their degrees of commitment towards them.

However, a major problem arises: people do not argue or explain with respect to any topic, with anyone and in any situation (Golder, 1996). Our earlier studies, in both the classroom and in computer-mediated situations revealed that students do not spontaneously argue or explain very often and in a very extended way, especially with respect to scientific notions. Our main aim is thus to understand why this is so, and to discover the specific situations in which students *will* be led to argue and explain about science. Factors involved include the domain of discourse, students' knowledge of the practices of explanation and argumentation, and social and communication situations. One approach would be to choose a contentious topic and to ask different students to play *pro* and *contra* roles with respect to it (c.f. Resnick, et al., 1993). We did not adopt this approach since we want epistemic interaction to arise spontaneously (albeit in a constrained situation), as an integral part of the science problem-solving activity: students should be explaining and defending their *own* views, towards which they have a certain degree of genuine commitment.

We explored these research problems through the design and experimentation of successive prototype Computer-Supported Learning Environments (CSCL), incorporating specifically adapted interfaces for quasi-synchronous typewritten computer-mediated communication (CMC). This choice may appear paradoxical, given that cognitive constraints of such interfaces are now well known (c.f. Clark & Brennan, 1991). However, CSCL environments provide the researcher with the possibility of structuring both the overall task sequence and the communication itself. They also provide resources (e.g. interaction histories) that could compensate for utterance production and interaction management problems. We have developed and experimented three systems (C-CHENE, CONNECT, and DAMOCLES) for learning about concepts in physics (energy and sound) and environmental studies (prevention and treatment of air and water pollution). The problem-solving tasks were specifically chosen for their openness and richness with respect to the variety of student conceptions.

In the rest of the paper we summarise the research programme, carried out over a period of around five years, referring to already published work (to which readers are referred for details of supporting data and analysis techniques), together with some unpublished work, with a view to bringing out more general lessons learned. Our hope is that such a synthesis will help to define more precise aims for future research.

C-CHENE

C-CHENE[1] is a CSCL environment for co-construction of the concept of energy in physics (Baker & Lund, 1996, 1997). Dyads of students use C-CHENE to construct diagrams called energy chains — qualitative models of storage, transfer and transformation of energy for simple experimental situations (Tiberghien & Megalakaki, 1995) — and to exchange synchronous typewritten messages.

Our main aim in designing and experimenting the first of two C-CHENE interfaces (chat-box interface) was to get a grasp of the main differences between CMC and face-to-face interactions[2]. The chat-box interface was experimented with four dyads from the same secondary school class (friendship pairs, aged 16-17 years). After a brief training period, the pairs solved three energy chain problems at a distance via the network, with full screen sharing.

The comparison of face-to-face and chat-box interactions revealed some predictable and less predictable results. Not surprisingly, the chat-box interactions contained very many less turns (58 on average) than the face-to-face ones, for an equivalent amount of time (30 minutes). This is not necessarily negative, since it depends on what the students were saying and doing. More importantly, three principal results were found.

- Analysis revealed that although the students said less with the chat-box interface, their utterances were pruned down to expressions of more complex modelling processes in physics (Tiberghien & de Vries, 1997).
- Students using the chat-box interface engaged very little in epistemic interaction (on average, 4 out of 58 interventions, 7 % of the interaction), usually contenting themselves just to draw the graphical solution.
- Rather than co-constructing solutions, students often restricted themselves to a form of cooperation that could be described as “you draw the solution, I’ll criticise if I don’t agree”.

In addition, we noticed how students sometimes invented and negotiated unexpected uses of interface resources. For example, some students in fact used the button that was designed for attracting the partner' s attention for coordination between the energy chain construction and the communication mode of the system, i.e. as a signal that they would switch modes.

On the basis of these results, we hypothesised that some degree of constraint on utterance production was not necessarily negative, and that providing some sort of communication buttons was a promising approach for facilitating utterance production and interaction management. We designed a second interface in which collaboration was structured by replacing each chat box with buttons for communicative acts. The buttons were designed on the basis of existing models of dialogue and collaborative problem-solving (Bunt, 1989; Baker, 1994), rational task analysis, and corpus analysis. They were grouped according to three basic functions: doing the task, coming to agreement, interaction management. Some buttons put a statement directly into the interaction history (e.g. “OK”, “Why?”), others provide a small free text window (e.g. “Because …”) and others still display menu choices for composing utterances (e.g. “I propose to …” <create a reservoir>).

This second dedicated button interface was also experimented with four dyads for the same task. Results of comparison with the chat-box interaction corpus (see Baker & Lund, op. cit.) were revealing and encouraging. Despite the fact that the average number of acts devoted to managing the interaction remained largely unchanged, with the dedicated interface the students engaged in a more task-focussed interaction (chat-box: 13 out of 58 communicative acts on average, 22%; dedicated: 24 out of 71 communicative acts on average, 34%), and they engaged in slightly more epistemic interaction, even though the amount was very small in each case (chat-box: 4 communicative acts out of 58; dedicated: 6 out of 71). We attributed this difference to the structuring of the interface. In general, students who had never used CMC before did not seem at all dissuaded by an interface that structured their communication almost entirely.

Several lessons were learned from this phase of our research:

- providing the right degree of constraint on typewritten CMC can in fact promote an interaction more focussed on reflexion and the fundamental concepts at stake;
- finding the right partners for collaborative problem-solving is crucial — our global results masked the fact that some dyads did not engage in epistemic interaction at all;
- students need to be able to adapt interfaces to their own needs — the designers' intentions and the students' situated uses of tools are distinct;
- problem-solving and interaction tasks need to be more interwoven via CMC in order to allow the emergence of a variety of forms of cooperation — students had a tendency to be drawn into the graphical task, to the detriment of communication. The chat-box interface enforces this separation while the dedicated interface integrates the graphical actions with the communicative acts.
- discussion during problem-solving remains difficult; discussion without problem-solving should be separated out as a distinct phase of the task sequence in order to help students concentrate on content.

These issues were pursued with the next system that we developed: CONNECT.

CONNECT

CONNECT[3] is a CSCL environment for critically comparing individuals' texts and for collaborative writing (see Baker, de Vries, & Lund, 1999; De Vries, Lund, & Baker, *to appear*). The design and experimentation of CONNECT enabled us to take our research project forward in several ways[4].

Firstly, it was clear to us that dyads had to be carefully constituted in order to create opportunities for epistemic interaction. In the CONNECT research we addressed this problem by asking students to write texts individually, which were then analysed in terms of underlying conceptions in the task domain, on the basis of which we constituted the dyads to maximise differences in conceptions.

Secondly, it is clear that the cognitive load imposed by performing a problem-solving task — such as writing a text or drawing an energy chain diagram — decreases the possibility of engaging in epistemic interaction *during* that task execution. We therefore structured the overall task sequence, as well as the communication, so as to impose an initial period during which individual textual solutions to a problem were critically compared and discussed.

Thirdly, we knew from our previous research that when invited to compare their problem solutions, students often avoid discussion and simply choose the one that appears best. We therefore wanted the students to perform some concrete activity in comparing their texts. For this, we asked them to express their opinions ("yes", "no", "?") with respect to segments of their texts. This activity of attitude elicitation could constitute a first step towards opposition of attitudes in argumentative interaction.

Fourthly, when students are asked to engage in explanatory and/or argumentative interaction, they do not necessarily understand what is expected of them. We therefore wanted to give them some guidance on how to carry out discussions.

These second, third and fourth points were addressed by providing students with an interface that — as with C-CHENE — comprised means for partially structured text-based communication (containing communication buttons for interaction and task management, a chat-box for typing messages and a commonly visible dialogue history) and for the task execution itself. The task interface allows to display individual student texts as a number of separate sentences and for students to express their opinion on each sentence of each text, i.e. *Yes* (I agree), *No* (I don' t agree), or ? (I don' t know). The combination of the opinions expressed for each sentence gives rise to the dynamic generation of a label representing an assignment, e.g. *Yes* and *No*, expressed by different students with respect to a given text segment, gives rise to a *Discuss* instruction (describing how argumentation should be carried out), *Yes* and *?*, to an *Explain* instruction, and so on.

Finally, we knew that if we simply asked students to compare and discuss their solutions, they would have difficulty in seeing the point of such an activity. We therefore asked students to discuss with a view to subsequently writing a common text. For this we provided a second interface, to be used after the first, that enables students to construct a common text on the basis of their individual texts.

CONNECT was experimented for a physics problem-solving task, requiring interpretation of a phenomenon of sound, with twelve secondary school students (six dyads). We chose this task since the variety of students' conceptions with respect to it create a large potential space of discussion, particularly with respect to concepts of vibration and propagation. The outcome of two students collaborating would not only be the quality of the products of the task itself (a graph, a text, a solution to some problem), but rather the emergent conceptions that the two students jointly construct in elaborating a solution (Roschelle, 1992).

Three types of results of the first CONNECT study should be mentioned here:

- Analysis revealed an important use of the "yes" and "?" opinion marks at the expense of the "no" opinion mark. Students seemed to be reluctant to overtly disagree with a sentence of their partner; rather, they expressed requests for clarification or explanation.
- With respect to main interaction categories, results showed a higher amount of explanation and argumentation in the first discussion phase as compared to the second text writing phase. However, task and interaction management still occupied an important part of the students' interaction.
- We also conducted detailed analyses of how students jointly construct meanings of domain notions. We found clear examples of conceptual differentiation in which students disentangled their differences by collaboratively refining the meaning of words and expressions. Yet, there were also cases in which student dialogue about domain notions did not lead to significant conceptual progress but that nevertheless constituted opportunities for pointing out aspects that needed explanation by a teacher.

In global terms, CONNECT was more successful than C-CHENE in promoting epistemic interaction, due to a complex combination of factors, notably the specific method for dyad constitution and overall structuring of the task sequence to encourage critical reflexion and attitude formation. Nevertheless, the degree of epistemic interaction in the discussion phase (56 %) did not appear as high as it could have been, given that this phase was intended to be entirely based on that activity. Three main points arose that we attempted to address in subsequent work:

- students are reluctant to express disagreement, this may be so because of its potential threat to their social relation;
- hand-done analysis of solutions for dyad constitution is far too time-consuming and could be based on a larger set of criteria than semantic-conceptual differences between individual solutions;
- the teacher's role needs to be considered —students themselves sometimes postpone epistemic or other discussion whilst explicitly stating that they would have to ask the teacher.

These issues were pursued with DAMOCLES and with studies relating to the teachers' roles.

DAMOCLES

DAMOCLES[5] is a system for computer-mediated collaborative construction and argumentative discussion of energy chains. Its principal aim is to favour argumentative interactions and to provide a research tool for modelling resulting cognitive changes. Important features include automatic constitution of dyads on the basis of automatic analysis of individual solutions, and automatic generation of summaries of the common ground of potential debate.

As in CONNECT, DAMOCLES imposes a specific structure on the students' individual and collaborative problem solving. We briefly describe this structured task sequence below together with the interfaces that were designed to support it, and their research rationales.

Cognitive confrontation between students is potentially sharpened if they have each produced, reflected upon and become committed to their individual problem solutions. It is potentially softened if cognitions are confronted whilst they are still in the process of elaboration (Nonnon, 1996). For this reason, students using DAMOCLES first draw individual energy chains. As argumentation is a language-based discursive activity, students can be helped to make the transitions between graphical and linguistic representations of their solutions (Cox & Brna, 1995). DAMOCLES therefore provides an automatic language description of the students' graphical solutions. These descriptions are then reproduced on a second interface that invites students to express their degree of certitude with respect to their solution elements, and to give explanations, justifications or reasons for them. This allows students to begin the subsequent discussion with elaborated arguments. The students can go back and forth between this reflective and language-based activity and their graphically represented solution until the process stabilises.

DAMOCLES then automatically analyses each individual solution on the basis of underlying conceptions and evaluates the argumentative potential of each possible dyad (see Quignard & Baker, 1999; Quignard 2000). The aim is to constitute dyads of students that drew energy chains based on different conceptions, followed differently the rules of the exercise and having different levels of correctness. Each of these differences may potentially give rise to requests for justification, attacks or negative evaluations in argumentative interaction.

The members of each dyad must know what they are to argue about. On the basis of its prior automatic analyses, DAMOCLES therefore generates textual summaries of the principal differences between students' solutions. These summaries are reproduced on a final interface, similar to the communication interfaces of C-CHENE and CONNECT, on which students are invited to engage in a typewritten CMC debate.

The final stage of the DAMOCLES task sequence mirrors the first stage : students are given the energy chain interface and asked to individually draw the energy chain on which they finally agreed with their partners. This enables the researcher to evaluate the degree of shared understanding and commitment, as well as to compare these final solutions with the initial ones, with the aim of modelling the influence of argumentation dialogue on cognitive change.

DAMOCLES was tested with eight secondary school students (aged 16 to 18)[6]. Their discussions lasted nearly one hour (64' for 35 to 60 turns). In cases that can be characterised as successful (three out of four dyads), argumentation emerged spontaneously after around three minutes following presentation of the verbal conflict situation. The average proportion of argumentation in these successful dialogues was 74% — an increase in comparison with CONNECT (56% epistemic interaction, i.e. *explanatory* as well as argumentative interaction). Three important points should be noted :

- students were able to express explanations/justifications for all of their solution elements in the second phase of the experiment; this was not at all obvious;
- there was a strong correlation between these prior explanations/justifications and the actual arguments expressed during dialogue;
- there was also a strong correlation between the common solutions as described by the students individually at the end of the sequence and the common solution expressed in the dialogue, which validates the sincerity of their argumentative activity (they were not just arguing because experimenters asked them to).

Finally, the crucial questions are: what did the students argue about, and what did they learn? The rating of the quality of initial and final energy chain solutions increased on average from 32% to 50%. But more importantly, in order to evaluate students' understanding of the concepts, task success was measured by looking at the quality of the dialogues. In fact, despite the highly argumentative nature, there was little evidence that their argumentative interaction dealt explicitly with the fundamental scientific concepts. Rather, it focussed mostly on the rules and constraints of the energy chain task, which is not surprising because invalidations of such rules constitute good potential argumentative attacks and refutations.

The lessons learned are quite clear:

- tt **is** possible to structure CSCL environments to favour epistemic interaction about scientific notions, but such environments must rely on a very complex set of factors and tools. In such environments the students require: 1) a debatable task, 2) cognitive preparation for debate, 3) multiple representations of their solutions, 4) the most compatible partners and 5) a clear idea of what is to be debated ;
- it may be too ambitious to expect argumentation dialogue itself to be a primary vehicle for co-construction of scientific notions. Argumentation dialogue may be a means for encouraging critical thinking and awareness about the task, for gaining a better understanding of what the problem is; afterwards, students in the DAMOCLES study did not only want to know what the right answer was, they also wanted the teacher to convince them of it; thus, epistemic interaction can be seen as complementary to teachers' work.

The final phase of our research programme deals with the question of what teachers' roles are and could be, with respect to supporting epistemic interactions between students, in CSCL environments for co-construction of scientific notions.

Studies on the teachers' roles[7]

In our fine-tuning of CSCL environments, the next step was to address the teacher's role in such situations. On one hand, students naturally seek the teacher's help when they realise that more information is needed to profitably continue an epistemic interaction. On the other, teachers are socially responsible for students learning: how can we help them to fulfil those responsibilities in CSCL situations? We address three questions: how can teachers help students, how can teachers be helped to help students, and how can teachers learn, be trained, as a result of helping students?

With respect to the latter question, teacher reflexion on videos of their own or others' teaching interventions has been the object of a growing body of research (Schön, 1983; Maheshwari & Raina, 1998), but little research has been carried out on the possibility that teachers can derive useful knowledge from observing or participating with their students in CSCL environments (c.f. Lund & Baker, 1999).

We have studied two of the many possible scenarios for teacher intervention in CSCL environments[8]:

1. *Off-line analysis preceding intervention*: the teacher studies the students' CMC interaction, then intervenes at a distance across the network in order to help them produce a better solution[9];
2. *On-line intervention*: the teacher observes the students' CMC interaction in real-time, and intervenes during it to help them

Studies in the first scenario directly followed on from the C-CHENE and CONNECT studies. The students' CMC problem-solving interaction trace was printed out, and the teachers were asked to analyse that transcription in a group discussion (C-CHENE), or individually (CONNECT), with a view to subsequently intervening in a trilogue at a distance, to correct the students' solutions. One of our current research questions concerns how these interaction traces/transcriptions should be structured on-line, so as to facilitate the teachers' analysis task. Analysis of the teachers' interactions revealed that they only considered around one half of the transcription elements: what guided this initial choice, and how could we structure or filter the transcription so as to facilitate a teacher's search?

In these studies, the teachers were asked to *explain* the students collaborative problem-solving processes in terms of their underlying conceptions. It should be noted that this is a very unusual situation for teachers to be in: they are not normally aware of the specific processes by which students work together. Analysis of the teachers' explanation activity in this context (Lund & Baker, 1999) has shown that such explanations can not be viewed simply as the elaboration of an explanation (*explanans*) for phenomena (*explananda*) that are already well defined. In fact, there is a continual process of negotiation between conceptualisation of 'what is to be explained' (what did the students mean) and the teachers' explanation(s) for it.

Secondly, although the teachers explained the students' problem solving from analysing the interaction traces, such analyses appeared to have no noticeable effects on the way in which they subsequently tutored the students on-line. Teachers made almost no interventions that were directly based on their analysis results. In the teacher-student-student trilogues, the teachers seemed mostly concerned with correcting the errors in the final student production. They used indirect intervention methods that are well attested: reformulating students' proposals to the target 'teacher' language (Wertsch, 1991), and asking students to comment on each others' proposals.

The study in the second scenario (on-line intervention) concerned the domain of environmental science (prevention of water wastage and pollution), with a slightly modified version of the CONNECT interface. Two dyad discussions of their individual texts were mediated at a distance by a Natural Sciences teacher and by a French teacher. Each teacher mediated one dyad and all participants were on their own machines with full screen sharing. At the end of the sequence, the dyads each wrote a common text, and each of the teachers observed their own dyad at a distance.

Analyses of the teacher-student-student trilogues revealed that the teachers played multiple roles: providers of information, managers of the students' interaction, and moderators of the students' debate. However, the teachers played these roles differentially, in accordance with their teaching domains: the environmental science teacher concentrated on information providing, the French teacher concentrated almost exclusively on managing the debate. An intriguing possibility would be to enable teachers to combine both roles — experts in their discipline *and* (relative) experts in moderating debates. In comparison with the previous studies, the presence of a teacher, whether as a participant or as an observer, clearly had an effect on the students' interaction. Argumentative activity was slightly increased and 'social talk' was reduced.

At the present state of advancement of the studies on teachers' roles and practices, we can mention two main lessons learned that were not at all foregone conclusions:

- experienced teachers are able to engage in an activity of explaining how students solve problems together, but they have difficulties in integrating this new knowledge into their existing teaching practices;
- in CSCL situations, teachers' existing practices need to evolve towards new multiple skills in order to fully exploit the potential of CMC interactions between students.

Ongoing work involves studying how analysis of interaction traces between students can be used in the context of initial teacher education.

Lessons learned

Having mentioned a large number of lessons learned, we now try to circumscribe the limitations of our work and to single out just seven of these lessons that seem to be the most important for further research.

Our work has been restricted to the learning of scientific notions. However, this is in a sense the hardest place to start: it is much easier to stimulate epistemic interaction with respect to contentious topics touching on everyday life, about which students actually care. The question therefore arises as to how we can stimulate students 'to care about' science. As we suggested above, if we *can* in fact encourage students to argue about science, then this itself may be a means of motivating them to want to know.

Our small-scale *in situ* studies have been conducted within a process of successive prototyping of interfaces. We have worked on a determinate set of very complex situations and interfaces, which makes it difficult to identify specific features responsible for epistemic interaction. Complex types of interactions require equally complex environments. We therefore postulate that a holistic, inductive and engineering approach is necessary in order to take into account such complexity.

Finally, based on the above synthesis of our research programme, the experimental details of which can be found in the cited published work, we list seven (debatable) lessons for future research:

1. *Freedom and Constraint* : Some degree of constraint on communicative interaction is not necessarily negative from the point of view of favouring epistemic interactions. The right degree of freedom and constraint can lead students to concentrate on the most fundamental aspects of the task
2. *Structuring collaborative problem-solving sequences* : CSCL environments for epistemic interaction can not be based on requiring students to perform single aspects of tasks; a complex overall task sequence needs to be carefully structured in which epistemic discussion is given a specific and carefully prepared place.
3. *Rich environments* : Epistemic interactions are complex in terms of the necessary connection between richness of the knowledge domain and of the interactive processes that are produced with respect to it. A CSCL environment that aims to favour such interactions will therefore also have to be rich and complex, in terms of types of semiotic representations involved, the variety of types of (non)discursive and (non)cooperative tasks required, and the existing conceptual points of views of collaborating partners.
4. *Negotiable environments* : Designers of CSCL environments should not confuse their intentions in developing tools for students with the actual way in which these tools are appropriated. Within certain limits, it could be preferable to build in the possibility that students can adapt and negotiate tools to their perceived needs.
5. *Epistemic interactions and scientific notions* : Epistemic interactions may be more a means of getting students to understand the problematic nature of tasks, of awakening critical reflexion, of motivating them to want to learn, than actual collaborative learning mechanisms *per se*. How can students argue about concepts that are still being co-constructed?
6. *Cognitive and social Interaction* : Knowing how CSCL technologies transform social relations between students is crucial in determining their joint cognitive activities. Social and cognitive aspects of argumentation are inextricably linked (c.f. Perret-Clermont, Perret & Bell, 1991). In the absence of co-perception, such technologies allow being-together whilst being-apart, and reflexion in interaction. Designing for cognitive cooperative activities is necessarily designing for social interaction.
7. *Evolving communicative and educational practices* : Favouring epistemic interactions in CSCL environments is not just a matter of task and interface design. Students and teachers do not necessarily know what to argue and to explain means, and what is expected of them in a CMC situation. The success of CSCL environments based on argumentation and explanation ultimately depends on the possibility of students and teachers evolving new practices from existing ones, on the elaboration of a new culture of computer-mediated epistemic educational activity.

Acknowledgements

The research described here was mostly carried out within the COAST team of the GRIC Laboratory, whose past and present members, together with teachers and pupils in the Lyon area, are generously thanked for their support. We acknowledge financial support from the EEC, the Rhône-Alpes Region, the French Ministry of Education and the CNRS.

References

Baker, M.J. & Lund, K. (1996). Flexibly structuring the interaction in a CSCL environment. In P. Brna, A. Paiva & J. Self (Eds.), *Proceedings of the EuroAIED Conference* (pp. 401-407). Lisbon: Edições Colibri.

Baker, M.J. & Lund, K. (1997). Promoting reflective interactions in a computer-supported collaborative learning environment. *Journal of Computer Assisted Learning*, *13*, 175-193.

Baker, M.J. (1994). A Model for Negotiation in Teaching-Learning Dialogues. *Journal of Artificial Intelligence in Education*, *5*, 199-254.

Baker, M.J. (1996). Argumentation et co-construction des connaissances. *Interaction et Cognitions*, *2* (3), 157-191.

Baker, M.J. (1999). Argumentation and Constructive Interaction. In P. Coirier and J. Andriessen (Eds.), *Studies in Writing: Vol. 5. Foundations of Argumentative Text Processing* (pp. 179–202). Amsterdam: University of Amsterdam Press.

Baker, M.J., de Vries, E. & Lund, K. (1999). Designing computer-mediated epistemic interactions. In S.P. Lajoie & M. Vivet (Eds.), *Artificial Intelligence in Education. Open Learning Environments: New technologies to support learning, exploration and collaboration* (pp. 139-146). Amsterdam: IOS Press.

Bunt, H.C. (1995). Dialogue control functions and interaction design. In R.J. Beun, M.J. Baker, & M. Reiner (Eds.), *Dialogue and Instruction, Modeling Interaction in Intelligent Tutoring Systems* (pp. 197-214). Berlin: Springer.

Clark, H.H., & Brennan, S.E. (1991). Grounding in communication. In L. B. Resnick, J. M. Levine, & S. D. Teasley (Eds.), *Perspectives on socially shared cognition* (pp. 127-149). Washington, DC: APA.

Cox, R., Brna, P. (1995). Supporting the use of external representations in problem solving: The need for flexible learning environments. *Journal of Artificial Intelligence in Education*. 6(2/3), 239-302.

Cox, R., McKendree, J., Robin, R. Lee, J., & Mayes, T. (1999). Vicarious learning from dialogue and discourse. *Instructional Science*, *27*, 431-458.

Crook, C. (1996). *Computers and the Collaborative Experience of Learning*. London: Routledge.

De Vries, E., Lund, K., & Baker, M. (*to appear*) Computer-mediated epistemic dialogue: Explanation and argumentation as vehicles for understanding scientific notions. *Journal of the Learning Sciences*.

Golder, C. (1996). Le développement des discours argumentatifs. Lausanne: Delachaux et Niestlé.

Lund, K. & Baker, M.J. (1999). Teachers' collaborative interpretations of students' computer-mediated collaborative problem-solving interactions. In S.P. Lajoie & M. Vivet (Eds.), *Artificial Intelligence in Education. Open Learning Environments: New technologies to support learning, exploration and collaboration* (pp. 147-154). Amsterdam: IOS Press.

Maheshwari, A.N. & Raina, V.K. (1998). In service training of primary teachers through interactive video technology: an indian experience. *International Review of Education*, *44(1)*, 87-101.

Nonnon, E. (1996, December). Activités argumentatives et élaboration de connaissances nouvelles: le dialogue comme espace d' exploration*Langue Française*, *112*, 67-87.

Ohlsson, S. (1995). Learning to do and learning to understand: A lesson and a challenge for cognitive modeling, In P. Reiman and H. Spade (Eds.), *Learning in Humans and Machines: Towards an interdisciplinary learning science* (pp. 37-62). Oxford: Elsevier Science.

Perret-Clermont, A-N., Perret, J-F., & Bell, N. (1991). The Social Construction of Meaning and Cognitive Activity in Elementary School Children. In L.B. Resnick, J.M. Levine, & S.D. Teasley (Eds.), *Perspectives on Socially Shared Cognition* (pp. 41-62). Washington D.C.: APA.

Quignard, M. & Baker, M.J. (1999). Favouring modellable computer-mediated argumentative dialogue in collaborative problem-solving situations. In S.P. Lajoie & M. Vivet (Eds.), *Artificial Intelligence in Education. Open Learning Environments: New technologies to support learning, exploration and collaboration* (pp. 129-136). Amsterdam: IOS Press.

Quignard, M. (2000). *Modélisation cognitive de l'argumentation dans le dialogue: étude de dialogues d'élèves en résolution de problème de sciences physiques*. Unpublished thesis in Cognitive Science. Grenoble: University Joseph Fourier.

Renkl, A. (1997). Learning from worked-out examples: A study of interindividual differences. *Cognitive Science*, *21*, 1-29.

Resnick, L.B., Salmon, M.H., Zeitz, C.M., Wathen, S.H. & Holowchak, M. (1993). Reasoning in conversation. Cognition and Instruction, 11(3&4), 347-364.

Roschelle, J. (1992). Learning by collaborating: Convergent conceptual change. *Journal of the Learning Sciences*, *2*, 235-276.

Schön, D. (1983). *The Reflective Practitioner*. Aldershot: Arena Publishing Limited.

Tiberghien, A., & De Vries, E. (1997). Relating characteristics of learning situations to learner activities. *Journal of Computer Assisted Learning*, *13*, 163-174.

Tiberghien, A. & Megalakaki, O. (1995). Characterization of a modelling activity for a first qualitative approach to the concept of energy. *European Journal of Psychology of Education*, *10*, 369-284.

Webb, N. (1989). Peer interaction and learning in small groups. *International Journal of Educational Research*, *13*, 21-39.

Wertsch, J. V. (1991). *Voices of the Mind. A Sociocultural Approach to Mediated Action*. USA: Harvester Wheatsheaf.

---

[1] C-CHENE means Collaborative CHENE. CHENE means CHaîne ENErgétique (energy chain)

[2] We already collected and analysed an extensive corpus of classroom interactions (see e.g. Baker, 1999). The corpus, in the original French, is available at: http://sir.univ-lyon2.fr/GRIC-COAST/DRED/default.html

[3] CONNECT stands for Confrontation, Negotiation, and Construction of Text

[4] E. de Vries' research was carried out when she was a visiting post-doctoral researcher in the COAST team

[5] DAMOCLES means Dialogues Argumentatifs Médiatisés par Ordinateur pour la Compréhension de l'Energie en Sciences (Computer-Mediated Argumentative Dialogues for the Comprehension of Energy in Science). The system was developed and experimented as part of M. Quignard's PhD thesis

[6] Constituting 4 dyads out of the 8 students required the algorithm to consider a large number of possible combinations.

[7] This work was carried out as part of K. Lund's PhD thesis.

[8] For example, the teacher could 'come in cold' on an interaction between two students, with no previous knowledge of its context (as when a teacher walks around a classroom where the students are working in small groups).

[9] C.f. Cox, et. al. (1999) on vicarious learning from dialogue: in our case the learners are teachers rather than students.