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COMPUTER-MEDIATED ARGUMENTATIVE INTERACTIONS FOR THE CO-ELABORATION OF SCIENTIFIC NOTIONS

INTRODUCTION

It is now well recognised that argumentative interactions can be vehicles of collaborative learning, especially on a conceptual plane (see e.g. Andriessen & Coirier, 1999). Information and communication technologies such as Computer-Supported Collaborative Learning ("CSCL") environments can play an important role in such learning to the extent that they enable task sequences and interpersonal communication media to be structured in ways that favour the co-elaboration[1] of knowledge (e.g. Baker, 1996, 1999; Baker, de Vries, Lund & Quignard, 2001).

This chapter adopts a general perspective in educational psychology and technology according to which understanding the cognitive, linguistic and interpersonal *processes* of interactive learning is a primary basis for design of learning situations, together with the tasks and tools that comprise them. Such an emphasis on the study of interactive learning processes now crosscuts theoretical perspectives and currents as diverse as situated learning, social psychology, as well as Vygotskian and post-Piagetian psychologies of learning (e.g. Resnick, Levine & Teasley, 1991; Pontecorvo, 1993; Gilly, Roux & Trognon, 1999), in the general attempt to understand how understanding emerges from interaction (e.g. Roschelle, 1992). If we could gain better understanding of the processes by which different types of knowledge are elaborated in argumentative interactions, this could enable us to better design CSCL environments that exploit this learning potential.

Within this perspective, we present a case study analysis of a corpus of interactions that was collected in a situation where students used the "CONNECT" CSCL environment (Baker, de Vries & Lund, 1999; De Vries, Lund & Baker, 2002) to collaboratively solve a problem of interpreting a sound phenomenon in physics. CONNECT enables dyads of students to critically reflect upon and to collaboratively write texts across the Internet. As background for the analyses, we first sketch a theoretical approach to understanding the relations between argumentation, interaction and collaborative problem solving, out of which emerge a number of reasons why learning might occur as a result of engaging in an argumentative interaction. We then briefly describe the CONNECT study and present illustrative analyses of the corpus that was collected during it. Our analyses emphasise the way in which the dialectical game of argumentation relates to expressed changes of attitudes towards solutions, and how the playing out of this game goes hand in hand with renegotiation of the conceptual background within which it is situated. In conclusion, we discuss potentials and limits of CSCL environments in relation to productive argumentative interactions.

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ARGUMENTATIVE INTERACTION, COLLABORATIVE PROBLEM-SOLVING AND COLLABORATIVE LEARNING

Argumentative interaction and collaborative problem-solving

Understanding how argumentative interaction can lead to collaborative learning requires setting it in the context of collaborative problem-solving activity. Within such a research goal, we see argumentative interaction fundamentally as a type of *dialogical or dialectical game* that is played upon and arises from the 'terrain' of *collaborative problem solving*, and that is associated with *collaborative meaning-making*. Although negotiation of meaning is of course an integral part of any communicative interaction, our conjecture is that the interpersonal and interactive pressures imposed by the necessity to deal with conflicting points of view are particularly conducive to collaborative sense-making.

Although argumentation can occur with respect to any aspect of a problem space, as classically defined by Newell and Simon (1972), it will be convenient here to restrict our discussion to possible *solutions* to (sub-)problems in the task domain, that may be proposed by collaborating problem solvers. Let us term the task domain problem "*P*", and name different possible solutions that are proposed for it *s1*, *s2*, etc. Suppose that a single solution is proposed and is mutually accepted; in that case, problem solving presumably proceeds without notable interruption. Argumentation can get off the ground in the case where either more than one solution is proposed, or else where a single proposed solution is not mutually accepted. We term the extent to which an interlocutor is willing to accept (believe, endorse, commit to, etc.) a solution its *epistemic status*, "*e*", from the point of view of that interlocutor. The starting point for argumentation in collaborative problem-solving situations thus requires a certain degree of *diversity* — either in terms of solutions that are proposed for the task domain problem, and/or else in terms of the epistemic statuses of one or more solutions. The existence of such diversity creates a second level interlocutory problem, "*I*" (c.f. Quignard, 2000)[2]: which of the *s* for *P*, with their associated *e*, should be chosen? We assume that it is inherent in the problem-solving situation that either a single *s* must be chosen, or possibly that *s*'s should be ranked in order of their epistemic statuses[3].

Thus far, an interlocutory problem *I* (i.e. one that rises in exchange between interlocutors) has arisen from a task domain problem, *P*. But how can *I* be solved? On the first level, the answer is clearly: by *transforming epistemic statuses of solutions*, so that one appears more acceptable, believable, etc., than others. This intuition is in fact one of the bases of the classical *rhetorical* approach to argumentation (see van Eemeren, Grootendorst & Henkemans, 1996, for a modern account), according to which argumentation fundamentally aims at persuasion, or changing an auditory's point of view. But clearly, not all argumentative interactions are of this type; speakers' goals could be simply to decide which solution is to be preferred, without necessarily trying to impose their own views (Walton, 1989). Similarly, argumentation can take place in interaction with respect to several solutions proposed by a single speaker, whose interlocutor cooperates in helping to make a choice. To that extent, argumentation in collaborative problem-solving situations can often be seen more as a cooperative exploration of a dialogical space (Nonnon, 1996) than as an adversarial confrontation of well-elaborated and entrenched points of view.

But how can epistemic statuses of solutions be transformed, so as to decide which solution to prefer? We propose that there are two main and complementary ways: firstly, by *argumentation*, and secondly, by *negotiation of meaning*.

As a *discursive* activity, argumentation involves establishing specific types of (inferential or other) relations between the solutions being discussed, *s*, and other sources of knowledge, *k*, the establishment of which potentially influences the epistemic statuses of the solutions. An "argument" strengthens the epistemic status of a solution, and a "counter-argument" weakens it, from interlocutors' points of view. The sources of knowledge, *k*, must be different from the views to which they relate; they must *not* be understandable as developments, paraphrases, redefinitions, etc., of views (otherwise, the interaction becomes negotiation of meaning, or else explanation, in certain cases). A typology of (counter-)argumentation can be defined in terms of the nature of the inferential links, whether they are intended to strengthen or weaken epistemic statuses, and the nature of knowledge sources, *k*, drawn upon.

As a *dialogical* activity, argumentation involves somewhat more than linking in new knowledge sources to the ongoing discussion. Along its dialogical, or dialectical dimension, it is useful in the present context to

theorise argumentation using certain elements of formal dialectics (Barth & Krabbe, 1982) and pragma-dialectics (van Eemeren & Grootendorst, 1984). Firstly, interlocutors' views with respect to epistemic statuses can become somewhat stabilised into *stances*, or *dialectical roles* — opponent and proponent — and the solutions under discussion then take on the form of *theses*. Although in formal dialectical models such roles must be stable (e.g. an opponent must be systematically *contra* all of the proponent's statements), in real students' interactions, positions can naturally shift in a more flexible way. Secondly, interlocutors must play the game of producing (counter-)arguments according to certain (usually implicit) *ground rules*. These ground rules are partly logical — e.g. logical contradiction will usually be pointed out, as will inconsistent expression of dialectical roles, such as being both *pro* and *contra* a given statement — and partly pragmatic or cooperative (in a Gricean sense). Pragmatic/cooperative rules fulfil the function of enabling the discussion to move forward to a determinate outcome: given the arguments that have been expressed as dialectical moves (attacks, defenses, retractions, etc.), which thesis has 'won out'? For example, arguing round in repetitive circles may be legitimately sanctioned, and the outcome of the discussion must be expressed explicitly. As a result of such dialogical games, however flexible the roles may be, the interlocutors may be in a position to decide which of the solutions-theses should be retained, as a function of dialectical roles to be adopted towards them, which in turn encapsulate epistemic statuses with respect to domain problem solutions. Of course, participants may have their own private or unexpressed opinions; but dialectical models maintain that argumentation functions fundamentally in terms of what has been publicly expressed and recognised.

As stated above, the second way of resolving an interlocutionary problem is by negotiation of meaning. By this we mean any interactive and communicative means by which interlocutors transform, redefine or reformulate linguistic expressions relating to the domain of discourse. Clearly, such negotiation of meaning goes hand in hand with argumentation in interaction, since in any exchange, interlocutors express the way in which they have interpreted the preceding dialogue (c.f. Clark & Shaefer, 1989). A number of argumentation theorists have already described ways in which debate is associated with negotiation of meaning. Thus Walton (1992) has described how topics of debate often shift gradually towards more fundamental issues (he gives the example of a conversation about the institution of tipping in the USA that is transformed into a debate about the role of the state in regulating commercial practices). Naess (1966) has proposed that the process of making theses more precise is intrinsic to argumentation itself: a debate about the legitimacy of taking a human life is more likely to result in a refined understanding of the concept of human life than in a determinate dialectical outcome. There are two further ways in which negotiation of meaning can occur in argumentative interaction. The first is by dissociating concepts from each other (Perelman & Olbrechts-Tyteca, 1958/1988), thus redefining their meanings, and the second is by so-called compromise outcomes, in which new solutions are created by complex combinations and elaborations of existing ones. In all of these cases, it is clear that once meanings of statements or utterances shift, then so do their epistemic statuses. Whether you accept a statement or not obviously depends on what is meant by it. It is perhaps more precise to say that the epistemic statuses of the original solutions do not change, but rather than new solutions or even domain task problems are defined in a way that 'dis-solves' rather than 're-solves' the original problem (Baker, 1999).

This general theoretical perspective on argumentation and collaborative problem solving, that forms the basis for analysis techniques to be described in a subsequent section, is summarised in Figure 1 below.

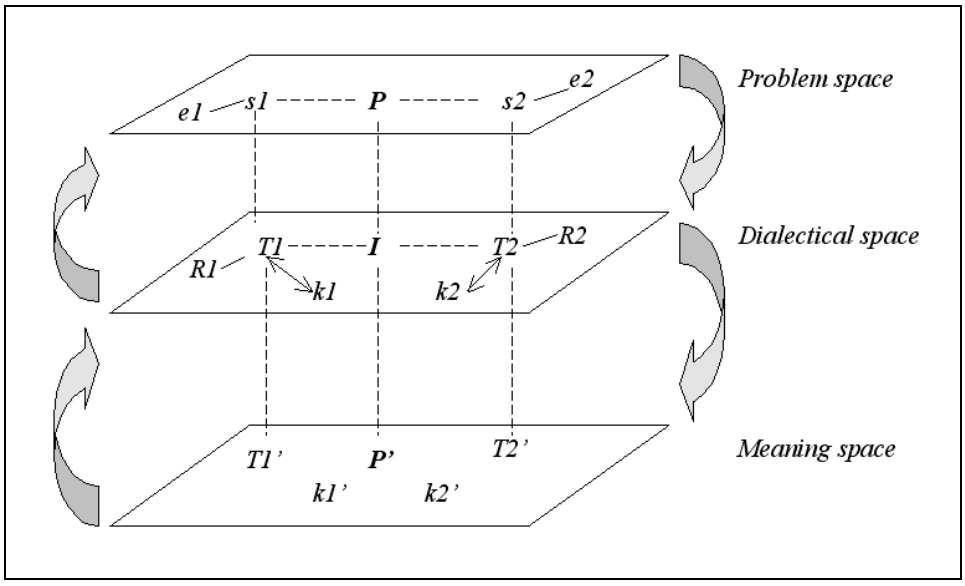

Figure 1. Basic approach to analysing argumentative interactions in cooperative problem-solving situations.

The diagram represents the point of view of a single speaker; clearly, different people can have different understandings of all elements of the diagram, especially the nature of the problem, *P*. In the problem space, two solutions are shown (there could be others), with their epistemic statuses. In the dialectical space, the problem is to choose between the solutions for *P*, each of which become theses (*T*) with associated dialectical roles. New knowledge sources (*k*) are linked to the theses as (counter-)arguments. This process leads to clarification of dialectical roles with respect to the theses, that 'feed back' into choice of solution for *P*. In their interactions, students usually glide seamlessly between these two types of problems, the interlocutionary problem arising from the task-level one, and task-level problem solving being resumed when students stop attempting to solve the interlocutionary problem (because they believe it to be solved, because they redefine it, because they 'let it drop', and so on). Concomitantly, the meaning of theses, arguments, and even the original problem *P*, can be negotiated. Thus, the semi-circular arrows in the diagram (Figure 1) represent possible transitions between the spaces: dialectics arises out of diversity and necessity for choice in the problem space, then in turn feeds back into it; dialectics involves and requires negotiation of meaning, that in turn influences the course of the argumentative interaction. Although this is not represented in the diagram, negotiation of meaning can of course occur in problem-solving outside dialectical contexts (i.e. a direct arrow between problem and meaning spaces).

Argumentative interaction and collaborative learning

Given the above characterisation of argumentative interactions in collaborative problem-solving situations, it is now easier to understand how these complex collective activities could lead to elaboration of new knowledge and understanding.

The first process by which this can occur relates to the discursive dimension of argumentation, by which new knowledge sources, *k*, are linked to theses in an attempt to solve an interlocutionary problem, *P*, i.e. production of (counter-)arguments. One possibility would be to see argument generation as a process of rendering explicit explanations for solutions, that could lead to knowledge restructuring in a manner analogous to the "self-explanation effect" (Chi et al., 1989). More generally, verbalisation of problem-solving processes in the context of a communicative interaction can enable interlocutors to elaborate more coherent points of view (Crook, 1994) or, at the very least, to become acquainted with the diversity of points of view.

The second potentially productive process relates to the dialectical dimension of argumentation, that is orientated towards clarifying dialectical roles and ultimately the epistemic statuses that are ascribed to problem solutions: what are the problem solutions that students are led to (publicly) accept or reject? The

most straightforward cases would be dropping or acquiring beliefs in solutions (c.f. Harman, 1986) as a result of successful dialectical refutations or defenses, respectively. Clearly, students' dialogical activity, even assuming it is completely frank and sincere, is not a simple determinant of more stable changes in their knowledge. But the acceptance of a proposal, in the sense of agreeing to use it as a basis for continuing joint reasoning (Cohen, 1992), may lead to its being appropriated in a deeper sense. In addition, changes in perceived epistemic status are of course not necessarily all or nothing; in fact more subtle and potentially beneficial changes may correspond to the simple realisation that a proposal is not as sure as was originally thought, and thus merits further inquiry. In all of these cases, when students argue without a teacher's supervision, and they can find no conclusive (counter-)arguments in the problem-solving situation, there is of course no guarantee that normatively preferred proposals will not be commonly rejected.

Finally, it is clear that the processes of negotiation of meaning, conceptual dissociation and knowledge elaboration, referred to above as integral parts of the argumentative process, are potentially the primary means by which collaborative learning can occur, especially on a conceptual level.

Our aim in the rest of this chapter will be to analyse and examine these processes at work in a specific corpus of computer-mediated interactions, collected with the CONNECT CSCL environment.

THE CONNECT ENVIRONMENT AND EMPIRICAL STUDY

CSCL interface design

CONNECT[4] (Baker, de Vries & Lund, 1999; de Vries, Lund & Baker, 2002) is a CSCL environment for collaborative critical comparison and writing of texts, via Internet. It was developed as part of a long-term research programme (see Baker, de Vries, Lund & Quignard, 2001, for a short synthesis), involving several CSCL interfaces, the main aim of which was to understand what aspects of the overall learning environment were most conducive to enabling students to engage in "epistemic interactions" bearing on scientific notions. In analogy with Ohlsson's (1996) notion of epistemic discourse, by an epistemic interaction we mean an interaction in which goes beyond stating problem solutions and methods, to discussion of conceptual foundations of problem solving. Our hypothesis is that such interactions will be predominantly argumentative and explicative.

In previous work on the C-CHENE CSCL environment (Baker & Lund, 1997), we had remarked that collaborating students rarely argued or explained their solutions during problem-solving itself, when starting together 'from scratch', and that when we presented them with alternative solutions, their choice between them was usually based on very superficial analysis. In CONNECT we tried to remedy this by a combination of means. Firstly, students produce individual problem-solutions before coming together to collaborate, which enables them to elaborate initial knowledge to be discussed, and enables the researcher to create working groups on the basis of maximising conceptual distances between individual solutions[5]. Secondly, a phase devoted to reflexion upon and comparison of solutions/texts was separated from the main problem-solving phase, so as to leave room for epistemic interaction. This phase is carried out using the interface shown in Figure 2 below.

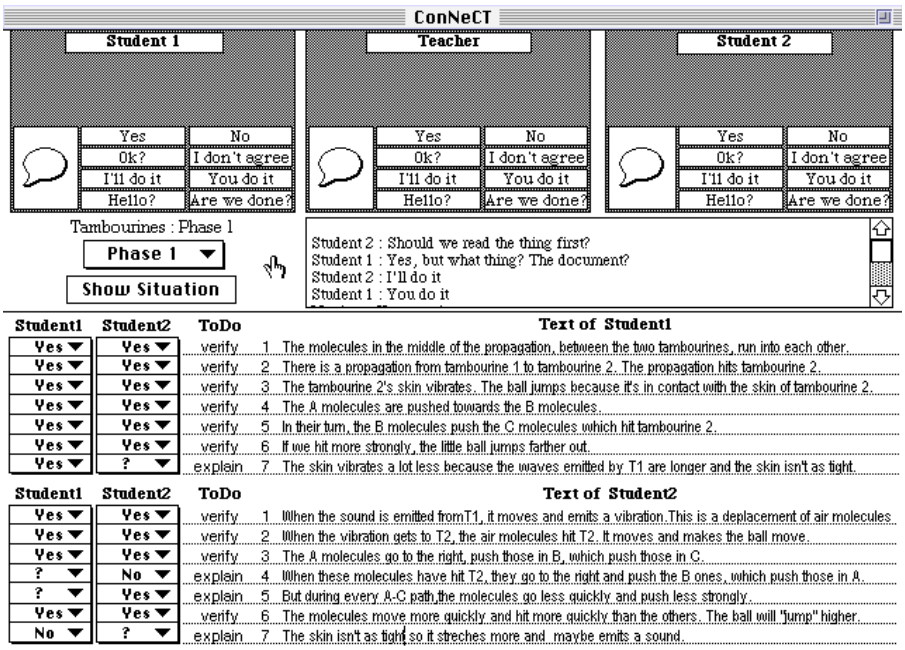

Figure 2. First interface of CONNECT (comparing texts and expressing attitudes)

The screen is divided into main upper and lower parts. The upper part is for typewritten synchronous communication across the network, with full screen sharing. Students (or the teacher) can take the floor by clicking on the speech balloons, and can also use some structured communication buttons. The lower part of the screen is for critical comparison of texts. On the right hand side, two students' texts have been segmented into statements; on the left hand side, students use check boxes to express their opinions — restricted to "YES, "NO" and "?" — with respect to every text segment, including segments of their own texts. The idea of asking students to do this was to find a means of requiring them to read actively their texts. As a function of pairs of attitudes for each text segment (e.g. "YES"/"NO", "?"/"YES", etc.), CONNECT generates some advice (a short statement) on how the students could go about discussing that segment. In this way, we hoped to help students to focus on key points, differences and similarities in or between their texts, which could be profitably discussed and explained. The text advice relating to attitude pairs is shown in Table 1 below.

Table 1: Attitude pairs and discussion instructions in CONNECT

Attitude combinations	*Discussion type*	*Instructions*
YES-YES, NO-NO	verify	verify both of you that you understand the same thing by the sentence
YES - NO	discuss	discuss in order to reach agreement, each one defending their points of view
YES - ?, NO - ?	explain	explain what you meant to say to your partner who put the "? "
? - ?	to be seen …	both of you verify that it's really what you meant to put

From a methodological point of view, asking students to express their attitudes its interesting, since it enables us to study the precise relations between types of dialogue and types of changes in attitudes (see analyses below).

Once they have finished discussing individual texts, the students move onto the next phase of the activity, during which they are given an interface (the precise details of which are not our principal concern here) for collaboratively writing a new text on the basis of their individual texts. At the end of the task sequence, the students' interaction log-files are passed to teachers for analysis, as a basis for subsequently going on-line to help the students improve their solutions and understandings (c.f. Lund & Baker, 1999). The overall task sequence lasts around three hours.

An empirical study with CONNECT

An empirical study was carried out using CONNECT, in the domain of interpreting sound phenomena in physics. The students' task was to interpret a simple situation in terms of a molecular model of air: two tambourines are suspended from a support, a short distance apart, with a small ball being suspended so that it touches the outer skin of the second tambourine; when the first tambourine is struck, the ball against the second moves in a certain way (see Figure 3 below).

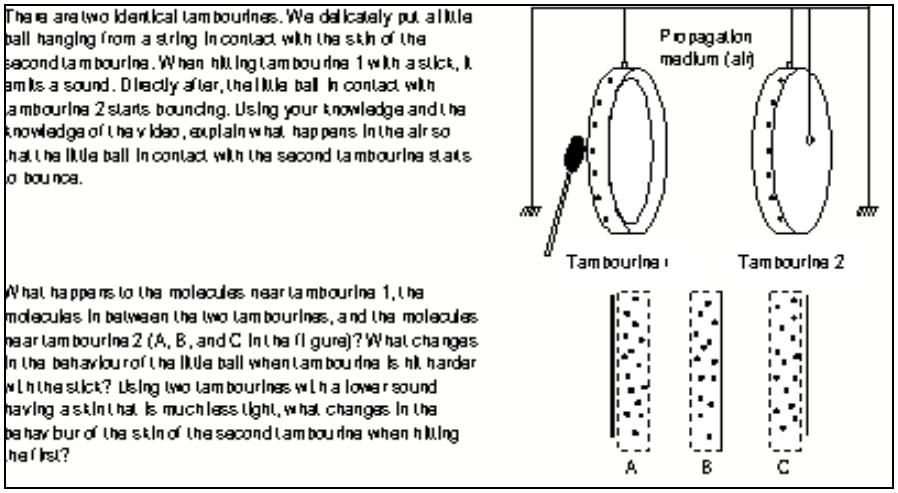

Figure 3. The sound task carried out with CONNECT

We chose to study this task since it is known that students typically have a variety of different mental models of sound (Maurines, 1998; Linder & Erickson, 1989), the confrontation of which in interaction was, we hypothesised, likely to lead to productive epistemic interactions. For example, according to a microscopic perspective, students may conceive of sound as being 'carried' by individual molecules, or as being transferred from one another. From a macroscopic perspective, sound can be conceived as a travelling 'substance' or else as a travelling pattern. The task shown in Figure 3 is partly designed so as to enable us to identify these different ways of conceiving of sound. For example, indicators of students' different understandings are likely to turn around the question as to whether the "A" molecules will be in contact or not with the "C" molecules: if they are, this could be an indicator of a 'travelling impetus' perspective, otherwise, together with other indicators, perhaps of a 'travelling pattern' perspective. Considerations of this kind were used to pair students together on the basis of the different perspectives on sound underlying their texts.

In reality, what is at stake for the teacher is that the students should come to understand that sound is a type of *displacement* of *vibrations* of air molecules — in a sense, a movement of a vibration. Since vibration is also a certain type of movement, the conceptual difficulty is to grasp the notion of sound as a "movement of a movement".

We worked with a class of secondary school students (aged 16-17 years) and their teacher, from whose individual texts we were able to create and study seven dyads, within each of which the students had different

mental models of sound. Due to technological constraints, the working session was carried out in computer rooms in our laboratory.

At the end of the session (lasting a little over 3 hours), we collected the automatically recorded log files (time-stamped typewritten interventions, interwoven with actions on the task interfaces, including all modifications of the texts).

CORPUS ANALYSES

A first qualitative-quantitative analysis of the CONNECT corpus was carried out, with a view to identifying the extent to which the students engaged in epistemic interaction. Results were globally encouraging (see de Vries, Lund & Baker, 2002, for details) in that during the text comparison/discussion phase, 23% of the interaction was argumentative and 33% was explanatory.

We now present and discuss results of further qualitative analyses of the argumentation sequences that were analysed according to the theoretical perspective described earlier in this chapter. In the discussion phase, 7 argumentation sequences[6] occurred in all, across the complete corpus collected for the 7 dyads. All of the sequences apart from one were "simple conflicts" (Barth & Krabbe, 1982), to the extent that a single segment of one student's text was discussed. However, in some cases, changes in attitudes with respect to one text segment logically triggered changes elsewhere, as the following student utterance illustrates: "since you put "no" for the 3 [3rd text segment] you should also put "no" there [for the 4th segment]".

Our analyses focus on attempting to explain different types of expressed attitude changes, as a function of characteristics of the argumentative interaction. We shall introduce the necessary analytical machinery as required.

Changes in epistemic status

As mentioned above, during the discussion phase of the CONNECT task sequence, students were first asked to express their attitudes — "YES", "NO" or "?" — with respect to each text segment. At the end of each argumentation sequence (as well as in other sequences), the students updated their attitudes on the interface as they felt appropriate. Such explicit changes therefore provide us with a set of phenomena to be explained: why, as a function of their interaction, did the students change their attitudes in the way that they did? For example, when one student initially expresses the attitude "YES" towards her own statement "Since the groups of A and B mol arrive towards the C mol, they make an impact with the tam", then, following a short discussion with her partner, changes this attitude to "NO", why, in this concrete case, did she do that? To what extent can an explanation be found in interactive processes?

As a preliminary, it is necessary to point out that from our theoretical point of view, the fact that there may be a difference between what the students "really think" and the attitudes they express is besides the point for the analysis of argumentative interaction. Argumentative interaction is concerned with "dialogical attitudes", such as commitments (c.f. Winograd & Flores, 1986) and acceptances (Cohen, 1992), and as such bears an indirect relation to more deep-seated beliefs. It is clear that argumentative concession does not necessarily imply a deep change of belief or opinion (c.f. Dennett, 1981); but what is important is that a student *did* in fact (publicly) concede, and can thus be held responsible for his or her public dialogical acts. What is said is said and cannot be unsaid. We will never know what people 'really think' (admitting that that expression is in fact meaningful) 'behind' their dialogue (Edwards, 1993); we can only interpret their discourse, in a wide sense of the term. Dialogue is not a "window on the mind", it a manifestation of minds in operation.

We analyse the ways in which students' attitudes could change into the following three categories[7]:

1. no expressed change (e.g. "YES" ➔ "YES"),
2. strengthening in epistemic value ("NO" ➔ "?" ➔ "YES "), or
3. weakening in epistemic value ("YES" ➔ "?" ➔ "NO").

Table 2 below summarises the seven argumentation sequences in the CONNECT corpus, in terms of epistemic statuses accorded to text segments by two speakers, A and B, before and after discussion, using the three values "YES", "NO" and "?", expressed by the students on the interface (e.g. "A: NO" means that speaker "A" expressed the attitude "NO" with respect to a given text segment currently under discussion). In the second column, the attitude that has changed is marked in bold. In fact, there are eight types of attitude

change in all, since in one sequence, two attitude changes occurred with respect to two different text segments. In an argumentative interaction, the "?" symbol is interpreted (by students and by the researcher) as expressing doubts, or as requesting a defense of a view. In an explanatory interaction it would be interpreted as expression of lack of understanding.

Table 2: Changes in expressed attitudes as a result of discussion in the CONNECT corpus

Attitudes before discussion	*Attitudes after discussion*	*Type of attitude change*	*N*
Dialectical opposition:	A: **NO** | B: NO	Weakening	2
A: YES | B: NO	A: YES | B: **YES**	Strengthening	1
	A: **?** | B: **?**	Weakening	1
Interrogative opposition:	A: YES | B: ?	No change	2
A: YES | B: ?	A: **?** | B: ?	Weakening	1
	A: **NO** | B: **NO**	Weakening	1

From Table 2 it can be seen that argumentation more often leads to weakening of attitudes (5 changes out of 8) than to no change (2 out of 8) and strengthening (1 out of 8). In two cases, each of which involve weakening of attitudes, both students' attitudes change, whereas in the other six cases, only one student's attitude changes.

We now examine examples of argumentation sequences associated with each of these types of attitude change (weakening, strengthening and no change). Fundamentally, our analyses and explanations of results depend on three main factors (see Baker, 1999):

(1) the dialectical interplay of argumentative attacks and defenses;
(2) the types of knowledge and understandings that are appealed to; and
(3) the way in which meanings are transformed or negotiated.

The dialectical interplay should, as we previously mentioned, function in a way that relates to externalised argumentation outcomes, with their associated attitude changes. Understanding the types of knowledge and understandings[8] expressed in debates is also important with respect to overall outcomes, given that certain types of arguments 'weigh' more than others. In the present case, types of understandings correspond principally to the students' models[9] of the sound phenomena, as described above.

Strengthening of attitudes

The single case of strengthening of attitudes in the corpus, where Andrew's "NO" is changed to a "YES", is shown in Table 3 below. As with similar tables reproduced below, the text typed by the students is translated from the original French, whilst attempting to transliterate spelling and typing errors. Students' names are changed whilst preserving their gender. The first column shows the time (in minutes and seconds) elapsed since the beginning of the session, and the second column consists of a simple numbering of interventions. An intervention corresponds to the text typed by a single student, that is then sent to the interaction history (see upper middle of interface shown in Figure 2) by pressing the return key.

Table 3: Example of a sequence leading to attitude strengthening (CONNECT corpus)

T(m:s)	*L*	*Andrew*	*John*
			Statement 1: "It perturbs the air molecules contained between t1 and t2. They move away from each other"
		Attitudes before:	
		NO	**YES**
8:19	32	They don't move away from each other, they all go towards t2	
(…)	(…)	*<Section omitted: Andrew completes his expression of opinions towards John's other statements, using the check boxes>*	
14:08	40		my 1: in the film we saw that the air molecules that were positioned in a certain way stretched out towards the front, here T2, thus creating a greater space between the molecules than before OK?YES OR NO
14:13	41	Yes	
(…)	(…)	*<Section omitted: different argumentation sequence with respect to John's statement 7>*	
4:12	60		To my sentence that you can see, you replied YES: why haven't you written it in the opinions table. Perhaps you weren't completely in agreement.
5:53	61	You mean why I haven't written in the text?	
6:27	62		look at what I'm going to show you <designates the opinions check boxes on the screen with the mouse pointer>
7:16	63	Q	
7:27	64		ritt yo read
9:01	65	Stop writing at the same time as me.	
10:07	66		there it wasnnxt me let's begin
10:09	67	No	
13:04	68	I haven't replied to your question. When I wrote that I didn't remember the film. O	
14:12	69	SSTO P !!!!!! We can begin.	
14:17	70		Yes
		Attitudes after:	
		YES	**YES**

In this sequence the problem, *P* is the second question shown in Figure 3: "What happens to the molecules near tambourine 1, the molecules in between the two tambourines, and the molecules near tambourine 2, and the molecules near tambourine 2 … ?". The first solution, *s1*, proposed by John, corresponds to the second part of statement 1 of his text: "*...They move away from each other"*. S1 becomes a dialectical thesis, T1, once Andrew has criticised it (line 32) and John has defended his thesis from this criticism (line 40). It has become a thesis since, by their dialogical actions, the students have adopted the dialectical roles of proponent and opponent.

Basic principles of dialectical analysis

In order to present the dialectical analysis of this sequence, we shall introduce a little notation, to be used below (see Baker, 1996, 1999, for further details).

Each dialectical move is analysed into three aspects, namely a *type of content*, a *speech act category* and a *pragmatic function*, as follows:

(1) *Contents* of moves can be propositions in the domain of discourse, notated "A, B, C, etc", predications of dialectical roles (*pro* or *contra*, or sometimes *no-commitment*) with respect to such

propositions, or else references to ground rules of the debate, notated "GR-1, GR-2, GR-3, etc." (see below). A special marker "(?)P" is used for hypothetical statements, glossed as "I am willing to defend P in this debate", or "might not P be the case?". Where moves involve complex propositions (see subsequent analyses), the reasoning involved will be reconstructed. To that extent, reasoning is clearly distinguished from argumentation, in a dialectical sense of the term.

(2) *Speech act categories* apply to propositions, and are given force indicators: "?" for interrogatives (questions, requests), absence of an indicator for assertives, and "!" for exclamatives. The "!" indicator will most often be used with respect to special propositions, that represent the ground rules of debate. For example, Barth and Krabbe (1982) define a special move called "*Ipse dixisti!*", or "You already said it yourself!", which signals that the interlocutor has just attacked a statement that (s)he previously defended. In a less restricted dialectical system, such as a "forensic debate" in the sense of Walton (1989), involving a cooperative search for the truth of the matter, *Ipse dixisti* would not necessarily be viewed as a foul move, but rather as part of the game. Our aim here is clearly not to impose a normative system, but rather to describe the ground rules with which the students appear to be operating, and to which they explicitly refer.

(3) The *pragmatic character* of a dialectical move refers to its function with respect to the debate. The principal functions are "attacks" on statements (theses) and defenses of statements/theses, which can be either direct supports of a thesis, or counteractive defenses (attacks on attacks). Pragmatic character is distinct from the speech act used in a move since, for example, an attack can be made by raising a question or else by making a new assertion, whose content would show the attacked statement to be unacceptable in some way.

It is important to emphasise that such dialectical analyses are deliberately reductionist: they only represent purely argumentative dimensions of interaction, to the exclusion of all others, such as negotiation of meaning, the type of knowledge involved, and social dimensions of interaction. Our proposal is that by separating out dimensions in this way, we can better see their interrelations.

Dialectical analysis of the example

A dialectical analysis of the interaction sequence reproduced in Table 3 is shown in Table 4 below.

Table 4: Dialectical analysis of attitude strengthening sequence[*]

L	*Andrew*	*John*	*Pragmatic character of dialectical move*
—		A, B	John's first statement in his text, the second part of which (B) retroactively becomes a thesis to be defended.
	contra(A,B)	*pro*(A,B)	Andrew's and John's expression contra and pro roles on interface check-boxes
32a	¬ B		*Contra* B, by expression of negation of B.
32b	C		Attack on B.
40a		D	Direct defense of thesis, B.
40b		[*pro*(D) ∨ *contra*(D)]?	Request for clarification of dialectical role
41	*pro*(D)		Concession of D
60a		*pro*(A,B)?	Request for clarification of dialectical outcome
60b		GR-1!	"Infraction against GR-1!"
	pro(A,B)		Concession of John's thesis A,B, explicitation of dialectical outcome

[*] *Key: A: It [t1] perturbs the air molecules contained between t1 and t2*
B: They[the air molecules contained between t1 and t2] move away from each other
C: They [the air molecules contained between t1 and t2] all go towards t2
D: in the film we saw that the air molecules that were positioned in a certain way stretched out towards the front, here T2, thus creating a greater space between the molecules than before
GR-1: The outcome of the debate must be externalised.

In purely dialectical terms, what is interesting about this sequence is that John, from line 60 onwards, has to insist so that Andrew makes the outcome of the sequence explicit, i.e. John has successfully defended his

thesis, B. John points out, in line 60, that since Andrew conceded D, which defends B, then he should also make clear, on the opinions interface, that he concedes B (or rather the statement A;B) as well. But in fact, Andrew moves on to considering other statements in the interval between lines 41 and 60. One possible interpretation of John's request that Andrew make the outcome explicit is to see this as an implicit reference to what Barth and Krabbe (1982) term an "externalisation" rule of formal dialectics. The provision of check boxes for expression of attitudes can in fact be seen as encouraging this. But *why* did Andrew not openly admit defeat? One possible reason lies in his expression of annoyance at his partner typing at the same time: is this only frustration with the interface, or does it also reveal the fundamentally *social* character of argumentation (Muntig & Turnbull, 1998), i.e. losing an argument means losing 'face'?

To complete our brief analysis of this short, yet interesting, sequence, let us finally make some remarks about the types of knowledge expressed and about negotiation of meaning.

The two students' utterances can here be easily interpreted as expressions of different 'models', or understandings, of the way in which sound works on a molecular level. For Andrew, sound is a sort of wind, or displacement of substance, whereby all molecules are pushed along from left to right. John's understanding is closer to a vibration model of sound, in that he speaks of molecules moving away from each other to leave a space. It turns out that John's understanding is closer to objectives of physics teaching; but was this why he managed to make Andrew concede? Perhaps. But another possibility could lie in the fact that he makes explicit reference to an introductory film that both students saw ("in the film we saw that …"): seeing — or rather having seen — is believing. This interpretation would be coherent with our previous results (Baker, 1999), where it was shown, for a different physics problem-solving task, that students' debates were almost always resolved by making appeal to perceptual (and thus 'undeniable') facts, either within the experimental situation, or else derived from everyday experience.

With respect to negotiation of meaning, this short sequence can also be seen as a process of *explaining*, *elaborating*, or making more *precise* the students' (opposed) views. At the beginning of the sequence, Andrew states that it is the second part of John's statement (B) with which he does not agree. Andrew's defense, using D, can be seen as an explanation of the expression "move away from each other", i.e. the molecules are "stretched out", leaving a "greater space". To that extent, in this case argumentation does seem to have an "other-explanation" function, since students are led to make their underlying understandings explicit, under the interactional pressure of their interlocutionary problem, and to further develop them in interaction.

In conclusion to the analysis to this sequence, why, therefore, did a student who was against a statement about a sound phenomenon then say that he was in favour of it? The answer cannot of course be simple. It appears that the student could find no reason to deny something that he himself had seen; but his partner had to work hard to make him admit openly that this showed his thesis to be successfully defended. An interesting conjecture would be that this latter fact underlines the importance of social dimensions of interaction, as influenced by the CSCL communication situation.

Weakening of attitudes

We now turn to summarised analyses of two examples of weakening of attitudes. In the first example (see Table 5 below), one girl changed her "YES" to a "NO. The second example (see Table 7 below) is complex, in that two statements are discussed together, and all four attitudes weaken towards uncertainty ("?").

Table 5: First example of attitude weakening ("YES" to "NO")

T(m:s)	*L*	*Linda*	*Elaine*
			Statement 3: "Since the groups of A and B mol arrive towards the C mol, they make an impact with the tam"
		Attitudes before:	
		NO	**YES**
9:36	36	it was nice of you to have put yes to everything for me, but for the 3, I think that the "a" mol aren't in contact with the "c" mol	
14:40	37		of course they are, because if you have a wave all the molecules, like billiard balls, will be displaced because the hit on the tambourine it's as if we'd pushed them all the mols will mix up and hit on the tam no,
17:39	38	ah! after all perhaps you're right, but I ask myself whether they'll mix together as much as all that, don't you think that the "b" will create a barrier between the "a" and the "c"	
20:36	39		i don't know maybe i'm wrong so i'm going to chang[e] and after we change question to go onto the 6
		Attitudes after	
		NO	**NO**

In the sequence reproduced in Table 5, the same problem, *P*, is discussed as with the sequence shown in Table 3 — what happens to the A,B and C molecules between the two tambourines?

The dialectical analysis of this sequence is shown in Table 6 below.

Table 6: Dialectical analysis of first attitude weakening sequence[*]

L	*Linda*	*Elaine*	*Pragmatic character of dialectical move*
		A	Statement 3 of Elaine's text
	contra(A)	*pro*(A)	Expression of attitudes on check-boxes
36	B		Attack on A
37a		¬ B	Counter-active defense of A: attack on B (that attacks A)
37b		C	Defenses of ¬ B
37c		D	
38a	D?		Calling D into question; request for justification of D.
38b	E		Attack on D
39		(?)*pro*(E)	Concession of E (attack on D, that defended thesis A), in an hypothetical form "perhaps".
		contra(A)	Concession of refutation of A, expressed on interface check-box

[*] *Key:* A: Since the groups of A and B mol arrive towards the C mol, they make an impact with the tam.
B: the "a" mol aren't in contact with the "c" mol
C: if you have a wave all the molecules, like billiard balls, will be displaced because the hit on the tambourine it's as if we'd pushed them
D: all the mols will mix up and hit on the tam
E: the "b" will create a barrier between the "a" and the "c"

The sequence appears to be a straightforward refutation, since Elaine was forced to concede Linda's attack on her idea of the molecules mixing up together, according to which the B molecules would create a barrier between the A and C molecules. However, something significant is not sufficiently highlighted in this analysis, which is that the students use many modal expressions, such as "perhaps you're right", "I think that", "I ask myself", "I don't know, maybe i'm wrong". These expressions indicate the students' general lack of certainty with respect to their proposals, and probably the social dimension of politeness in interaction. It is worth noting that although Elaine has several reasons in favour of her proposal, it is refutation that determines the outcome of this dialectical game. As with the previous sequence analysed above (Tables 3 and 4), the pressure of argumentation forces the students to negotiate the meaning of certain expressions (e.g. "arrive towards" is more precisely defined as a wave, and in terms of "mixing up"), and to express their different understandings. Perhaps surprisingly, it is again the less elaborate understanding of sound — a wave or wind of molecules that are all displaced — that is eliminated from consideration.

Our second example of weakening of attitudes is shown in Table 7 below, between the same two students as above. In fact, there is a complex set of related changes of attitudes: Elaine's two "YES"s weaken to "?", and Linda's "?" remains unchanged, whilst her "NO" slightly strengthens to a "?".

Table 7: Second example of weakening of attitudes (all to "?")

T(m:s)	*L*	*Linda*	*Elaine*
			Statement 4: The mol which will be in C will leave again with the mol in A and in B towards the left Statement 6: The little ball will jump faster with a greater frequency
		Attitudes before:	
		Statement 4: ? **Statement 6: NO**	**Statement 4: YES** **Statement 6: YES**
23:24	43	there's **[Elaine's statement 6]** a thorny issue ! since it jumps higher it takes more time to come down again therefore the frequency is perhaps not more rapid	
28:27	44		i'm not sure so we'll take away "with a greater frequency". for the 4 i'll explain it to you: since I thought they would mix up together and that they would strike each other, I thought they would come back together no?
30:05	45	yes, that's logical but since you put "no" for the 3 you should put "no" also	
30:25	46		<Expresses "NO" for Elaine's Statement 4>
30:28	47		<Expresses "?" for Elaine's Statement 4>
30:38	48		<Expresses "?" for Elaine's Statement 6>
30:41	49	Expresses "?" for Elaine's Statement 6	
33:02	50		that we are not sure so we shouldn't take a firm view in the text and we'll start it now since everything's sorted out
		Attitudes after:	
		Statement 4:? **Statement 6: ?**	**Statement 4: ?** **Statement 6: ?**

For considerations of space, we shall not present a detailed dialectical analysis of this sequence, but shall rather restrict ourselves to discussion of a new aspect that is important for understanding why the students' change their expressed attitudes. This key aspect is revealed by Elaine's statement that "[since] we are not

sure … we shouldn't take a firm view". It is as if the students function according to a principle of consensus in uncertainty. In other words, since a view has been called into question, all that can be said is that "*we* are not sure".

This general point is in accordance with results of argumentation analysis for another physics problem-solving task (drawing energy chains), with respect to which it was found that argumentation functioned as a mechanism for "weeding out flawed proposals", rather than as a means for imposing them (Baker, 1996, 1999). In Miller's (1986) terms, a view that is contested cannot become part of the "collectively valid".

No change in attitude

Finally, we analyse a complex sequence that resulted in no explicit change of attitude. The sequence is interesting given the complexity of the reasoning involved, as well as the range of types of knowledge appealed to, and processes of negotiation of meaning by conceptual dissociation. The example sequence is reproduced in Table 8 below.

Table 8. Example of no explicit change in attitudes.

T(m:s)	*L*	*Alan*	*John*
			Statement 7: "With the less tight skin, it is easier for the molecules to make it shift but the ball shifts less."
		Attitudes before:	
		?	**YES**
16:19	43	If the skin shifts more why does the ball shift less?	
19:15	44		the skin shifts more because it is less tight but the pressure that the air exerts is the same. This skin "marries" [wraps around] thus the form of the ball.
21:24	45	Not agreed. In my opinion the skin of T2 shifts less (see my 7). <Statement 7 of Alan, to which both marked "YES", is: "The less tight skin of tambourine 2 absorbs vibrations more, and thus vibrates less itself">	
27:20	46		difficult to know when one looks at the skin, one sees it shift more that has the tighter skin when you hit on something hard, that is stable in space, it won't shift whereas a rag that is not stretched tight, for example, yes [it will]
33:14	47	Another explanation: take a string that is not tight. If you touch [strike] it it will shift a lot but it will vibrate little. By contrast, a tight string, like a guitar one, it will shift little but vibrate a lot.	
36:37	48		i agree with your 7 but at one point I thought you didn't agree with mine. For me, the two sentences are right, they simply don't explain the same thing(vibrations and movements)
39:23	49	NO. If a less tight skin vibrates less it shifts more, therefore the ball must shift more as well.	
40:34	50	pardon, have you understood?	
43:29	51		Hypothesis: with the same force of the air exerted on T2: a tight skin will

			vibrate more than a less tight skin but will shift less than it
43:37	52	<changes "NO" to "YES" for opinion with respect to John's statement 1: "It perturbs the air molecules contained between t1 and t2. The molecules go away from each other.">	
43:44	53	Yes	
43:47	54	Yes	
47:55	55		for the ball, I think it will shift less with the not-tight skin because it will vibrate less thus it will "transmit" many less vibrations
48:27	56		Agreed?
49:09	57	Perhaps	
		Attitudes after:	
		? (no change marked)	**YES (no change marked)**

Given the complexity of the students' reasoning, drawing on "more" or "higher" and "less" or "lower" values for factors such as force, pressure and tension, in some cases we shall represent this in the dialectical analysis using the following predicates: "x shifts" = "S(x)"; "x moves" = "M(x)"; "the tension of x" = "T(x)"; "x vibrates" = "V(x)"; "pressure of x" = "P(x)"; "W(x,y)" = "x wraps around y"; "x absorbs y" = "A(x,y)"; "x transmits to y" = "transmits(x,y); "x increases, is higher, etc." = "↑(x)"; "x is lower, decreases, etc." = "↓(x)"; "x remains the same, is constant, etc." = "↔(x)"; "x" can refer to objects such as skin, strings, a ball, etc.

The students' reasoning is expressed in many linguistic forms, such as: "x since y", "x because y", "x thus y", "x causes or leads to y", and so on. For simplification of the analysis, we shall (brutally) reduce all such expressions to an IF/THEN form, "x → y".

In order to highlight operations on meaning, we shall represent a reformulated version of a proposition X, or a version that makes its meaning explicit ("in other words …"), as X'. The predicate "*n-c*()" represents a non-committed dialectical role. To avoid repeating whole complex propositions, they will sometimes be referred to by their line numbers (e.g. "45c").

We use the verb "to shift", rather than "to move", in this case for an important reason, which is that in the original French, two distinct words are used to refer to movement in general: "*bouger*", which is an everyday familiar word, that we have translated by "to shift", and "*mouvement*", that can be a more scientific term, that we have translated by "movement". For learning viewed as appropriation of language (e.g. Wertsch, 1991), the interplay of everyday and scientific discourse is important here. As will be seen, the students' discussion in everyday language ("bouger", to shift) culminates in a (proposed but not accepted) distinction between movement and vibration.

The dialectical analysis of the sequence reproduced in Table 8 is shown in Table 9.

Table 9. Dialectical analysis of sequence with no explicit attitude change.

L	*Alan*	*John*	*Pragmatic character of dialectical move*
		↓T(skin) ∧ ↑S(skin) ∧ ↓S(ball)	John's statement 7. Thesis T1
	n-c(T1)	*pro*(T1)	Dialectical roles expressed on interface
43	(↑S(skin) ∧ ↓S(ball))?		Attack on part of T1: how do you defend that?
44a		↓T(skin) ∧ ↔P(air) → ↑S(skin) →	Defense of why skin shifts more
44b		W(skin, ball) → ↓S(ball)	Defense of why ball shifts less
45a	*contra*(↑S(skin))		Attack on proposition that skin shifts more.
45b	↓S(skin)		
45c	↓T(skin) → ↑A(skin,V(x)) → ↓V(skin)		Defense of skin shifting less, using a statement that John has already conceded (Alan's statement 7).
46a		*n-c*(↓V(skin))	Partial concession.
46b		(?)↑T(skin) →↑S(skin)	Intended defense of first part of T1
46c		↑T(x) →↓S(x)	Attack on 45c, that states that low tension leads to low vibration (a type of "shifting")
46d		↓T(x) →↑S(x)	
47a	↓T(string) →↑S(string) ∧ ↓V(string)		Defense of own statement 45c *and* of John's 46c: attempt to resolve by dissociating "shifting" from "vibration".
47b	↑T(guitar-string) →↓S(string) ∧ ↑V(string)		
48a		*pro*(45c)	Concedes Alan's defense using his statement 7.
48b		*pro*(T1)?	Request for clarification of dialectical role with respect to own thesis T1.
48c		*pro*(45c ∧ T1)	Attempted resolution of conflict: both are correct, but not equivalent.
48d		M(x) ≠ V(x)	
49a	*contra*(45c ∧ T1)		Attempted resolution not accepted!
49b	↓T(skin) → ↓V(string) → ↑S(skin) → ↑S(ball)		Attack on second part of T1 (the ball must shift *more*), using own statement 47a, which was not denied by John.
50	*pro*(49b)?		Request for expression of dialectical role
51		↑T(skin) → ↑V(skin) ∧ ↓S(skin)	Concession of 47b
53-4	*pro*(51)		Ratifies concession
55		↓T(skin) → ↓V(skin) →	Attack on 49b: with a

		↓transmits(skin, V(skin)) ↓S(ball)	→	slacker skin, ball moves less not more!
56		*pro*(55)?		
57	*n-c*(55)			

When looked at under the microscope of analysis, the above sequence is highly complex. We shall restrict ourselves to a few main points relating to co-elaboration of understanding in a dialectical framework, without commenting every detail of the analysis.

In contrast to the previous examples, the task problem, *P*, that the students address here is as follows: "Using two tambourines with a lower sound, having a skin that is much less tight, what changes in the behaviour of the skin of the second tambourine when hitting the first?". John's proposed solution, *s1*, is firstly, that when the skin is less tight, it can be *moved (shifted) more easily*, and secondly, that in this case, however, *the ball moves less*. From a dialectical point of view, the sequence proceeds by focussing on the second statement, then the first, then returning to the second. To Alan's attack, "If the skin shifts more, why does the ball shift less?", John replies with an imaginative image — "the slack skin wraps around the ball" — to which he returns at the end of the sequence, stating that a slack skin will not transmit much vibration.

In order to strengthen his attack, Alan refers to his own statement (7), in which he states that a slack skin absorbs vibration and so vibrates less." From then on, the whole sequence can be seen as an attempt to make more precise what *shifting*, *movement* and *vibration* mean, and how they are to be dissociated from each other. At certain points, it seems that by "shifting" of the skin, John means something like its *amplitude*, the extent of movement, and at others, the 'amount' of movement, or its *frequency*. To that extent, the students touch upon the key concepts at stake here — sound as a *displacement of a vibration*, or, in a sense, a 'movement of a movement'. However, although John and Alan recognise that movement and vibration need to be dissociated (they have opposed "more" and "less" values: higher vibration means lower movement and lower vibration means more movement), this does not really help them to gain a clearer understanding of each notion. The fact that each student is, in a sense, talking about something different, helps to explain why the debate, despite numerous attacks, defenses and concessions, can not come to a conclusive outcome, producing explicit attitude changes concerning what is explicitly debated.

However, it appears that the necessity to express his view about John's statement 7, leads Alan to change his mind (line 52) with respect to another of John's statements (number 1): since John speaks of molecules moving away from each other, this is closer to Alan's insistence on the notion of vibration, so he changes his NO to a YES. This is perhaps an example of argumentative interaction leading to a more coherent discourse (see reference to Crook, 1995, above).

Finally, in order to try to resolve their interlocutionary problem, the students draw extensively on their everyday life experience, of rags and guitar strings. This does not, however, help them to dispel confusion, since the notions of movement they are working with are not sufficiently defined.

Synthesis of analysis results

In conclusion to this section, we summarise the main results of our analyses, to be discussed in the final section of the chapter.

The corpus analysed here was collected in a situation where pairs of students used a specific interface of the CONNECT CSCL environment to solve a problem of understanding sound, in physics, using a molecular model. That interface invites students to express their attitudes — "YES", "NO" or "?" — towards each segment of each of their texts, as a means of focussing critical analysis, reflexion and discussion. As a result of discussion, students can, and often did, change the attitudes they expressed. The CONNECT corpus thus lends itself to attempting to understand the interactive processes that potentially relate to those attitude changes.

After having identified the seven argumentative interaction sequences in the corpus, we categorised them into types of attitude changes, as follows: strengthening of attitudes (e.g. "NO" → "YES"), weakening of attitudes (e.g. "YES" → "?"), and no explicit change in attitudes (e.g. "NO" → "NO"). Our analyses were presented as a function of these three types of changes.

Only one example of *attitude strengthening* occurred, in which a student changed his attitude from a "NO" to a "YES", with respect to one of his partner's statements. In this case, the 'winning' student had to work

hard to oblige his partner to explicitly represent this attitude change on the CONNECT interface. We analysed this as an implicit reference to a ground rule of dialectics that requires externalisation of outcomes of the debate, and speculated that failure to immediately comply with this rule illustrated the social dimension of facework (face-loss, in this case) of argumentative interaction. In this example, a more elaborated understanding of sound was successfully defended. The students' interaction was also analysed as a process of making explicit and more precise the meaning of an aspect of the more elaborated sound model, involving the notion of molecules moving away from each other.

Attitude weakening was the case with 5 out of 8 argumentative sequences. We analysed two examples, involving dialectical refutation[10] ("YES" → "NO") and a common movement towards being unsure ("?" for each student). Weakening is associated with expressions of uncertainty ("I don't know", "I ask myself"), and modal expressions ("perhaps", "could") that were analysed as 'softeners' of loss of face, on the level of social interaction. In one case, given that doubts had been raised, students agreed on a type of consensus in uncertainty. Attitudes were weakened with respect to less elaborated models of sound.

When there was *no manifest change in attitudes*, this was associated with, and explained by, the fact that the students' understandings of important domain notions had been renegotiated. We analysed a complex case in which the students attempted to dissociate everyday and possibly scientific notions of movement and vibration, the latter being a specific case of the former.

Our principal results, with respect to the CONNECT corpus, can thus be summarised as the following five points. These results apply also to the sequences (3 out of 7) whose analyses have not been presented here.

(1) *Attitudes weaken rather than strengthen.* Attitude strengthening is rare; attitude weakening and absence of change in attitudes, in that order, are more frequent.
(2) *Students' argumentative interactions display dialogical rationality.* Attitude changes, when they occur, can be analysed as adhering to a certain dialogical rationality; they can be explained as a function of dialectical moves (e.g. failure to defend against an attack means losing the game) and in terms of adherence to certain ground rules, such as a requirement for clarification of the outcome.
(3) *Understandings are co-elaborated*. In argumentative interaction, students are led to render explicit, to co-elaborate and to make more precise their discourses on their understandings of the task domain. Argumentative interaction goes hand in hand with negotiation of the meaning of the notions at stake.
(4) *Less adequate understandings are eliminated*. When more and less adequate models of sound are confronted, and associated with an attitude change, in these cases, the less adequate understanding is eliminated from consideration, or the more adequate understanding wins out.
(5) *Argumentative interaction is social interaction*. The playing out of the dialectical game, often involving winners and losers, is intimately associated with attempts to manage and maintain a viable social interaction, involving expression of emotional disquiet and minimisation of loss of face.

DISCUSSION

We interpret these results in terms of the interrelations between three main dimensions of the CSCL collaborative problem-solving situation: *epistemological-cognitive*, *socio-interactional* and *technological*. The first concerns the nature of the problem-solving domain, the students' understanding of it, and the sequence of tasks. The second concerns the nature of the students' interpersonal relationship, as it evolves in the interaction, along factors such as face threatening/preserving, friendliness/hostility, positive/negative emotions, within a socio-institutional situation that defines them as equals in the hierarchy (both are "students" of the same class). The technological aspect concerns specific characteristics of the interface tools, such as the fact that no visual contact is provided, each can overtype at the same time, etc. These are analytical, not empirical dimensions: it could be maintained that in practice, the three are inseparable, or should not be dissociated. In particular, the interface can only be meaningfully analysed with respect to the task for which it is intended.

Why does there seem to be a general tendency for attitudes to weaken, with respect to problem solutions? One possible reason lies in the epistemological-cognitive dimension in the collaborative learning situation. As discussed previously, the problem to be solved is potentially suitable for argumentative discussions, given the range of alternative understandings that students can have with respect to it. In addition, we created dyads precisely to maximise these differences between students, and created a phase for solving the interlocutory

problem (see above) that was separated from problem solving in the task domain. However, as Nonnon (1996) has pointed out, there is a paradox with respect to argumentative discussions in learning situations: in learning situations, new knowledge is supposed to be co-constructed; so it is unlikely that students will be in a position to adopt firm attitudes with respect to such knowledge. Rather, students' positions will most probably be quite volatile, shifting for and against, as they explore around the problem, dialectical and meaning spaces. What is remarkable in this corpus is that collaboration between students with different interpretations of sound leads to less elaborate or adequate solutions being eliminated. Why should this be the case, when students usually are able to defend solutions irrespective of their quality? Is there something about a better solution that is 'just obvious'?

A second possible line of explanation for attitude weakening lies in the nature of the students' interpersonal relations. In several cases, the students' attitudes seem to weaken because it would be only 'fair' to their partners to weaken their attitudes a little, given that doubts have been raised with respect to a statement. In one case, this requirement for fairness went so far as a consensus in uncertainty. The fact that the students' are communicating at a distance, with no face-to-face contact, does not appear to prevent the students from using linguistic resources to 'soften' the possible loss of face associated with criticism and refutation.

Our proposal that students' argumentative interactions could be analysed in terms of ground rules for "rational discussions", derived from formal dialectical models (Barth & Krabbe, *op. cit.*), may appear contentious. In particular, we propose that students' adherence to the two following rules is a plausible analysis of their interaction: "argumentative outcomes must be made explicit", "an attack must be followed by a defense, otherwise you lose the game". To these we can add "attacks and defenses must not be repeated", given that the students always redefined and re-elaborated their defenses and attacks, along the dimension of negotiation of meaning. Our claim may appear less contentious given the following two points. The first point is that dialogical rationality is not the same as individual rationality. In cognitive science the latter has often been conceived as a matter of acting in a way that one believes will maximise achievement of one's goals. But dialogical rationality is about how one acts in communication and cooperation with others. It is thus plausible that groups will impose stronger constraints on rationality than individuals will upon themselves. The second point relates to the nature of dialectical rules in accordance with dialogical rationality. Such rules should not be seen as restricted to a specific and idealised form of interaction. In fact, they are expressions of more general principles of cooperation and communication (c.f. Allwood, 1976). It is thus not surprising that students' communicative inter-actions can be interpreted in terms of these rules and principles.

Finally, interpreting the extent to which students explain their understandings and negotiate the meaning of notions in the task domain requires, in addition to the above points, an examination of the characteristics of the CSCL interface tools. Constraints associated with synchronous typewritten communication across the network (e.g. Clark & Brennan, 1991) are now well known. For example, one could predict that typewritten communication inhibits free expression of elaborate ideas in complex types of interaction, and that absence of non-verbal clues at a distance would lead to problems in establishing intercomprehension. What is it, then, about the CONNECT CSCL situation — by "situation" we mean the tools-task-situation-social actors — that favours or allows expression and elaboration of understandings in the task domain? One possibility is that the careful choice of the task and of participants in dyads was able to outweigh interface constraints. Another is that the provision of check boxes for expressing attitudes for each segments of texts enabled the students to *focus* on the important points to be discussed, or, as we defined them above, the interlocutionary problems. Finally, it is not certain that some form of constraint on expression of ideas in typewritten CMC is necessarily negative from the point of view of problem solving. For example, Tiberghien and de Vries (1997) have shown that in CMC interactions, students restrict themselves to expressing the most complex operations of modelling in physics. Perhaps CMC helps to cut out verbiage, whilst not obviating the necessity to maintain an adequate interpersonal relation?

CONCLUSION

In this chapter, we have presented a theoretical approach to understanding how students engaged in collaborative problem solving can co-elaborate new understandings in and by argumentative interactions. The approach depends on describing interrelations between three "spaces": the problem space, the dialectical

space and the meaning space. This approach was applied in the analysis of a corpus of interactions that was collected when dyads of students used the CONNECT CSCL environment to solve a problem of interpreting a sound phenomenon in physics.

In conclusion, we discuss the generalisability of our results, and provide some indications on further work.

Generalisation of our results beyond the CONNECT corpus requires a painstaking inductive approach (accumulation of supplementary evidence), involving similarly detailed analyses to the ones presented above. The analyses would need to cover a wide range of variations in tasks, groups and interfaces. Such an enterprise represents a major and daunting challenge for the cognitive science of collaborative learning. We make the conjecture that the most effective way of achieving this goal is to develop strong theories and models, and to apply them to the deep analysis of specific cases.

It turns out that our results are largely concordant with those obtained from the analysis of a corpus of spoken interactions, collected with respect to an analogous problem involving modelling energy in physics (Baker, 1996, 1999). For example, in that research it was found that students' argumentative interactions mostly functioned as means of eliminating proposals that were seen to be 'flawed' in some way, rather than as a means of defending and commonly adopting proposals (see result 1 above). An alternative to the inductive approach would be to see our results as existential statements that falsify universal ones (the existence of a black swan falsifies the statement that all swans are white, i.e. not black). For example, our results would contradict the belief (assuming that it was widespread) that typewritten CMC communication necessarily prevents production of potentially constructive epistemic interactions.

We have shown that students can interact with and via the CONNECT CSCL environment students in order to choose better problem solutions and to co-elaborate deeper understandings in and as a result of engaging in argumentative interactions. But there are clearly limits to what students can achieve in their argumentative interactions, without outside help. Clearly, students need a teacher's help in order to resolve certain questions, and to integrate what they believe to have learned into their existing knowledge, within constraints inherent in the educational system. One line of research that we are currently exploring aims to define the teacher's role in CSCL environments based on the pedagogical power of argumentative interactions.

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NOTES

[1] Throughout this chapter we shall use the terms "co-elaborate" and "co-elaboration", rather than the more common "co-construct" and "co-construction", for a specific reason. We view the term "co-construction" as an architectural metaphor, that could lead to the view

that collaboration involves each partner adding a new separable element to the solution, in the way that builders might add bricks to a building. In fact, from our previous research (Baker, 1994, 1995), we propose that collaboration proceeds by each participant ("co-") *transforming*, or elaborating, previous contributions. A better metaphor would therefore be that of a group of people each moulding a common piece of clay until the result satisfies them.

[2] The theoretical perspective according to which argumentation can be seen as the attempt to solve these two types of problems is a basis of M. Quignard's PhD thesis in Cognitive Science (Quignard, 2000), research for which was carried out in the GRIC Laboratory, Lyon, under the supervision of M. Baker and J. Caelen. Echos of this approach are also to be found in the "problematology" of Meyer (1986).

[3] See, for example, Baker (2000), for an analysis of argumentative interactions in which experienced and less experienced doctors discussed alternative medical diagnoses in order to rank them in order of plausibility.

[4] "CONNECT" means "CONfrontation, NEgotiation and Construction of Text".

[5] For precise details on the procedure for pairing students, together with other experimental details, readers are referred to de Vries, Lund & Baker (2002).

[6] Strictly speaking, we should rather say "sequences in which argumentation is the predominant discursive process", rather than "argumentation sequences", since argumentation almost never occurs as a 'pure' genre, usually being combined with explanation, negotiation of meaning and different types of interaction management.

[7] Clearly, even more fine-grained categories could be used, that exploit individuals' attitude changes in the group. For example, there are many ways in which attitudes could be weakened: from YES/YES to YES/?, YES/NO, ?/?, NO/?, NO/NO, and so on. Examples of only some of these possibilities are presented here, for reasons of brevity.

[8] By the terms "knowledge" and "understanding" in this context, we do not mean to say that what the students think is true. Rather, we mean an understanding of a problem solving situation, in a sense closer to the French term *connaissance* rather than to *savoir*.

[9] Elsewhere in this chapter we shall use the less theoretically-charged terms "understandings" and "points of view", instead of (mental) models (Johnson-Laird, 1983). Given our preoccupation with discourse in interaction, we do not necessarily mean to imply that the students possess fully elaborated and coherent mental representations, whether they correspond to scientific models or not.

[10] Dialectical refutation of a thesis means that its proponent lost the dialectical game, i.e. was unable to provide a defense against an attack. This is not the same as 'genuine refutation', in some normative sense of the term.

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