

## **Promoting reflective interactions in a CACL environment**

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**Abstract** Engaging in reflective activities in interaction, such as explaining, justifying and evaluating problem solutions, has been shown to be potentially productive for learning. This paper addresses the problem of how these activities may be promoted in the context of computer-mediated communication during a modelling task in physics. The design principles of two different communication interfaces are presented. The first allows free text to be exchanged, and the second structures the interaction by providing a restricted set of communicative possibilities. Comparative analyses of interaction corpora produced with the two communication interfaces are then described. The analyses show that use of the second structured interface in performing the problem-solving task is feasible for students, and that it promotes a task-focussed and reflective interaction. In conclusion the different resources provided by different media and the relative degrees of effort that their use requires are discussed.

*Keywords:* Collaborative problem-solving; Computer-mediated communication; Dialogue; Reflection; Speech act theory.

### **Introduction**

Over the past decade there has been a shift of emphasis in research on collaborative learning (Dillenbourg *et al.*, 1995). The study of the conditions under which pairs learn more effectively is now combined with a growing interest in more process-oriented studies of the dynamics of collaborative interactions themselves (e.g. Resnick *et al.*, 1991). Within this interactionist paradigm, the commonly shared hypothesis is that specific types of interaction may engender equally specific types of learning. For example, interactions in which verbal conflicts are cooperatively resolved (Mavarech & Light, 1992; Baker, 1996) may lead to restructuring of knowledge, and those in which subjects verbalise task-related explanations may lead to deeper conceptual

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understanding (Chi & VanLehn, 1991). A common factor of many such types of interactions is that they involve *metacognitive processes* such as mutual regulation and reflection on the foundations or understanding of the problem-solving activity (Brown, 1987).

The design of Computer-Supported Collaborative Learning (CSCL) environments — especially those where students work and communicate at a distance via a network — offers specific advantages for research on the cognitive effects of interactions. When students collaborate side-by-side at a computer, the usual approach is to study the verbal interactions that turn out to be produced under certain conditions and to attempt to relate features of them to possible learning effects. In the case of CSCL environments, there is the possibility of controlling or structuring the computer-mediated interaction itself, in the attempt to favour the incidence of certain forms of communicative acts rather than others.

The latter approach is the one that has been adopted in the research described here. The extent to which reflective interactions — those that involve explanation, justification and evaluation — are promoted by two different communication interfaces, used within the same CSCL environment, were examined. The first interface (dialogue-box) allows free typewritten text to be exchanged between learners, whilst managing interaction control; the second (structured) promotes an interaction of a certain form using interface buttons for specific communicative acts. The CSCL environment is called *C-CHENE\** (Lund *et al.*, 1996; Baker & Lund, 1996) and is designed to support qualitative modelling of energy in physics.

This paper describes first the general approach to structuring interactions in a CSCL environment, then the environment itself, together with the two communication interfaces with which it may be used. This is then followed by comparative analyses of interaction corpora generated with the two interfaces with a view to identifying to what extent reflective interaction is promoted. The conclusion discusses further work on interaction design in CSCL environments.

### **Structuring collaborative problem solving interactions**

#### *Previous research on structuring interactions*

Two main approaches to constraining interactions towards forms that promote learning have already been described in the literature. The first is termed 'scripting' (Webb, *et al.*, 1991; Reinhard *et al.*, 1997) which involves requiring subjects on most or all occasions to make a particular type of speech act in a specific context. For example, all domain-related assertions must be followed by explanations of them. This has been shown to produce strong positive learning effects. Although this is effective in the context of experiments in educational psychology, it is not obvious that it constitutes a suitable *pedagogical approach*. Although explanation may promote learning it is possible that *enforcing* it on all occasions could be demotivating, it could interrupt the process of co-

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\* *CHENE* = *CH*aine *ENE*rgétique = Energy Chain; *C-CHENE* = Collaborative *CHENE*

constructing solutions in interactions and lead to rather uneconomical communication (for instance, re-explaining what has already been explained). The decision as to *when* it will be preferable to request explanation, in a real-life learning situation, may thus be a complex matter that requires a deep understanding of interaction contexts.

The second approach that has been described involves constraining a particular space of 'legal' speech act *sequences* using a dialogue grammar. For example, Winograd (1988) has described a communication tool called 'The Coordinator' that uses a set of augmented transition network grammars to constrain the different speech act sequences that may be performed in different types of 'conversations' within work settings (for example, 'conversations for action', 'conversations for clarification', or 'conversations for orientation'). Okamoto, *et al.* (1995) have described similar grammars for use in collaborative learning settings.

From a theoretical point of view, dialogue grammars are somewhat contentious. It now seems clear that there can be no such thing as a *descriptive* grammar of dialogue (Good, 1989). Firstly, the lexical items used by such a grammar — speech acts — are inherently ambiguous, given the multifunctionality of utterances (Sadock, 1994) and the fact that speech act status in interaction is open to negotiation and retrospective interpretation (Edmondson, 1981). Secondly, the notion of well-formedness, developed for the phrase level, cannot be extended to the supra-sentential level of sequences of utterances produced by distinct speakers. There is nothing that is necessarily ill-formed about a dialogue in which assertions are not explained, or questions not answered; other goals may take precedence or the topic of the initial speech act may no longer be the focus of the discussion. At best, one can establish a system of *expectations*. Since the links between successive utterances in dialogue are not wholly dependent on their grammatical structure they depend rather on attentional and intentional structures (Grosz & Sidner, 1986). This does not of course preclude the use of a dialogue grammar for hierarchically constructing dialogue histories.

A final possibility is that a dialogue grammar could be used in a normative way, i.e. as a model of how the dialogue should be structured if a given extra-interactional goal is to be achieved. In the case considered here, the aim is to propose a 'dialogue for learning' (Lund *et al.*, 1996), i.e. one that constrains the dialogues to preferred forms that generally promote learning. The research described may be viewed as an intermediary step towards defining such a normative grammar.

#### *The theoretical approach: flexible structuring*

The main research goal was to determine how to design a system that structures the collaborative interaction between learners so as to favour the incidence of 'preferred collaborative interaction patterns', i.e. those that have been shown, potentially, to favour learning, on the basis of previous research. Very few precise guidelines can be abstracted for defining such patterns from existing research, and these are relatively general when compared with the degree of specificity required for a computer implementation. The following are three

plausible examples of preferred patterns that are prevalent in the literature:

- *task-focussed*: an interaction that is oriented towards the problem-solving task (rather than on how to use the interface, controlling the interaction, off-task talk, . . .);
- *symmetrical interaction*: an interaction in which both partners make relatively equal contributions in producing intermediary problem solutions (joint participation is required for learning);
- *reflective*: an interaction in which partners do not simply state problem solutions, but rather where they attempt to explain, evaluate and/or justify them.

The following sections of this paper concentrate on possibilities for the first and the third criteria: *to what extent do the communication interfaces promote interactions that are task-focussed and reflective?* By doing so, a specific computer implementation that aims to support these types of examples of preferred collaborative interaction patterns is explored.

The approach described, termed *flexible structuring*, involves attempting to steer a middle way between complete constraint on the interaction, and total absence of constraints. It involves the following two aspects:

- providing a restricted set of communicative acts\* that can be used in the interaction, without necessarily enforcing their use in given contexts;
- providing flexible constraints and guidance on the use of certain communicative act sequences in specific dialogue contexts.

This paper focuses on only the first point (but see Lund *et al.*, 1996). Flexible structuring has three main potential advantages:

- the provision (explicit representation) of certain communicative acts (such as 'Why?') could encourage the students to use them;
- a specialised communication interface based on graphical interaction could lighten students' typing load and facilitate coordination, thus potentially allowing a more task-focussed and reflective interaction;
- 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 dialogue history is rendered explicit by the students) and would facilitate an automated belief-modelling task.

### **The design approach**

The approach to system development used in human-computer interaction research was adopted; this is characterised by iterations of the cycle: (re)design, implementation, and evaluation. Following Hutchins *et al.* (1986), system design was carried out with a mind to reducing the Gulfs of Execution (from user's goals to system) and Evaluation (from system to user's goals). Two cycles for two communication interfaces are described. The theoretical principles of the designs and implementations, derived from dialogue theory, are discussed in

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\* In accordance with Bunt (1989), the term 'communicative' rather than 'speech' act is used in order to avoid the association of the latter with exclusively spoken language.

subsequent sections of the paper.

The approach to evaluating the *C-CHENE* CSCL system exploited the fact that it was designed to facilitate computer-mediated *interaction* between human learners. The evaluation was therefore based on analysing the qualitative aspects of the interaction that learners produced whilst using the system. The interaction corpora were collected in situations that relate to educational practice. It is therefore important to note that the results of these analyses, presented later in the paper, are designed to make explicit the extent to which the system being used was adapted to the users' needs in a specific collaborative learning situation. The results provide evidence to inform the re-design of the system, rather than to test hypotheses within a controlled experiment.

Within the first development cycle, a corpus of face-to-face interactions between students working in pairs at a single computer on the energy chain task was collected within the constraints of a physics classroom (Megalakaki & Tiberghien, 1995; Lund, 1997). Clearly, many characteristics of such verbal interactions cannot be directly *transferred* to the Computer-Mediated Communication (CMC) situation (Cohen, 1984). Rather, the corpus was viewed as a rich source of phenomena from which transpositions of the basic communicative and collaborative problem-solving functions to the CMC situation could be made. On the basis of analysis of collaborative interaction patterns and communicative functions (see Baker, 1994, 1995), together with existing dialogue theory, a first 'dialogue-box' CMC interface was designed, implemented and evaluated. The different constraints of this medium required a transposition and modification of the instantiation of interaction management functions such as turn-taking and interruptions. Analysis of the dialogue-box interaction corpus revealed, for example, that a restricted set of collaborative interaction patterns were used; the students mostly adopted a 'you construct then I'll comment' pattern, and the interactions displayed few reflective activities.

A second development cycle was therefore put into effect, based on the idea that structuring the interface might alleviate coordination and written utterance production problems, thus allowing the emergence of richer collaboration patterns and a more reflective interaction. Analysis of the set of communicative acts used in the dialogue-box corpus thus led to design, implementation and evaluation of the second structured interface.

To recapitulate, the interaction forms that relate to collaborative learning (i.e. reflective and task focussed interaction) were used to design and implement communication interfaces that aimed to promote the generation of such forms. The extent to which such forms are in fact generated in the interaction corpus was evaluated.

Rather than using existing CMC technologies in conjunction with the energy-chain construction interface, a new design and implementation was created for a number of reasons. Firstly, there was a need to be able to experiment with as many aspects of the communication interfaces as possible. Secondly, the design and implementation of interfaces were undertaken with a view to implementing an underlying automatic modelling and guidance system. Finally, within the

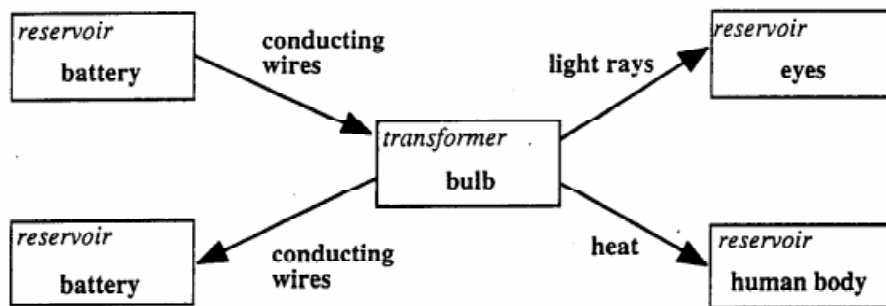
new implementation it was possible to make a strong integration between the problem-solving and collaboration/communication tasks at the interface level. Although this approach makes the communication interface less generic, it is suggested that such an integration promotes the learner's view of communication as intrinsic to the collaborative problem-solving task.

**C-CHENE— a CSCL system for modelling energy in physics**

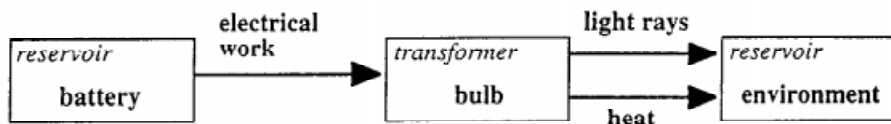
C-CHENE was developed within a long-term research project on the teaching and (collaborative) learning of modelling in physics (Tiberghien, 1994; Bental & Brna, 1995; Baker & Bielaczyc, 1995; Devi *et. al.*, 1996). The task studied required students to (co-)construct qualitative models for energy storage, transfer and transformation ('energy chains') for simple experiments, using a specially designed graphical interface. The students were also provided with real experimental apparatus (e.g. a bulb connected to a battery via two wires), and a text that gave the basic definitions of energy, together with a set of syntactic rules to which energy chains must conform (e.g. 'A complete energy chain must start and end with a reservoir')\*.

Figure 1 shows an example energy chain that was drawn by two students using a dialogue-box communication interface for a real experiment where a bulb was connected to a battery by two wires. For reference, a correct energy chain for this experiment is shown below the students' solution.

*Students' energy chain:*



*A correct solution:*



**Fig. 1.** An energy chain for the battery-wires-bulb experiment drawn by two students (the correct solution is shown below for reference).

\* See Tiberghien & de Vries (1997) for more details on the task and teaching sequence (see this issue, pp. 163-174).

The errors in the students' solution illustrate several important difficulties that they experience with this task. Firstly, there is not always a one-to-one matching between model elements and entities in the experimental field. Thus, the students have (wrongly) assumed that the two wires must correspond to two energy transfers. Secondly, the students have confused electrical current with energy (the conducting wire transfers go round as if in an electrical circuit). Finally, elements of the model may correspond to entities that have no determinate physical location, such as the environment. The students thus spontaneously invented other determinate physical objects (eyes, body) to correspond to the final reservoirs.

In the problem-solving situation studied, students worked in pairs at a distance in a network, each having their own real 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 developed in Hypercard™. These interfaces were projected simultaneously onto the students' computer screens using MAE™ and ShowMe™ on SUN Sparc workstations. 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. This section describes the communicative possibilities that the system offered to the students to enable them to perform these tasks, together with the underlying model of collaborative dialogue.

#### *The dialogue-box communication interface*

Figure 2 shows a screen dump of the dialogue-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', 'name', 'delete', 'move', . . .), and use of the lower 'communicate' area is blocked. The 'communicate' area is activated by the button 'communiquer', 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 dialogue-box for each of the two students (below left and right) and a dynamically updated dialogue history trace (above, middle). Students type messages in their respective dialogue-boxes, then 'send' them by hitting the Tabkey, which clears the message in their box, adding it to the end of the dialogue history. It also closes their own

dialogue-box and opens that of the other student. The students can observe all of each other's actions on the screen (construction or communicate) in real time.

The screenshot displays the C-CHENE software interface. At the top, a circuit diagram shows a battery connected to a bulb, which is then connected to two resistors labeled 'eyes' and 'body'. The circuit is annotated with labels: '2-wire' and '1-wire' between the battery and bulb, '1-light rays' between the bulb and 'eyes', and '1-beat' between the bulb and 'body'. Below the diagram are two buttons: 'construire' (construct) and 'communiquer' (communicate). The main area is a dialogue box with a scroll bar, containing a list of messages in French with timestamps. The messages are:

- (3008s) Audrey : si je parle trop lentement alors donnez une réponse
- (3161s) Céline : ok ma vieille! la réponse est que c'est l'autre groupe qui a donné la meilleure solution car nous avons pu faire évoluer notre montage il est trop simple tu es d'accord Audrey
- (3192s) Audrey : oui passons à la deuxième
- (3254s) Céline : bon je commence à le modifier et tu fais le reste ok
- (3313s) Audrey : ok mais que se que tu vas faire
- (3379s) Céline : je vais changer le montage ne t'affoile pas car on est à la boum ok
- (3405s) Audrey : alors commence
- (3882s) Céline : on a fini

At the bottom of the dialogue box, the names 'Céline' and 'Audrey' are visible. Below the dialogue box, there are two buttons: 'oui mais' (yes but) and a scroll bar.

**Fig. 2.** The dialogue-box interface of *C-CHENE*, with students' solution for the battery-wires-bulb experiment. (The energy chain has been relabelled in English, the text in the dialogue history is left in the original French).

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 Student A is typing in his/her dialogue-box, Student B can interrupt in order to communicate by clicking the 'communiquer' button, or interrupt to construct by clicking on the 'construire' button, and so on for other cases (e.g. 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 not accepted, control remains with the initial speaker, otherwise it is given to the interrupter.

The design of the interface was based on the fact that in face-to-face/side-by-side collaborative activity it is possible to speak and act in parallel (e.g. speaking whilst demonstrating an action, overlapping speech, ...), whereas in this CMC situation 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 is not possible to communicate and construct at the same time. Similarly, the flipping between dialogue-boxes was intended to enforce strict turn-taking (with possibility of interruption), i.e. it would always be clear who was communicating at any given moment.

The dialogue history is viewed as an important resource in collaborative dialogue since it provides a common objective reference to previous activity (unlike most spoken dialogues) that may encourage reflection and more effective collaboration (Collins & Brown, 1988). This is one way of exploiting an advantage of this communication medium in comparison with spoken interactions.

#### *The structured communication interface*

Figure 3 shows the communication window of the second structured communication interface (redrawn from the original in French). It shows the set of communicative act buttons that replace the dialogue-boxes of the first interface.

<b>Construct the chain</b>	<b>Come to agreement</b>
I propose to...	OK      not OK
I think that...	Do you agree?
Why?	What?      Yes, but...
Because...	I don't know
What is its name?	<b>Manage the interaction</b>
Its name is...	Where do we start?
Which one?	Wait!      Wake up!
From what to what?	You go      I'll go
<b>Do something else</b>	What should we do now?
Read the handout	I made a mistake
Look at the experiment	Are we done?

**Fig. 3.** Communicative act buttons of the structured communication interface of *C-CHENE* (translated into English).

As with the dialogue-box interface, the screen is divided into construction and communication areas. The lower part of the latter contains a set of communicative acts (hereafter, CA) for each student to use, and the upper part the ongoing dialogue 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) heterogeneous list of buttons.

Once the student has clicked on a specific button, one of three things happens:

- 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>;
- some buttons, relating to interaction management (e.g. [Ok]) simply send the corresponding message into the visible dialogue history;
- finally, some buttons (such as "I think that . . .") allow the student to type free text in a small dialogue-box window (as before, the text is sent to the interaction history).

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

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

Bunt (1995) 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 in the left column; dialogue control in the right column).

A second important distinction is between *initiative* and *reactive* CAs (Moeschler, 1985) which 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 communicative 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).

## An empirical study of the interfaces

### *The situation studied*

Empirical studies were performed in the laboratory, with pairs of students using both interfaces (dialogue-box and structured). The main aim was to study the extent to which the two interfaces led to the generation of different CAs. The subjects were secondary school students (16-17 years old) for whom participation in the experiment constituted extra-curricular instruction on energy and modelling. Within these constraints it was possible to work, initially, with sixteen students (eight pairs), where four pairs used the dialogue-box interface and four pairs the structured 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 were then each seated at separate computers (SUNS linked by ShowMe™) where visual and auditory contact was prevented. The students carried out 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 obtain preliminary answers to the following types of questions with respect to the corpus:

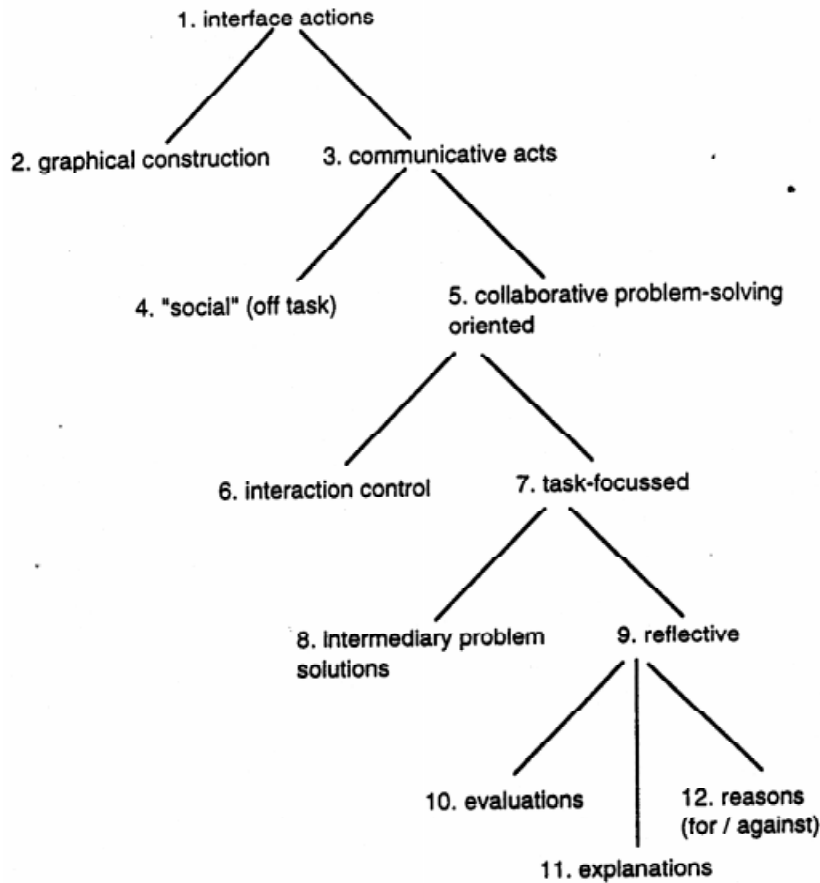
#### *Comparing dialogue-box and structured interface interactions*

- What was the relative proportion of graphics actions vs. communicative acts (CAs)?
- What was the relative proportion of interaction control vs. task-focussed vs. social acts?
- What was the relative proportion of CAs that express intermediary problem-solution vs. those that express reflective activities?

As shown in Fig. 4, a simple and operational set of analysis categories and subcategories was developed (see also Table 1 for examples of the utterances within categories).

**Table 1.** Analysis categories with examples

Category Number and Name	Example
2. graphical construction actions	"transformer created:transformer1"
4. CA: "social" (off-task)	"You should stop drinking and smoking!"
6. CA: interaction control	"Are you there?"
8. CA: intermediary problem-solutions	"I propose to create a reservoir."
10. CA: reflective : evaluations	"I think that we weren't far from the right solution."
11. CA: reflective : explanations	"Because the current goes from the battery to the bulb."
12. CA: reflective : reasons	"Yes, but in the experiment there's only one battery."



**Fig. 4.** Analysis categories and subcategories.

Category 1 contains all of the interaction. It is subdivided into categories 2 and 3 that refer to use of the interface's construction and communication modes, respectively.

Category 3 (communicative acts, hereafter CAs) is separated into Category 4 ('social') and Category 5 (collaborative problem-solving oriented). The former includes jokes, chatting about everyday life, etc. while the latter is directly related to collaborative problem solving.

Collaborative problem solving breaks down into Category 6 (interaction control) and Category 7 (task-focussed). Category 6 contains CAs whose function is to control some aspect of the problem-solving or communicative activities themselves (e.g. controlling who will speak or perform an action, feedback on agreement, perception, . . .). Category 7 contains CAs that refer directly to some aspect of the energy chain construction task.

Category 7 is divided in turn into Category 8 (intermediary problem-solution) and Category 9 (reflective). Problem solution utterances contain CAs that refer directly to problem solutions and reflective utterances contain task-focussed statements that do not fall into Category 8.

In fact, Category 9 was initially defined by a process of elimination. It contains a number of different phenomena, relating to reflection on the task. Three main categories were identified. Category 10 (evaluations) contains statements about the acceptability, plausibility or degree of certainty of the solution as well as statements about understanding. Category 11 contains explanations and Category 12 contains reasons for and against within an argumentative context. Categories 11 and 12 contain some overlapping utterances (see next paragraph) but were in general distinguished in the following way: a reason has the object of modifying a belief value regarding a statement while an explanation deals with the 'why' of the statement (Grize, 1996). The part in italics of the example statement "I think we should create another reservoir, *like the energy model says at the end*", is classified as a reason since it is to be viewed as support for creating a reservoir. On the other hand, the utterances in italics of the following example dialogue . . .

A. "What do you call a reservoir of energy?"

B. "*The falling weight makes the thing turn and then it's transformed into energy and goes to the motor.*"

are classified as explanations because student B is attempting to clarify for student A what he means by a reservoir of energy.

Applying the categories required segmenting utterances into CAs based on separable semantic contents and sentence forms markers (e.g. '?'). The CAs were subsequently classified in terms of both problem-solving task domain and communicative intention. 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-focussed [7] / intermediary problem-solution [8] since it makes some statement about what the solution is, but it is also interaction control [6] since it is proposing who should actually perform the next interface action. In these cases the communicative act was counted *twice*, i.e. for each communicative function, in 8 and in 6 (Bunt, 1989).

## Results and interpretation

The main results of the analyses of the data are shown in Figures 5, 6 and 7 below, comparing the two interfaces described above. The bar charts show average numbers of actions and CAs for four dialogue-box interactions compared with four structured interface interactions.

There were no major differences in the quality of the energy chain solutions produced between pairs and interfaces; the work in fact concentrates on understanding qualitative differences in the nature of the interactions in the compared situations.

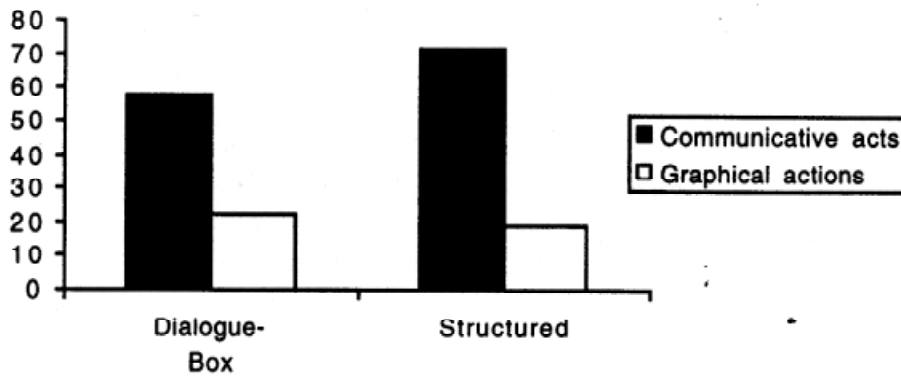
Bearing in mind the restricted nature of the data, the following points arise from the above figures:

- the balance between communication and graphical action remained approximately the same with the two interfaces;
- the amounts of interaction control acts and social acts produced with both interfaces were approximately the same;

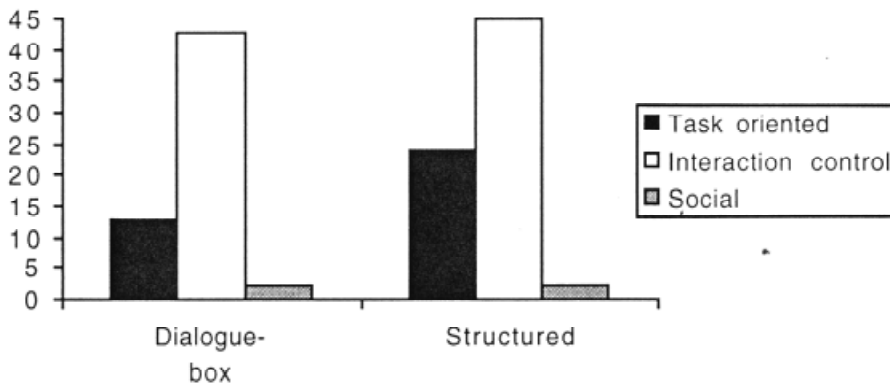
- the amount of task-focussed CAs and intermediary problem-solution CAs produced with the structured (hereafter, **S**) interface was higher (around twice as much) than with the dialogue-box (hereafter, **DB**) interface, i.e. *the structured interface promoted a more task-focussed interaction*,
- the number of reflective CAs produced with the **S** interface was higher than that produced with the **DB** interface, although in both cases the number was quite small, i.e. *the structured interface promoted a (slightly) more reflective interaction*.

Although the first two points 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 **DB** interface (simply clicking on a button).

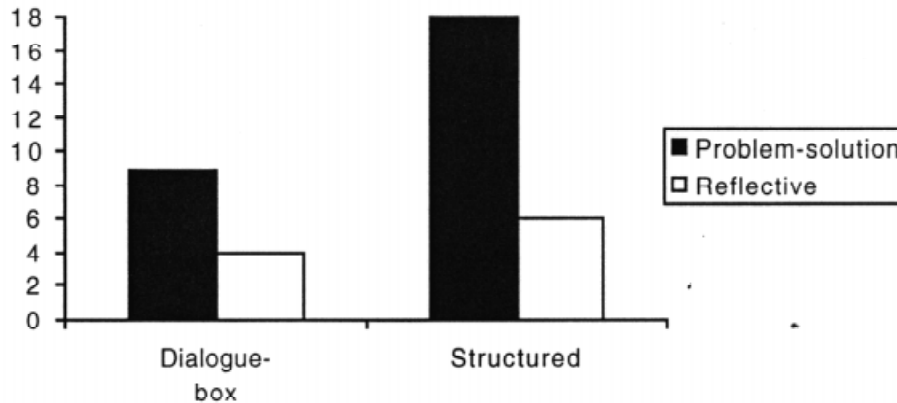
The third and fourth points indicate that, in comparison with the **DB** interface, the **S** interface appears to allow an interaction that is based to a greater extent on task-focussed and reflective communication, i.e. proposing problem solutions and thinking about them.



**Fig. 5.** Average numbers of communicative acts and graphical actions with the two interfaces.



**Fig. 6.** Average numbers of task-focussed, interaction control and social communicative acts with the two interfaces.



**Fig. 7.** Average numbers of problem-solution and reflective acts with the two interfaces.

### Discussion

The main outcome of this empirical study is that the structured interface is able to promote an interaction that enables learners to collaborate effectively in problem-solving, using flexibly structured CMC. The interactions produced with the structured interface are more task-focussed and reflective than those produced with the dialogue-box one. Such an outcome was not at all obvious at the outset of designing the structured interface, largely because it was not clear to what extent learners would be able to auto-classify their communicative action. Although this outcome must be considered with caution, given the relatively small size of the interaction corpora, it is nevertheless encouraging for the future re-design of the *C-CHENE* system.

There seem to be two main possible (and related) lines of explanation for the outcomes of this study: 'production costs', and 'explicitness' in communication (and cognition). Clark & Brennan (1991) point out that different media bring different resources and constraints on 'grounding' (the process of attaining mutual understanding in communication), as well as having different associated 'costs' (i.e. the amount of effort required). Clearly, the hypothesis is that the greater the 'cost', given limited human cognitive resources, the less likely an action will be performed. The following types of costs may be important for explaining the results of this study:

- production costs (how easy is it to articulate the message?);
- asynchrony costs (to what extent is it easy to tell what is being responded to?);
- speaker change costs (what effort is required to change speaker?).

One possibility would therefore be that the structured interface reduces costs along some or all of these dimensions, quite simply leaving more time and energy for engaging in task-focussed and reflective activities. However, whilst it is plausible that production costs may be reduced in most cases with the structured interface, it is possible that the following cost, relating to explicitness in communication, may work against this factor:

- formulation costs (how easy is it to decide exactly what to say?).

Thus, the fact that the students using the structured interface have to auto-classify their communicative action (which button to use now to say what I want to say?), may in fact increase the general effort required to use the interface. Alternatively, this auto-classification may itself trigger task-focussed reflection ("What do I *really* want to say?"). The attempt to decide between these possible explanations is left for future research.

Finally, there are important theoretical and deontological problems associated with the approach of constraining communication between social actors, and attempting to base this on a fixed set of speech acts\*. Thus, Suchman (1994) has argued against the pernicious effects of controlling computer-mediated communication in organisations, and against the notion of fixed categories of speech acts. There are two main general responses to these complex issues.

The first response is that given the varieties of speech act theory that exist, the one adopted in this study does not assume fixed and unidimensional categories. Speech acts are multidimensional. Every speech act, in context, operates at least on the three following dimensions: social commitment, expression of psychological states and representation of the world in a certain way (Sadock, 1994). For example, clicking on an "are you there?" button could, in a given context, express commitment to continuing the interaction, psychological frustration, and a representation of the interaction itself as 'stagnating'.

The second response concerns the interesting possibility for future research that students who really use a CSCL system over a long period of time, could be given the flexibility to partially structure their *own* interaction. Clearly, this would not be likely to occur with respect to specific learning tasks since they are usually only performed a few times. It would appear to be more likely for aspects of collaborative interaction that are common across tasks. For example, if for several tasks students discover that they frequently type requests for criticism of their proposals, then they may want to specialise a generic request button. The study of such a possibility would require large-scale integration of computer-based synchronous communication into educational practices.

### **Conclusions and further work**

The research reported here suggests that it is feasible to structure interactions in CSCL environments in a sufficiently fine-grained way so as to favour certain forms of interaction, and in particular those that are task-focussed and that concentrate on the reflective activities of evaluation, explanation and giving reasons. Clearly, such work relies on existing research results on the relationships between interaction and learning. However, in future research it appears feasible to use CSCL environments as tools or 'test-beds' for identifying other interaction structures that may relate to learning, in conjunction with

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\* See the special issue of the journal *Computer Supported Collaborative Work*, 1994/95, Vol. 3, No. 1, for extensive discussion of these issues.



experimental evaluation of associated learning effects.

The results from the present study are restricted to a single task, and a restricted corpus. In future work the interface and the CSCL environment will be extended to support a wider range of tasks, and to continue the work on designing an automatic guidance model for collaborative activity will be continued. Such a model will be based on studies of teacher-student-student trilogues.

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