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Flexibly structuring the interaction in a CSCL environment

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Abstract: We describe two communication interfaces of the C-CHENE Computer-Supported Collaborative Learning ("CSCL") environment that is used for solving physics problems at a distance in a network. The first manages text-based interaction using 'chat-boxes', and the second *flexibly structures* the interaction by providing a restricted set of communicative acts. Results of analyses of communicative acts generated in interactions with the two interfaces suggest that such flexible structuring may facilitate and encourage more knowledge-based and explanatory interactions, to the detriment interaction control acts and 'social' talk, where the former have been claimed to be more productive to learning in collaboration. In conclusion we briefly discuss an approach to generating automatic guidance based on forms of collaboration.

Pedagogically exploiting forms of collaborative interaction

AI and Education research up to the late 1980s was almost exclusively conceived within what may be termed the "invididualised [intelligent] instruction" paradigm. More recently some Artificial Intelligence and Education (AI-ED) research has attempted to respond to the challenge of applying and extending its results in different types of collaborative educational environments. For example, Chan and co-workers (e.g. Chan, et al. 1988) and Dillenbourg (Dillenbourg, et al. 1992) have described co-learner or "collaborator" systems, and (Hoppe, 1995) has used techniques for modelling individual learners in order to "parametrise" subsequent collaborative interactions between learners.

CSCL environments - especially distributed ones, involving heterogenous groups of artificial and human agents - are characterised by the predominance of a single phenomenon : **language interaction**. In one sense, if such interactions are viewed as 'transparent' information exchanges, no radically new extension of AI-ED research is required in distributed CSCL environments - we can apply similar student, domain and pedagogical modelling techniques to the exchanged information. However, if we take a broader look at Cognitive Science research on teaching and learning, we can see that collaborative ("learning", "problem-solving") interactions also involve explanation, reflection, verification, critical assessment, argumentation, co-construction of knowledge and meanings, … and other activities that are potential triggers for different forms of learning. The generally accepted hypothesis, then, is that **specific forms of collaborative interaction are related to specific forms of learning** (such as conceptual change, knowledge restructuring, belief revision, …). One possible approach for AI-ED-in-CSCL is therefore to attempt to exploit the learning potential of specific forms of collaborative interaction by facilitating and encouraging their occurrence. We term this approach **"flexible structuring"** of the collaborative-learning interaction. Flexible structuring comprises two aspects, related by the common pedagogical approach of minimal tutorial intervention (Bruner 1986) : (1) providing some specific types of communicative acts and excluding others, but without enforcing their use in given contexts, and (2) providing negotiated automatic guidance on the domain, communication and the form of the collaborative interaction. In this paper we concentrate on the first aspect ; the second is briefly discussed in conclusion.

Two approaches to constraining the collaborative interaction towards forms that promote learning have already been described in the literature : "scripting" the interaction (e.g. Webb, et al. 1991) on a fixed basis (e.g., imposing "explanation" after all domain-related assertions), and constraining 'legal' communicative act *sequences* using a dialogue grammar (Okamoto, et al. 1995). On our view, rigid "scripting" could lead to a very uneconomical interaction, since the speakers may be obliged to re-explain already understood "common ground" unnecessarily, and could also interrupt development of coherent problem-solving. Secondly, there are good arguments against the existence of a *descriptive* dialogue grammars (e.g. Good, 1989), although this does not preclude their use for constructing **hierarchically** interaction histories rather than for *controlling* the form of the dialogue.

Flexible structuring has three main potential advantages : (1) the provision of certain communicative possibilities (such as "give reasons") could encourage the students to use them, but without *requiring* their use on all occasions ; (2) a specialised communication interface based on graphical interaction lightens students' typing load and facilitates *coordination*, thus potentially allowing a more knowledge-based interaction, concerning the concepts underlying proposed problem solutions ; (3) from the system's point of view the specialised interface allows some natural language understanding problems to be avoided (the communicative act performed, together with its links to the interaction history is rendered explicit by the students) and would facilitate a belief-modelling task.

In this paper we concentrate on describing the design and preliminary experimentation of two communication interfaces used in the C-CHENE[1] CSCL environment for teaching modelling and the concept of energy in physics, these being preliminary steps in a long-term research project. We first describe C-CHENE, then successively describe the design principles of both communication interfaces. We then present and compare analyses of interactions between students using the interfaces. In conclusion we briefly discuss further work on integrating AI-ED techniques in C-CHENE in order to generate different types of guidance.

C-CHENE - a CSCL for modelling in physics

C-CHENE was developed within a long-term research project that has been carried out on the teaching and (collaborative) learning of the activity of modelling in physics (see e.g. Tiberghien, 1994, Bental & Brna 1995, Baker & Bielaczyc, 1995, Devi et al, in press). The specific task studied requires students to (co-)construct qualitative models for energy storage, transfer and transformation ("energy chains") for simple experiments, using a specially designed graphical interface (see upper part of Figure 1 for an example energy chain for an experiment where a bulb was connected to a battery by two wires). In the problem-solving situation studied, students worked in pairs at a distance in a network, each having their own physics experiment available, as well as text describing the problems to be solved. Each student in a given pair had the same graphical interface and the same communication interface, both developped in Hypercard™. These interfaces were projected simultaneously onto the students' computer screens using MAE™ and ShowMe™ on SUN Sparc stations. The students (16-17 years old) constructed their energy chains together in this graphical interface and all of their discussion took place via specially designed communication interfaces.

Designing the collaborative problem-solving interaction

The students using C-CHENE have to perform two main interdependent cognitive tasks : *solve the problem* (modelling in physics), and *collaborate*. The latter requires that they *communicate*, in order to exchange domain-related information, coordinate actions and reach agreement. In this section we describe the communicative possibilities that the system offers to the students to enable them to perform these tasks, together with the underlying model of collaborative dialogue.

We chose to design and implement our own communication interfaces, rather than using existing computer-mediated communication (CMC) technologies in conjunction with the energy-chain construction interface, for a number of reasons. Firstly, we wanted to be able to experiment with as many aspects of the communication interface as possible. Secondly, we wanted to build our own interface with a view to ultimately implementing an underlying automatic modelling and guidance system. Finally, we made the hypothesis that a **strong integration** between the problem-solving and collaboration/communication tasks was preferable at the interface level (students would then not view communicating as a possibly tiresome additional task but rather as intrinsic to the problem-solving task).

Our research strategy was to design successive interfaces and use them to collect data on the students' interactions, the analysis of which could be used to inform the design of further prototypes. Our goal is to encourage productive forms of collaborative interaction. However, this presupposes knowledge of precisely what such forms *are*. One approach to identifying them is to perform experiments in educational psychology. Our (complementary) approach is closer to an *engineering* one : we construct experimental communication channels then determine to what extent they do or do not favour particular collaborative interaction forms (some of which may be shown to be more 'productive' than others).

The 'chat-box' communication interface

Figure 1 shows a screen dump of the "chat-box" interface in C-CHENE. The full screen is divided into two parts from top to bottom, by two buttons for shifting "mode" between "construct" ("construire") energy chains and "communicate" ("communiquer").

In "construct" mode menus appear which contain items for graphically constructing energy chains ("create", "delete", "move", …), and use of the lower "communicate" area is blocked. The "communicate" area is activated by the button "communiquer" (communicate), which blocks construction above by hiding the menus. The "communicate" screen area contains three windows (in addition to a button for terminating the exercise) : one chat-box for each of the two students (below left and right) and a dynamically updated interaction-history trace (above, middle). Students type their messages in their respective chat-boxes, then 'send' them by hitting 'tabkey', which clears the message in their box, adding it to the

[1] "CHENE" = "CHaîne ENErgétique" = "Energy Chain". "C-CHENE" = "Collaborative CHENE".

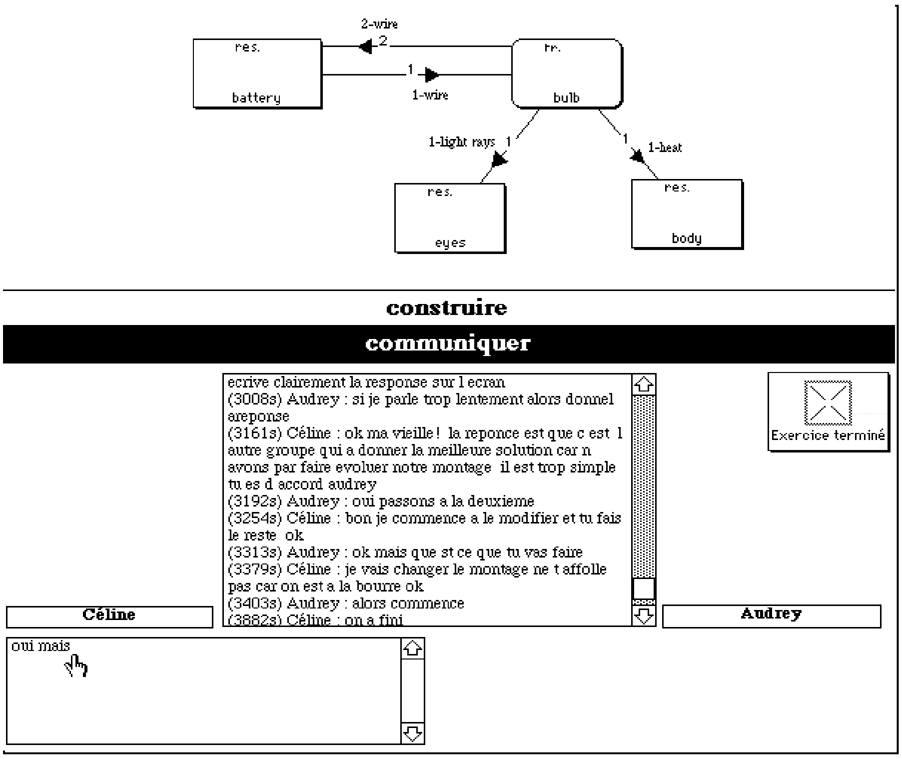

Figure 1. The "chat-box" interface of C-CHENE, with students' solution for battery-wires-bulb experiment. The energy chain has been relabelled in English, the text left in the original French.

end of the interaction history. It also closes their own chat-box and opens that of the other student. The students can observe all actions on screen (construction or communicate) of each other, in real time.

The possibility of **interruption** is provided in all situations, and is performed by clicking on the "communiquer" or "construire" buttons in the middle of the screen. For example, if student1 is typing in his/her chat-box, student2 can interrupt "to communicate" by clicking the "communiquer" button, or interrupt "to construct" by clicking on the "construire" button, and so on for other cases (eg construct->construct, construct->communicate,…). On interruption, a dialogue box appears saying "May I interrupt ?", providing "yes" or "no" as alternative buttons for the initial speaker/constructor. If the interruption is accepted, control remains with the initial speaker, otherwise it 'flips over' to the interruptor.

The design of this interface was based on the fact that whereas in face-to-face/side-by-side collaborative activity it is possible to speak and act in parallel (e.g. speak whilst demonstrating an action, overlap speech, …), in the CMC situation studied here this is not possible. The main goal was therefore to alleviate additional **coordination problems**. Thus, the rendering explicit (and enforcement) of construct / communicate mode switching was intended to remind students that it was not possible to 'speak' and 'act' at the same time. Similarly, the 'flipping' between chat boxes was intended to enforce strict turn-taking (with possibility of interruption), i.e. it would always be evident who was 'speaking' at any given moment.

In addition, the interaction history is viewed here as an important resource in collaborative dialogue since it provides a common objective reference to previous activity (unlike oral dialogues) that may encourage reflection and more effective collaboration (Collins & Brown, 1988 ; Katz & Lesgold, 1993). This is one way of exploiting an advantage of this communication medium in comparison with verbal interactions. In future research we plan to make the interaction history mouse-sensitive, to enable students to refer to or re-use previous type-written utterances without having to thematise this in their individual dialogue boxes.

The 'dedicated' communication interface

The second "dedicated" communication interface is shown in Figure 2.[2] As with the chat-box interface, the full screen is divided into construction and communication area. The lower part of the latter contains a set of communicative acts ("**CA**") for each student to use, and the upper part the ongoing interaction history, displayed for the students as before.

The CA buttons are grouped according to their function with respect to the collaborative interaction, in order to impose a more easily understandable structure on what would otherwise be a (long) heterogenous list of buttons. Once the student has clicked on a specific button, one of three things happens :

(1) for certain buttons, relating directly to the energy chain construction task, a set of hierarchical menu choices is presented. For example, after clicking [I propose to …] the student is given choices that correspond to menu choices in the construction screen area, such as <Create a reservoir> ;

(2) some buttons, relating to interaction management (e.g. [Ok]) simply send the corresponding message into the visible dialogue history ;

(3) finally, some buttons (such as "I think that …") allow the student to type arbitrary free text in a small chat-box

[2] The figure has been redrawn since the original is in French.

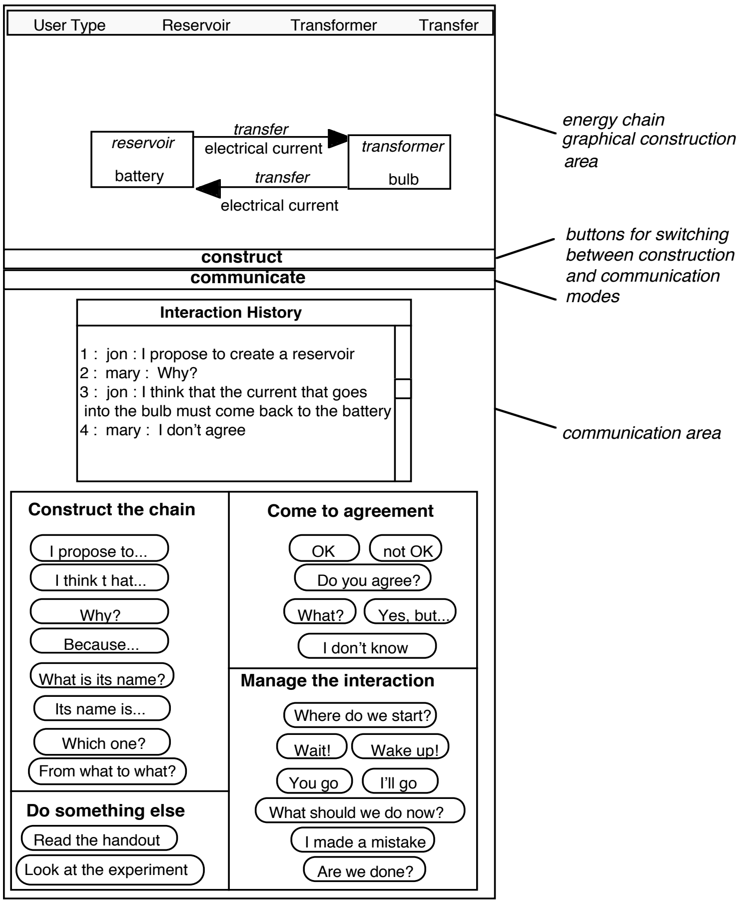

Figure 2. C-CHENE "dedicated" communication interface.

window (as before, the textt is sent to the dialogue history.

As with the chat-box interface, all actions are added, numbered and time-stamped, to the end of the dynamic interaction history.

This new interface evolved from our previous research on the "chat-box" interface where we initially tested the use of a restricted set of "short cut" buttons - e.g. for saying [OK], [Not OK], [Go Ahead], [Are you there?]. The first rationale for designing the new button-based interface was therefore to ease the typing load, thus freeing up time for more problem-solving task related discussion. With a previous interface that mixed chat-box interactions with a smaller set of buttons, these appeared to be appreciated since on several occasions the students typed to each other remarks such as "use the OK button instead of typing, it goes quicker !". An interesting finding was that the students did not necessarily use these buttons for the purpose intended by the designer. For example, we provided a "beep" button, whose function was intended to be that of attracting the other's attention, assuring that (s)he was listening. In fact, one group of students spontaneously discussed and agreed on a protocol for using this button in managing **coordination** : "Look, when you want to go up and construct something, tell me using the beep". These initial findings encouraged us to develop and experiment an interface based completely around CA buttons.

Secondly, we made the hypothesis that providing a limited set of buttons for each type of CA necessary for the collaborative interaction would encourage the students to engage in certain preferred communicative activities. For example, that they would use the [Because …] button to give reasons and explanations for their proposed intermediary solutions.

Finally, the design allows some natural language interpretation problems to be avoided (e.g. illocutionary force recognition). In fact, the communication interface was also designed with dialogue analysis and belief inference specifically in mind.

The actual set of CA buttons provided was designed on the basis of analysis of a corpus of 'chat-box' interactions with C-CHENE, existing models for information dialogues (Moeschler, 1985 ; Bunt, 1995) and for collaborative problem-solving interactions (Baker, 1994).

Bunt (op.cit.) makes a distinction between *task-oriented* CAs, whose primary function is to accomplish the task external to the dialogue (e.g. transfer of information, problem-solving), and *dialogue control* CAs, the function of which is to keep the dialogue itself 'on track'. The latter category includes classes of acts for giving feedback on attitudes (agreement, disagreement), perception and understanding, and others for structuring the dialogue (e.g. opening and closing, time management, etc.). This fundamental distinction is reflected in the organisation of the two basic columns of buttons in the communication interface (task-oriented = left column ; dialogue control = right column).

A second important distinction is between *initiative* and *reactive* CAs (Moeschler, 1985). This is reflected in the different types of *semantic content* of CAs. Firstly, initiative acts, such as [I propose to …] generally have a *propositional* content, that is determined by selection on a hierarchical set of menus that are displayed once the button is clicked. For example, following [I propose to …], the student can select one of {<create a reservoir>, <create a transformer>, …}. Other acts refer either to *the dialogue itself* (e.g. [Are we done ?] or to propositions stated in previous CAs (e.g. [Why?] refers to a previously asserted proposition). Finally, some CAs will have a content that is a (presently unanalysed) free text string (e.g. [I think that...] "the battery should be a reservoir").

Finally, a third distinction is made in terms of the type of *illocutionary act* concerned (e.g. QUESTION, REQUEST, ASSERTION. In terms of these three distinctions, [I propose to …] is, for example, *task-oriented* (it is designed to achieve the problem-solving task], *initiative* (it does not necessarily *react* to a previous CA), and has an OFFER communicative function (see Baker, 1994).

Preliminary study of the interfaces

The situation studied

We performed preliminary studies, in the laboratory, with pairs of students using both interfaces (chat-box and "dedicated"). The aim was to test the extent to which the two interfaces were even 'usable' by students, and to generate plausible hypotheses to be tested at a later date. The "subjects" were secondary school students (16-17 years old) for whom participation in the experiment actually constituted part of their physics instruction on energy and modelling, within the constraints of the curriculum and the timetable. Within these constraints we were initially able to work with sixteen students (eight pairs), where four pairs used the chat-box interface and four pairs the "dedicated" one.

The students were asked to study a short text describing the elements of the energy chain model, together with the principle of conservation of energy and a set of rules to be respected in constructing energy chains (e.g. "a complete chain must start and end with a different reservoir"). Once assigned to "friendship pairs", students then were each seated at separate computers (SUNS linked by ShowMe™) where visual and auditory contact was prevented. They performed three experiments and constructed three energy chains successively, during a session that lasted 3 hours. Automatic traces of their interactions were recorded for analysis (around 24 hours of automatically transcribed interaction in all).

Analysis approach

The analysis categories were designed to enable us to provide preliminary answers to the following types of questions with respect to the corpus : *(Comparing chat-box and ded*icated interface interactions), what was the relative proportion of graphics actions vs communicative acts ? What was the relative proportion of interaction control vs task-domain-oriented acts ? What was the relative proportion of problem-solution CAs vs "meta" (explanation, …) CAs ? We initially developed a simple and operational set of analysis categories, as shown in Figure 3.

The distinction between categories 1 and 2 is clear - it simply corresponds to use of the construction or communication modes of the interface. Category 3 ("social") refers to remarks made that are not directly related to the collaborative problem-solving (category 4), such as making jokes, chatting about everyday life, …. The basic definitions of the other categories are as follows :

5 - control CAs (see above), whose function is to control some aspect of the problem-solving or communicative activities themselves (eg controlling who will speak or perform an action, feedback on agreement, perception, …) ;

6 - task-oriented CAs, that refer directly to some aspect of the energy chain construction task.

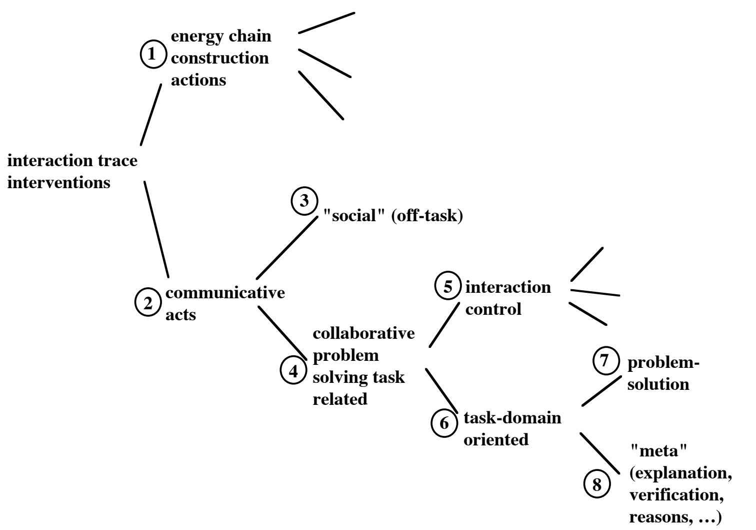

Figure 3. Analysis categories for the computer-mediated interactions.

7 - problem-solution : task-oriented CAs directly referring to problem solutions (eg "the bulb is a reservoir")

8 - "meta" - task-oriented statements that do not fall into category 5 (they involve explaining the solution, giving reasons for or against, bringing in new information that is relevant to supporting some problem-solution CA, …).

We decided to define category 8 'by elimination' given theoretical difficulties inherent in defining explanation. In fact, this category includes a number of different phenomena, relating to metacognitive reflection on the task (see below). Clearly, given results on the learning effects of "self-explanation" (Chi & VanLehn, 1991), the relative incidence of utterances this category between interfaces is of particular interest to us.

Some categories are necessarily partially overlapping (multifunctionality of utterances). For example, an utterance such as "You go ahead and construct a reservoir for the battery" is clearly **task-oriented[6] / problem-solution[7]** since it makes some statement about what the solution is, but it is also **control[5]** since it is proposing who should actually perform that interface action. In these cases the communicative act was counted *twice*, i.e. for each **communicative function**, in 7 and in 5.

Applying the categories required segmenting utterances into CAs based on separable semantic contents and illocutionary force markers (eg "?").

Results and Interpretation

The main results of our analyses of the data are shown in the table below, comparing the two interfaces described above. Table 1 shows average numbers of actions and CAs for four "chat-box" interactions compared with four "dedicated interface" interactions.

There was no significant difference in the quality of the energy chain solutions produced between pairs and interfaces (although there were obvious differences in the relative degree of *understanding* that students had gained of the underlying concepts (modelling, energy).

Table 1. Average numbers of graphic actions and communicative acts.
[The column numbers in parentheses refer to those in Figure 3.)

Interface Type	(8) "Meta" CAs	(7) Problem-Solution CAs	(6) Task-Domain Oriented CAs	(5) Interaction Control CAs	(3) Social CAs	(2) CAs [(6)+(5) + (3)]	(1) Graphic actions	Total actions [(2) + (1)]
Chat-Box (**CB**)	3	9	13	43	2	58	22	80
Dedicated (**D**)	6	18	24	45	2	71	19	90

Given the practical constraints mentioned above, we have not yet collected a sufficiently large corpus of interactions for us to be able to present statistically significant results. However, the intial results obtained are sufficiently suggestive to encourage futher work in this research direction. Bearing in mind the restricted nature of the data, the following points arising from the above tables are nevertheless worthy of note :

(a) (With respect to this corpus) the balance between communication and graphical action remained approximately the same with the two interfaces.

(b) (With respect to this corpus) the amounts of interaction control acts and social acts produced with both interfaces were approximately the same.

(c) (With respect to this corpus) the amount of task-domain CAs and problem-solution CAs produced with the **D** interface was higher (around twice as much) than with the **CB** interface.

(d) (With respect to this corpus) the number of "meta" CAs produced with the **D** interface was higher than that produced with the **CB** interface, although in both cases the number was quite small.

Although points (a) and (b) might indicate that there was no real difference in the relative ease of interaction management between the two interfaces, this may in fact be due to the fact that - paradoxically - it is easier to perform a control act with the **CB** interface (simply clicking on a button).

Points (c) and (d) indicate that, in comparison with the **CB** interface, the **D** interface appears to allow an interaction that is based to a greater extent on task-related communication, i.e. proposing problem solutions and reflecting upon them. We make the hypothesis that such an increased focalisation and reflection on the task will be more effective in collaborative learning (the hypothesis has been validated for other tasks, such as with respect to the "self-explanation" paradigm, but remains to be tested with respect to the task studied here).

Finally, upon examination of the students' interaction traces, the "meta" category of acts (i.e. those concerned with the problem to be solved but which are not simple statements of solution elements) contains a number of different activities, such as the following :

• *verifications* of the current solution by reference to task-related information (e.g. "the first reservoir must be different from the last one") ;

• *causal explanations* of the experiment to be modelled (e.g. "[the motor is a reservoir] because it produces energy under the effect of the rotation of the axle") ;

• *subjective evaluations* of the current solution (e.g. "we're not so far from the right solution").

In future work we intend to perform more detailed analyses of acts in this category, in order to understanding how to flexibly structure the interaction to promote some rather than others.

Conclusions and further work

We have described the successive design and implementation of two interfaces that are designed to favour productive collaboration between students working together on physics problem-solving tasks, at a distance in a network. The design of the second interface was guided by the concept of "flexible structuring" of the collaborative interaction, which involves encouraging students to use certain communicative acts by the provision of specialised buttons for them, yet without enforcing their use on every occasion. In addition, the approach described facilitates automatic analysis of the students' collaborative activities, with a view to providing flexible guidance on the levels of the domain, communication problems and preferred forms of collaborative interaction (see Lund, Baker & Baron, 1996). Flexible structuring therefore comprises two elements, synthesising an 'environments' approach (constraining the communication/task environment) and an 'ITS' approach to generating flexible guidance (Moyse & Elsom-Cook, 1992).

Results obtained from analysing interactions with the two interfaces indicate that this is a promising research direction to follow, since it may create a 'space' within which educationally preferred forms of collaborative interaction can emerge. In the light of our analyses we intend to redesign the dedicated interface - particularly in order to favour explanation, evaluation and verification of problem solutions - and to conduct larger scale experimental evaluations with students. Our current research on integrating AI-Ed techniques (see Lund, Baker & Baron, 1996) is focussed on three main directions : inferring hierarchical structures in the interaction history, modelling students' beliefs in collaborative problem-solving interactions and designing appropriate guidance mechanisms that draw on the structure of the interaction as well as on domain-related activities.

References

Baker, M. (1994). A Model for Negotiation in Teaching-Learning Dialogues. *Journal of Artificial Intelligence in Education*, 5 (2), 199-254.

Baker, M., Bielaczyc, K. (1995). Missed opportunities for learning in collaborative problem-solving interactions. *The Proceedings of Artificial Intelligence in Education,* 1995, August, Washington, D.C. 210-217.

Bental, D., Brna, P. (1995). Enabling Abstractions: Key Steps in Building Physics Models. *The Proceedings of Artificial Intelligence in Education,* 1995, August, Washington, D.C. 162-169.

Bruner, J.S. (1986). *Actual Minds, Possible Worlds*. Cambridge, Mass. : Harvard University Press.

Bunt, H.C. (1995). Dialogue Control Functions and Interaction Design. In R.J. Beun, M. Baker, M. Reiner (Eds.), *Dialogue and Instruction, Modeling Interaction in Intelligent Tutoring Systems*. Proceedings of the NATO Advanced Research Workshop on Natural Dialogue and Interactive Student Modeling, (pp. 197-214). Berlin, Germany: Springer.

Chan, T.W., Chou, C.Y., Lee, M.F., Chang, M.H. (1995). Reciprocal-tutoring-kids: Tutor-tutee role playing systems. *The Proceedings of Artificial Intelligence in Education,* 1995, August, Washington, D.C. 226-233.

Chi, M.T.H. & VanLehn, K.A. (1991). The Content of Physics Self-Explanations. *Jnl of the Learning Sciences*, 1(1), 69-105.

Collins, A. & Brown, J.S. (1988). The computer as a tool for learning through reflection. In H. Mandl & A. Lesgold (eds.) *Learning Issues for Intelligent Tutoring Systems*, pp. 1-18, New York : Springer Verlag.

Devi, R., Tiberghien, A, Baker, M., & Brna, P. (in press) Modelling students' construction of energy models in physics. *Instructional Science*.

Dillenbourg, P. & Self, J. (1992). A computational approach to socially distributed cognition. *European Journal of Psychology of Education*, 7 (4), 353-372.

Good, D.A. (1989). The Viability of Conversational Grammars. In M.M. Taylor, F. Néel, D.G. Bouwhuis (Eds.), Human Factors in Information Technology 4, *The Structure of Multimodal Dialogue*. Amsterdam: Elsevier Science Publishers B.V.

Hoppe, H.U. (1995).The Use of Multiple Student Modeling to Parametrize Group Learning. *The Proceedings of Artificial Intelligence in Education,* 1995, August, Washington, D.C. 234-249.

Katz, S. & Lesgold, A. (1993). The role of the tutor in computer-based collaborative learning situations. In S. Lajoie & S. Derry (eds.) *Computers as Cognitive Tools*. Hillsdale NJ : Lawrence Erlbaum Associates.

Lund, K., Baker, M.J. & Baron, M. (1996). Modelling dialogue and beliefs as a basis for generating guidance in a CSCL environment. *Proceedings of the International Conference on Intelligent Tutoring Systems,* 1996, June, Montreal.

Moeschler, J. (1985). *Argumentation et Conversation* . Paris : Crédif-Hatier.

Moyse, R. & Elsom-Cook, M. (1992). *Knowledge Negotiation*. London :Academic Press.

Okamoto, T., Inaba, A., Hasaba, Y. (1995). The Intelligent Learning Support System on the Distributed Cooperative Environment. *The Proceedings of Artificial Intelligence in Education,* 1995, August, Washington, D.C. 588.

Tiberghien, A. (1994). Modeling as a basis for analyzing teaching-learning situations. *Learning and Instruction* 4, 71-87.

Webb, N.M. (1991) Task Related Verbal Interaction and Mathematical Learning in Small Groups. *Research in Mathematics Education*. 22 (5) 366-389.

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