ARGUMENTATION DIALOGUE, COGNITIVE-LINGUISTIC OPERATIONS AND LEARNING TO MODEL IN SCIENCE[•]

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LEMMAS Conference, Ajaccio, Corsica, April 1999

Note : *Please do not disseminate this document beyond the conference itself.* This is a draft, consisting of notes to accompany a conference presentation, based on edited extracts from papers that are published, or in the process of being published, copies of which can be obtained upon request from the author (see references marked "*" at the end).

1. Overview

The main aim of what has been termed the "interactions paradigm" in cooperative learning research (Dillenbourg, Baker, Blaye & O'Malley, 1995) is to understand the relations between different types of communicative interactions involving learners, and different types of learning that can be produced.

Within this framework, I concentrate on the specific case of the **cognitive-linguistic operations** (Vignaux, 1988, 1990) that are associated with **argumentation dialogue** produced by learners engaged **modelling tasks** in school science. Cognitive-linguistic operations are "the means by which discourse performs … cognitive work on representations" (Vignaux, 1990, p. 307). They include *predicating*, *refining* definitions for concepts, *generalising* them and, above all, *differentiating* concepts from each other.

Intuitively, there are many ways in which argumentation dialogue could relate to cooperative problem-solving and learning. For instance, argumentation could lead to knowledge restructuring and a more coherent set of beliefs when an unsatisfactory problem solution is refuted. Defending one's views in argumentation could lead to making them better articulated (Crook, 1994). However, my main claim here is that **the principal role of argumentation dialogue in cooperative problem solving is to oblige students to *differentiate* and *define* different forms of knowledge and concepts, this being an essential aspect of learning to model.** Argumentative contexts impose special types of *interactive* and *interactional pressure* on participants to resolve (or 'dissolve') verbal conflicts ; and one way of responding to this pressure is to transform the universe of reference using specific cognitive-linguistic operations. In a sense this is obvious : the way in which a claim can be defended or criticised depends on how it is understood.

I shall illustrate this claim with respect to analysis of three extracts of argumentation dialogue, produced by learners who are attempting to perform three different modelling tasks in physics. The analyses are based a theoretical approach to understanding argumentation dialogue and cooperative problem-solving that involves analysing five dimensions of the interaction (Baker, 1999b in press) : dialectical, rhetorical, interactive, epistemological and conceptual.

2. Why might argumentation dialogue be a vehicule of cooperative learning ?

The answer might appear obvious, since debate has always been an integral part of the practice of elaborating scientific knowledge. For the present I'll operate with a quite intuitive notion of what argumentation is — to be defined later — as a type of communicative interaction that is orientated towards addressing, or resolving, contradictory views, verbal conflicts, etc. From a review of different areas of research in cognitive science we can isolate some more specific candidate *interactive learning mechanisms* in relation to argumentation dialogue :

- *Socio-cognitive conflict* (Doise & colleagues) — neo-Piagetian psychology — conflicts of centrations socially marked, social pressure towards resolution leads to focussing on conflicts, sharing of indications as to how the conflict can be resolved, conflict resolution process requires greater cognitive activity". Some recent results (e.g. Blaye, 1990) suggest that incidence of socio-cognitive conflicts is not a productive factor. In my view, this does not invalidate the possible productive role of argumentation since in these studies argumentation was effectively excluded by the choice of task.
- *Explanation, articulation, reflexion* — cognitive psychology — the "self-explanation effect" (Chi, *et al.*, 1989 ; Chi & VanLehn, 1991 ; Webb, 1991) operating in an interactive context — argumentation obliges participants to render their views explicit, to reflect on them, producing a more coherent view — verbal expression and criticism leads to better articulated views (Crook, 1994)

[•] This presentation draws on a number of lines of research that have been carried out with several colleagues in COAST over the past five or more years — notably, Andrée Tiberghien, Kristine Lund, Erica de Vries, Matthieu Quignard — on related themes of learning to model in physics, cooperative problem-solving, argumentation dialogue and computer-mediated communication (see the bibliography at the end of this document).

- *Change in view* — artificial intelligence (e.g. Harman, 1986 ; Doyle, 1979 ; Gardenförs, 1992) — argumentation outcomes (refutation) lead to epistemic changes, e.g. loser drops belief
- *Knowledge negotiation* — (Moyse & Elsom-Cook, 1992 ; Baker, 1994, 1995) — knowledge co-elaborated, co-constructed during argumentation or as outcome (compromise)
- *Conceptual change* — argumentation research — (Walton, 1990 ; Naess,1966 ; Perelman & Olbrechts-Tyteca, 1958) — argumentation obliges participants to define what they mean, the debate naturally tends towards 'deepening', generalisation ?

I claim that the last mechanism is the most important in relation to the interactive processes that do actually operate in argumentation dialogues. In reality, the mechanisms are not of course mutually exclusive. I shall return to these possible interactive learning mechanisms after presenting an approach to analysing argumentation dialogue in cooperative learning situations.

2.1. An approach to analysing argumentation dialogue in cooperative learning situations

Most researchers have adopted more or less amended versions of Toumin's (1959) argument schemas : claim, conclusion, warrant, backing, modality, etc. (e.g Resnick, et al., 1993). I believe that this model, designed for textual analysis, is not directly appropriate for studying dialogue : a dialogue is not ('just') a text distributed across interlocutors. Interactivity makes a difference, it implies different cognitive and interactive processes. I basically adopt a pragma-dialectical approach to the study of argumentation dialogue (Barth & Krabbe, 1982 ; Van Eemeren & Grootendorst, 1984) :

- "pragma" = concerned with speech acts, attitudes, extra-linguistic context ;
- "dialectic" = argumentation as a verbal game, with specific moves, rules, outcomes etc.

Research on pragma-dialectics is quite difficult to apply to real dialogues. For example, one of the problems is that the idealised "stages" of argumentative discussions — opening, argumentation, discussion of outcome — are often left implicit. For purposes of analysing real argumentation dialogue, what is basically required is that a "conflict situation" be mutually recognised (there can be different types, e.g. belief vs non-belief with respect to a view v ; beliefs in v and not-v, …) that the participants take opposed dialectical positions with respect to the views, and that they perform communicative acts in accordance with these positions (there can of course be different forms of attack or defense). There may or may not be a specific discussion of the outcome (who has won or lost). This basic schema can be represented as follows (Baker, 1999b in press) :

Phase	*Moves*
(1) *Opening phase*	[Move 1 — X: expression of view(s) n]
(initial expression of views and mutual recognition of opposed positions with respect to them)	Move 2 — Y: attack on n (contra position) Move 3 — X: defence of n (pro position)
(2) *Argumentation phase*	Move 4 — Y: attack on n (confirmation of relative stability of contra position)
(communicative acts in accordance with positions)	Move 5 — X: defence of n (confirmation of relative stability of pro position)
	[…]
[(3) *Closing phase*	[Move 6 — Y: clarification of position with respect to n and outcome of argumentation phase
(discussion of outcome)]	Move 7 — X: clarification of position with respect to n and outcome of argumentation phase]

Dialectics is only *one* dimension (dialectical) of argumentation dialogue : it alone is not sufficient to answer our research problem. Our aim is to understand how argumentation, considered pragma-diactically, relates to more general interactive processes — e.g. maintaining the common ground (Clark & Schaefer, 1989), reformulation — to changes in participants mental states — and to the type of knowledge and concepts involved. For example, the way that an argumentation is resolved, in a dialectical sense, will depend on the type of knowledge referred to in arguments (cf., the 'strength' of arguments), and the extent to which views can be negotiated.

I propose an approach to analysing argumentation dialogue in cooperative problem-solving along five dimensions (Baker, 1999b in press) ; answers to our questions relating to co-elaboration of knowledge and meaning will lie in the interrelations between these dimensions :

- **D** — dialectical dimension — argumentation dialogue as an interactive game to be lost or won, using specific moves (speech acts), according to certain rules that govern what can and must be said when, as well as the outcome ;
- **R** — rhetorical dimension — argumentation as the attempt to influence one's partner's views, mental states — persuasion, not necessarily by rational means ;
- **E** — epistemological dimension — the nature of the knowledge involved in the argumentation dialogue, types of attacks and defenses, characterised according to cognitive processes, origin of the knowledge, social status, …
- **C** — conceptual dimension — the way that the meanings of linguistic entities are defined, the way in which the domain of discourse is conceptualised ;
- **I** — interactive dimension — the processes by which knowledge [epistemological dimension] or concepts/representations [conceptual dimension] are transformed, reformulated, refined, elaborated or *negotiated* in communicative interaction.

Note : the dialectical dimension is alone specific to argumentation dialogue ; the other dimensions obtain in other types of dialogues, but in the context of argumentation dialogue they taken on a different character — e.g. cognitive effects of any dialogue, become the "rhetorical" dimension in an argumentative context ; the epistemological dimension, in an argumentative context, relates specifically to argument strength and epistemic entrenchment.

An example of a relation between dimensions would be when participants each retain their proposals/theses, each having stronger belief in them (R) because they have "withstood the test of argument" when an outcome (D) is negotiated (I) so that the universe of reference is conceptualised (C) to enable each to be "right", but within separate fields of validity (e.g. you're right when it can be understood as an elastic impact, I'm right in the case of inelastic impact).

I believe that these are the interesting dimensions for understanding this research problem ; but, perhaps not surprisingly, they are the hardest to analyse (!) It will not be a matter of 'labelling' interactions according to easily comprehensible instructions. Interaction analysis is a technique that takes time to be acquired (cf. inter-coder reliabiliy).

2.2. Critical review of candidate interactive learning mechanisms

This analysis method has been applied to several corpora for modelling tasks (see references *). The analyses enable us to make a critical appraisal of the extent to which the interactive learning mechanisms described above could actually correspond to interactive processes that are at work in argumentation dialogues between learners :

- *self-explanation in interaction* — this is not "self" explanation ! (subjects 'explain' to an experimenter) — not just expression of knowledge underlying problem solving — active reconstruction of knowledge, search for "arguments" in the situation according to what would make the strongest case — often, a difference along epistemological dimension between knowledge expressed as arguments and knowledge underlying problem solving ; an alternative mechanism is **widening the epistemic field of verification**
- *change in view* — (of course) a wedge between concession and attitude revision (I accept but I don't believe it) — refutation works with the strongest perceptually based, or legitimised knowledge — function of **pruning 'flawed' proposals**
- *knowledge negotiation* — a compromise strategy, but the **compromises often superifical** justapositions ; outcomes often avoided by changing the topic, "letting it drop"
- *conceptual change* — [cf. Greeno : conceptual change is a relatively stable change in the form of discourse — EARLI 97] — this mechanism appears crucial (see below) — conceptual differentiation and generalisation, partitioning of the universe of reference.

Conclusion : argumentation dialogue is not primarily a means of expressing and articulating pre-existing views, nor of negotiating more refined knowledge, nor of causing changes in attitudes. It primarily functions as a means of :

- widening the field of knowledge taken into account in cooperative problem solving
- eliminating proposals that are 'flawed' (at least one counter-argument is mutually recognised as valid)
- re-defining or re-conceptualising the domain of reference, of the meaning of what is being discussed.

In the rest of the paper I concentrate on the last alternative, and particularly on *argumentation dialogue as a vehicle of conceptual differentiation.*

3. Three examples of argumentation dialogue, conceptual operations and modelling

In these accompanying notes I simply present the three modelling tasks and dialogue examples, noting some of the most important points. More detailed and systematic analyses will be presented at the conference. In order to frame the analyses, I first say a little more about the conceptual dimension of argumentation dialogue.

3.1. The conceptual dimension of argumentation dialogue

The conceptual dimension of argumentative interactions is concerned with the *form* of knowledge, the way in which it is *represented*, in the universe of reference (the 'external' task whose achievement is the reason why the communicative interaction takes place). From a theoretical point of view, it is thus not the same as the epistemological dimension, that deals with the *nature* of knowledge, although of course the notion of undifferentiated knowledge is probably meaningless. An example will perhaps make this clear.

Suppose that the topic of an educational interaction is "living beings", such as plants and animals. In such an interaction, along the epistemological dimension, students may appeal to different types of knowledge — of physiology, palaeontology, botany, … — coming from different sources (what they learned in school, in everyday life during a visit to the zoo, etc.). Now suppose that the teacher asks "what is the main difference between plants and animals ?" Establishing such a difference is a conceptual matter, it requires performing a type of *linguistic-cognitive operation*, termed *differentiation*. Such operations are "the means by which discourse performs … cognitive work on representations" (Vignaux, 1990, p. 307; see also Vignaux, 1988). For example, a student might reply "animals have legs and can move, whereas plants are fixed to the ground by their roots". Such differentiations (the separating out of representations or concepts from each other) are the bases for *determinations*, i.e. characterisations of the object of discourse, e.g. qualifications or properties which are being attributed ("animals have legs"). It is not possible to predicate or to evaluate propositions (predications) unless one can, to some extent, differentiate out concepts from each other.

The conceptual dimension relates directly to two important aspects of argumentative interactions that have already been described by argumentation theorists. The first aspect concerns the fact that in order to argue effectively, participants are often obliged to *clarify* their interpretations of utterances (Perelmena & Obrechts-Tyteca, 1958 ; Naess, 1966). The second relates to the fact that debates often shift towards 'deeper', more fundamental, or *general* issues (Walton, 1992)[1]. The *interactive pressure* [2] that requires conflicts to be resolved verbally in argumentation triggers such operations, and may in turn lead concepts to evolve (e.g. to the correct differentiation: "the difference between plants and animals lies in the way that they obtain their *energy* — via photosynthesis or by digestion.").

3.2. First example : modelling rebound behaviour

This example of argumentation dialogue is taken from a corpus collected by Françoise Langlois and Andrée Tiberghien (Langlois & Tiberghien, 1990). The students' task is to define a property of balls of different substances that can explain their different rebound behaviours (in fact, the coefficient of restitution).

Corpus example 1 : rebound behaviour

N	*Loc*	*Dialogue*
86	L	it [the ball] rebounds all the same a bit lower, that's normal, but after all ...
87	H	yes but look, with respect to the masses, look, one can see that the steel one is … is heavier
88	L	yes, but it's not a matter of mass
89	H	well, all the same there's the potential energy involved, I'm sorry ! < 3 sec>
90	L	... ok, but if you had ...
91	H	if we had ... ?
92	L	if you had a big steel ball ... it would rebound
93	H	and if we release them at the same height, so that one has a greater mass than the other, the one with the greater mass would have a higher potential energy ...
94	L	yes but
95	H	so there would be more
96	L	do you think that if … if you had an enormous rubber ball like that, that's a kilogramme, do you think it would rebound a lot ?
97	**H**	**yes, but that's only valid in the case of an elastic impact**
98	L	well
99	H	in fact I think ...
100	L	we'd be better off thinking about that since, theoretically, it's more simple, given that it's a soft impact
101	H	well yes, there is precisely … <laughs>
102	L	so what can we say if there is a soft impact ? < 2 sec>
103	H	well, that the energy … all the energy ...
104	L	well that the kinetic energy is theoretically nil !
105	H	it's nil on arrival, in fact ...
106	L	since ... since the object stops, in fact <releases ball> ah yes, above all, there it doesn't move, ah ...
107	H	it's nil at the start and it's nil on arrival <15 sec.> ... about energy ... yes but, in the case of a soft impact, what is it that ...
108	L	we've been doing that for quite a while now ! !
109	P	<sighs> I know, I know
110	H	but we've also ...
111	L	wait ... soft impact, well, y've got conservation of momentum but … the kinetic energy isn't conserved ! I think that that's what we've seen … by contrast, in an elastic impact, both are conserved...
112	H	yes, elastic impact, there is the total energy that's conserved
113	L	yes
114	H	yes, but there is the friction … of the air !
115	L	oh, I don't think that that's especially the air friction that enters into it !
116	H	but yes it is, otherwise, it would rebound to the same height
117	L	no [it wouldn't]
118	H	yes [it would]
119	L	it's the loss at the moment of impact
120	**H**	**it's the same, it's also a sort of friction ! it's a sort of friction either with the ground or with the air**
121	L	yes but, after all, air friction in comparison with friction … if if you call that friction with the ground, it's rather negligible
122	H	ah well yes

Remarks : This sequence is interesting for a number of reasons (e.g. transitions between everyday language — "weight" — and scientific language — "mass"). What concerns us here are two main phenomena that play an important role in the two argumentation sequences (86-113 ; 114-122) and in the modelling process :

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1 Walton (1992) gives the example of a debate on the desirability of the institution of tipping in the USA, that becomes a debate on the more fundamental issue of what should be the role of the state in regulating work practices.

2 Strictly speaking, we should distinguish *interactive* pressure — the obligation to respond in interaction, to think of one's reply in real time — from *interactional* pressure, which concerns social aspects of interaction (see Muntigl & Turnbull, 1998) such as loss or preservation of "face" (the person who is refuted may lose face, resolution of the verbal conflict must be negotiated so that face is preserved).

1. *partitioning the universe of reference* — in the first subsequence the introduction of the distinction between perfectly elastic and inelastic impacts enables the universe of reference to be divided up in a way that enables the verbal conflict to be resolved whilst preserving face ;

2. *conceptual identification* — in the second subsequence, identifying "loss at impact" as being both forms of "friction" is proposed as an argumentation resolution method, but which is rejected since L differentiates the two in terms of the importance of their effects.

In both cases, these are means of argumentation resolution/dissolution that work on the level of operations on the universe of reference (cf. resolution by refutation).

3.3. Example 2 : modelling energy

The corpus from which the sequence analysed here was taken, was collected in a physics class of a secondary school (*lycée*) in the Lyon area (France) by Andrée Tiberghien, Jean Gréa and myself. The class was experimental to the extent that a new teaching sequence, on the theory and model of energy in physics, was being tried out on the students (16-17 years old). The students' task was designed for learning about modelling in physics, and the theory/model of energy in particular (Tiberghien, 1994, 1996; Devi, Tiberghien, Baker & Brna, 1996). In the part of the energy modelling teaching sequence discussed here, students are asked to produce qualitative models (diagrams) called "energy chains" in order to represent energy storage, transfer and transformation in a series of three simple experimental situations. They do this sitting side by side in the classroom, on pencil and paper.

Corpus example 2 — energy chains

N	*Loc*	*Dialogue*
		réservoir transformer battery bulb ((Common solution up to this point :))
181.	G	So, right, now the transfers. So, the transfer
182.	F	The transfer, there are two
183.	G	The transfers. So, modes of transfer
184.	F	In face have to do an arrow in each direction. Transfer 1, transfer 2. We do a transfer like that and a transfer like that, that we'll name afterwards
185.	G	Then, wait, euh, so from the battery there's a transfer
186.	F	We've got a transfer that is uhh
187.	G	So that is ((*inaudible*)) by two conducting wires. So the first conducting wire
188.	F	So uhh I do an arrow like that, I put, 1, transfer 1, like that, Didier ?
189.	G	Mm !
190.	F	And uhh I put wire, first conducting wire ? ... Transfer 1, first conducting wire ? ... And after I put transfer 2, second conducting wire
191.	G	Therefore, mode of transfer. So 1st wire, conducting wire, you put it underneath
192.	F	We'll put transfer. And there, we'll do another one in the other direction, it's the second
193.	G	Ah, no, no, no, no !
194.	F	But yes [it is], but the circuit, it's obviously got to be closed
195.	G	Yeah, but the battery
196.	**F**	**Ah yes, but there isn't any energy, there isn't the case where, in fact, the bulb doesn't produce energy, so the wire that goes back to the battery, it's just for closing the circuit, it's not a transfer**
197.	G	Yeah but hang on, ok but wait, there's a negative pole. So, it goes from the negative pole to the negative pole ? ? And from the positive pole to the positive pole ?
198.	F	No, from the positive pole to the negative pole
199.	G	That's exactly what I thought !
200.	F	((*laughs*)) <…>
206.	**F**	**No but look, there really is a second transfer for closing the circuit. But in fact, it's not a transfer, it's just for closing the circuit, so that the energy can go through.**
207.	G	Hang on, the current circulates from the positive pole of the battery to the negative pole of the bulb, but from that thing there, on the stand ...
208.	F	And then after, it comes back from the positive to the negative or from the negative to the positive. Mmm.
209.	G	plus, minus and plus to minus... Well then yes it is, that's right, there are two transfers !
210.	F	But no, there aren't two transfers.
211.	G	But yes there are !
212.	F	But no, because look, you can't … or else …
213.	G	But in any case, if there's only one, it won't work, I'm sorry
214.	F	Well yes, but that's all you keep on saying
215.	**G**	**Ah yes, in fact there's only one mode of transfer, it's true**
216.	F	No, there's only one transfer because
217.	G	The mode of transfer it's …
218.	F	Look, you go from the plus to the minus
219.	G	Yes, yes no but
220.	F	After that it goes from the plus to the minus, minus plus. Yes, no but what I mean to say is …
221.	G	There's only one mode of transfer that …

222.	**F**	**The issue is, I really agree with you that there is a second wire that closes the circuit, but the question is whether it's a transfer or not**
223.	G	No but ok. No, it's not a transfer
224.	F	Because she says clearly that a transfer is the thing that
225.	**G**	**It's a sort of, it's a mode**
226.	**F**	**It's a system … a transfer**

Some important points to note :

- instability of dialectical roles, roles switch round, student who attacked a view then defends it => different types of argumentation dialogue (Walton), a strictly dialectical type unlikely since students views under construction (Nonnon)
- the 'volatile' nature of proposals : interactive thinking under construction
- gradual differentiation of the notions transfer/mode/energy/electricity throughout the sequence, gradual separation of these types of knowledge and their applicability in the modelling process

3.4. Example 3 : modelling sound (CONNECT)

CONNECT is an environment for collaborative text writing at a distance, involving synchronous typewritten CMC. It has been designed, implemented and experimented by Erica de Vries, Kris Lund and myself (De Vries, Lund & Baker, 1999a, submitted ; Baker, De Vries & Lund, 1999b, submitted). We have performed a study on a task that involves modelling sound in physics, using a molecular model. CONNECT was designed for stimulating production of epistemic discussions (Ohlsson, 1996), i.e. argumentation and explanation dialogue. The design principles of CONNECT provide a good illustration of problems of designing situations for constructive argumentation dialogue. The sound task is interesting from this point of view since students typically have a range of different conceptions with respect to it — e.g. sound as a type of wind, left to right displacement of molecules, …

The sound task is as follows. Two tambourines, T1 and T2, are hanging from a support, a small ball suspended from support touches skin of T2. When skin of T1 struck, the small ball resting on skin of T2 moves. Three zones of molecules, from left to right, between T1 and T2 : A (against T1),B (inbetween A and C), C (against T2).

> *Q: What happens to the molecules near tambourine 1, the molecules in between the two tambourines, and the molecules near tambourine 2 (A, B, and C in the figure)? What changes in the behaviour of the little ball when tambourine is hit harder with the stick? 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?*

This is an extract taken from the phase in which the students compare and discuss their texts using CONNECT :

Student	*Sentence discussed (text)*	*Attitudes expressed*	
		A	*B*
A	7. The less tight skin of tambourine 2 absorbs vibrations more, and so vibrates less itself	**YES**	**YES**
B	7. The less tight skin can be more easily moved by the molecules, but the ball moves less	**?**	**YES**

Corpus example 3 — CONNECT,CMC interaction, sound task

N°	*T (m:s)*	*Loc*	*Dialogue / actions sur l'interface*
43	16:19	A	If the skin moves more, why does the ball move less ?
44	19:15	B	the skin moves more because it is less tight, but the air pressure exerted is the same. This skin therefore "wraps around" the form of the ball.
45	21:24	A	Don't agree. In my opinion, the skin of T2 moves less (see my phrase 7).
46	27:20	B	difficult to know once one looks at the skin, one sees it move more that the one with the tighter skin when you hit something hard, which is stable in space, il won't move, whilst a piece of cloth that's not under tension, for example, yes [it will move]
47	33:14	A	Another explanation: take a string that's not under tension. If you touch it, it's going to move a lot but it won't vibrate much. By contrast, a string under tension, like a guitar one, it will move little but vibrate a lot.
48	**36:37**	**B**	**i agree with your 7 but at one point I thought that you didn't [agree] with mine. For me the two phrases are right, it's just that simply they don't explain the same thing (vibrations and movements)**
49	39:23	A	NO. If a less tense skin vibrates less, itm movesss more, therefore the ball must move more as well.
50	40:34	A	pardon,have you understood?
51	43:29	B	Hypothesis: with the same air force exerted on T2: a tight skin will vibrate more that a less tight skin but will move less than the latter
52	43:37	A	*[attitude « YES » on phrase 1 of B : « It perturbs the air molecules contained between t1 and t2. They move further away from each other. »]*
53	43:44	A	Yes
54	43:47	A	Yes
55	47:55	B	as for the ball , I think that it would move less with the less tight skin since the skin would vibrate less so it would "transmit" a lot less vibrations.

56	0:01	—	*[beginning]*
57	0:08	—	*[change to phase 3]*
58	0:33	B	Agreed ?
59	1:17	A	Maybe

Some important points to note : In this extract, the argumentation dialogue turns on differentiation of the notions /vibration/movement/. This is not a dialectical outcome, but rather one that is proposed on the basis of attempting to redefine the terms of the discussion. The differentiation is achieved by referring to gradual values "more/less". This is important with respect to this modelling task since potentially, each of those terms relates to alternative models that the students may have of sound — either molecules vibrating, with transmission of vibration, or else left to right movement of the molecules.

4. Synthesis, discussion, and conclusions : what role for argumentation dialogue in learning to model ?

In this presentation I have concentrated on one specific role of argumentation dialogue in cooperatively learning to model in science : argumentation dialogue as a motor for cognitive-linguistic operations on the level of the universe of reference, particularly with respect to conceptual operations such as differentiation. I would claim that argumentation dialogue imposes special forms of social and interactive pressure that lead to these operations being performed.

Learning to model in science involves bringing *different types of knowledge* to bear on the problem of establishing *complex matchings* between *different types of representations* (Tiberghien, 1994, 1996) — model, experimental field. Conceptual construction occurs when the learners establish a particular type of *semantic* relation between model and experimental field. This involves adjustments on the plane of model syntax and in way in which objects and events are selected so that a (partial) matching can be found.

Modelling tasks thus create a broad and complex potential space of debate. From the examples I have discussed, argumentation dialogue appears to be a form of interaction that precisely favours — or rather *forces* — the differentiation and definition of types of knowledge and concepts, this being a crucial part of modelling and learning to model.

A number of important issues remain to be addressed, apart from a more precise definition of the cognitive-linguistic operations that are associated with argumentation dialogue, and their roles in modelling. The first concerns the nature of the concepts that are the objects of cognitive-linguistic operations : under what circumstances will they be the ones that are crucial for modelling ? The second concerns the design of didactic situations for co-construction of concepts and for favouring the production of argumentation dialogue. It is now quite well known that it is very difficult indeed to provoke argumentation with respect to scientific concepts as they are taught in schools. We need better understanding of how these conditions can be satisfied whilst also satisfying conditions for conceptually-based learning. Situations involving computer-mediated communication are interesting in this respect given that they enable many aspects of the students' activity to be structured. Finally, I believe that the principal reason why argumentation dialogue, and resolution of verbal conflicts, are often avoided by students relates to dynamics of social relations in interaction. We need to understand how we can enable students to fully address their cognitive conflicts in a productive way, whilst at the same time maintaining their social relationships ("friendship").

Bibliography

*I list both specific references in the above text, and other articles and books relating to this topic. References marked with an asterisk * are papers on which this presentation is directly based.*

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