

# On the logics of students' argumentation dialogues

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## Introduction

If monological logics can be used as instruments for the evaluative analysis of individual human reasoning (Wason & Johnson-Laird, 1972)<sup>1</sup>, could dialogical logics (e.g. Barth & Krabbe, 1982) be similarly used with respect to collective reasoning in dialogue? In this chapter, we propose to discuss this question for the specific case of argumentation dialogues produced by students in collaborative problem-solving situations. This case is interesting for a number of reasons, relating to different fields of research.

Firstly, for several decades, researchers working on the processes of collaborative learning (e.g. Resnick, Levine & Teasley, 1991) have been looking for methods for analysing the processes of learning in interaction. In the wake of research on the role of socio-cognitive conflict in cognitive progress (Doise, Mugny & Perret-Clermont, 1975; Doise & Mugny, 1981), argumentation dialogues have been singled out for particular attention in this respect. The presence of an interlocutor imposes special 'pressures' upon students to take into account facts that are unfavourable to their own points of view, to be 'logical' or coherent, to justify proposals, to criticise divergent views, or even engage in a cooperative search for 'the truth of the matter' (c.f. Walton, 1989). In contrast with other more irenic forms of interaction, argumentation dialogue can thus lead students to reformulate and combine their respective proposals, creating new (intersubjectively defined) knowledge, and to radically elaborate or re-conceptualise the domain of discourse (Baker, 1996, 1999, 2002). In this context, a number of researchers (e.g. Trognon, 1990, 1993, this volume) have had successful recourse to different logics (dialogic, interlocutionary).

Secondly, the consideration of real and complex human dialogues may be of some interest for logico-linguists. For those who subscribe to the divorce of formal logic and processes or products of human thinking, this chapter provides some examples that could be seen as further proof of their point of view; for those who believe that formal logics do have potential utility for understanding language and thinking, the analysis of the examples leads to suggestions as to how such methods would need to be extended. In this context, although argumentation in dialogue should, *a priori*, be a good case for logic to consider, accounting for the co-construction of new meaning and knowledge provides a particular challenge to logics, given that they have traditionally been seen as rendering explicit information that was already contained in the premises.

Finally, the choice of a dialogic rather than a monologic logic for analysing dialogues requires some explanation: why might collective reasoning be different from individual reasoning? The principal reason resides quite simply in one of the foundations of pragmatics: the meaning of a proposition, once uttered in interpersonal communication, is partly determined by its position in the interaction context. In a monologue, stating that "x is a blackbird", and that "x is a bird", appears quite innocuous, given that a blackbird is a sort of bird; but in a dialogue, if Xavier states that "x is a blackbird" then Yolande that "x is a bird", one possible meaning for her utterance is "I agree that x is a bird, but not that it is a blackbird". The point does probably not need to be further argued here: reasoning in dialogue does not reduce to a monological demonstration whose elements are distributed across interlocutors. In a sense, the study of logic in a dialogical situation can be seen as a return to its origins in the human domain, both developmentally (Vygotsky, 1978, 1934/1986) and historically. As Mackenzie (1985) puts it, in

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<sup>1</sup> See Andler (1995) and Noveck & Politzer (2002) for a syntheses of work on developments in the psychology of reasoning following the famous "selection task".

reference to Robinson Crusoe, there could be "No logic before Friday". More recently, logicians themselves have attempted to use dialogic logic as a means for descriptive and prospective analysis of dialogues (Krabbe, 2002).

In what follows, we first summarise some of the main elements of dialogic logic systems, focussing on the presentation of Barth & Krabbe (1982), then compare these elements with examples of students' argumentation dialogues, extracted from various interaction corpora. The conclusions drawn bear mainly on the prospects for using amended logics for analysis of collective reasoning.

## Functional elements of dialogic logic systems

We shall not focus on technical details of using dialogic logic systems to perform demonstrations (see elsewhere in this volume)<sup>2</sup>, but rather on their functional elements that may be of interest for psychologists of interactive learning.

The first important aspect concerns the epistemology underlying dialogic logics. Truth and validity are not seen as monolithic, but rather as the agreed outcomes of rational discussion within specific language communities. Such rational discussions are to be seen as "dialogue games" concerning particular theses, that can be "won or lost", and that are played according to certain norms and rules in order to avoid interminable monologues or speaking at cross purposes. At this very general level, the epistemology is redolent of the views of Wittgenstein and of Habermas, both of which have had considerable influence in descriptive language sciences. The notion of the dynamics of intersubjectivity (Rommetveit, 1979; Forman, 1992) as a factor in cooperative learning is also relevant here.

But how are such dialogue games to be played out? For our purposes here, it will be sufficient to identify four main functional elements of the dynamic dialogue game situation: 1) conflict situations; 2) the language; 3) dialectical roles and moves; 4) dialectical rules. All references are to Barth & Krabbe's (*op.cit.*) presentation.

- 1) Situations of verbal conflict of "avowed opinions" are defined in terms of four elements:  $\langle Con, T, B, A \rangle$ . "A" and "B" are language users, "T" is the thesis being discussed, and "Con" is the list of concessions. In simple conflicts, a single thesis is discussed, and in mixed conflicts, several theses can be discussed. Concessions are particularly important for descriptive analysis: they are a set of propositions that are commonly agreed prior to discussion, and that can be augmented as a result of stating new propositions during the discussion. Crucially, certain rules concerning what can, can not, must or must not be said at certain stages of the discussion will refer to the background of concessions (a sort of dialogue history, or "common ground").
- 2) The 'pieces' with which the game is played are explicit statements (not private mental states), corresponding to propositions (dialogic logic can be built on propositional logic) with their associated speech acts. In one presentation, these can be restricted to: "U" (assertive), "U?" (interrogative requests for defenses — "how do you defend U?"), "(?)U" (hypothetical statements — "I am prepared to defend U in this discussion") and "U!" (exclamative statements, corresponding to evocations of infractions of dialectical rules, such as *Iipse dixisti!*, "You have already said U yourself (thus defending it, so you can not now attack it)").
- 3) By introducing statements into the discussion, language users can perform certain *dialectical moves*, such as "attacks" or "defenses". In defending a thesis, a "direct defense" is performed, and in attacking an attack, a "counteractive defense" is performed (and similarly for attacks). But what counts as an attack or a defense is defined by the underlying (usually propositional) logic. Thus, for example, if A states that " $X \rightarrow Y$ ", given the truth-functional semantics of this expression, that is false only in the case where X is true and Y is false, an attack would be to state that "X", and a defense by B, to state that "Y". Following Heinzmann (1992), we shall term rules for deciding what counts as an

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<sup>2</sup> An introduction to dialogue logic and formal dialectics can be found in chapter 9 of van Eemeren, Grootendorst & Snoeck Henkemans (1996). French-speaking readers can consult the excellent (and very succinct) account given in Heinzmann (1992).

attack or defense *Signification Rules*. In performing attacks and defenses with respect to theses, language users play out their *dialectical roles*: *proponent* or *opponent* (a third-party devil's advocate is not introduced into this system). Roles are fixed during discussions, and defined with respect to *dialogue attitudes* (pro, contra, neutral) and thus the moves that will be made (clearly, the opponent will attempt to attack the proponent's thesis). For example, with respect to a thesis T, the proponent P is pro(T), pro(own statements) and neutral(O, Opponent's statements); O is contra(T), pro(Con), pro(own statements) and contra(P's statements).

- 4) Dialogic logic embodies rules that govern what can and can not and what must and must not be said at a specific stage of the discussion. For convenience, we can divide these into two sets: rules for conduct of the debate and rules for the outcome of the debate. In the first class we find rules whose function is basically to make the debate converge and not go round in circles, for example: "You must defend the last statement attacked", "You must not repeat attacks", and "You must not attack a statement you previously defended, or defend a statement you previously attacked" (*Ipse Dixisti!* — You already said so yourself). In the second class, we find rules according to which the outcome (who has won or lost) must be externalised, and that such winning or losing is determined either by making a 'foul move' (c.f. *Ipse Dixisti!*) or else by having no further permissible move at one's disposition (exhaustion of rights to continue).

For purposes of comparison with students' dialogues, we can conveniently regroup these components of dialogic logic into *three logics*, *Logic in Dialogue*, *Logic of Dialogue* and *Logic of Intersubjectivity*:

- 1) *Logic in Dialogue* concerns the nature of elements of the domain of discourse, and logical (or other) relations between them; in dialogic logic, it corresponds to the language, to concessions, logical forms of statements, and signification rules.
- 2) The *Logic of Dialogue* encapsulates relations between dialectical moves in their pragmatic contexts, as a function of dialectical roles, and with respect to dialectical rules.
- 3) *The Logic of Intersubjectivity* concerns the way in which cognitive attitudes change as a function of the logics in and of dialogue: what is the nature of the outcome of the debate — the statement successfully defended or refuted — with respect to the cognitions of each participant? Is it a belief, an opinion? How will statements debated function with respect to the ensuing interaction? Will a statement once refuted be proposed again, or else definitively dropped. What will be the ensuing "Change in View" (Harman, 1986)?

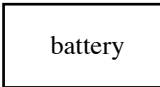
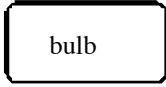
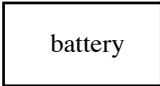

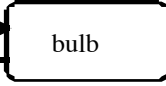
In the types of situations discussed here, the study of the relations between these 'logics' is a means of addressing the fundamental question of the processes by which cognition emerges in and by dialogue.

We begin with an illustrative example, introducing others as necessary.

### **An illustrative example**

Consider the example shown in Table 1 below. It is taken from a corpus of interactions between students (16-17 years old) in a secondary school physics class. The students' task is to draw a diagram representing energy storage, transfer and transformation in a simple electrical circuit: a bulb is linked to a battery by two wires. Up to this point, the students agreed that the battery is a reservoir of energy and the bulb a transformer of it. The problem they address concerns the nature of the transfer(s) of energy between battery and bulb.

TABLE 1. THE TWO BATTERIES EXAMPLE<sup>3</sup>

| N   | Loc  | Dialogue  | Graphical solutions   |
|-----|------|---|---|
|     |      |   | Common solution up to here:<br><div style="display: flex; justify-content: space-around; align-items: center;"> <div style="text-align: center;"> <i>reservoir</i><br/>  </div> <div style="text-align: center;"> <i>transformer</i><br/>  </div> </div>   |
| 178 | John | Right, there there's the /  |   |
| 179 | Mary | /transformer.<br>Do the transfer arrow  |   |
| 180 | John | There are several to be done.<br>One there.<br>Should another one be put there? | <div style="display: flex; justify-content: space-around; align-items: center;"> <div style="text-align: center;"> <i>reservoir</i><br/>  </div> <div style="text-align: center;">  </div> <div style="text-align: center;"> <i>transformer</i><br/>  </div> </div> |
| 181 | Mary | Pprrrttt !  |   |
| 182 | John | You see it leaves from a reservoir and it comes back to a reservoir             |   |
| 183 | Mary | It's true!?   |   |
| 184 | John | A reservoir to start and a reservoir to finish                                  |   |
| 185 | Mary | Have we got two batteries John ?  |   |
| 186 | John | No!   |   |
| 187 | Mary | Have we got two batteries !?  |   |
| 188 | John | No  |   |
| 189 | Mary | Then why do you talk nonsense!  |   |
| 190 | John | What have we forgotten then?  |   |

The first step of analysis is to reconstruct the Logic in Dialogue for this extract. Clearly, this involves going much further than considering the truth-functions of propositions, in order to make the relations explicit between John's proposed solution (line 180), John's statements in lines 182 and 184, and Mary's rhetorical question (one can assume that she is stating that there are in fact not two batteries in the circuit) in lines 185 and 187. Without such a reconstruction, the dialectical functions (attacks and defenses) of these utterances are not clear (although one suspects that John's utterances are designed to defend his proposal and Mary's to attack it).

Figure 1 below shows an elementary logical analysis of these statements, remaining close to what is explicitly stated, together with the logical relations that need to be reconstructed.

<sup>3</sup> As with all other examples shown in this chapter, they have been translated by the author from the original French; students' names have been changed whilst preserving gender. The continuation of this particular example is analysed in greater detail in Baker (1996).

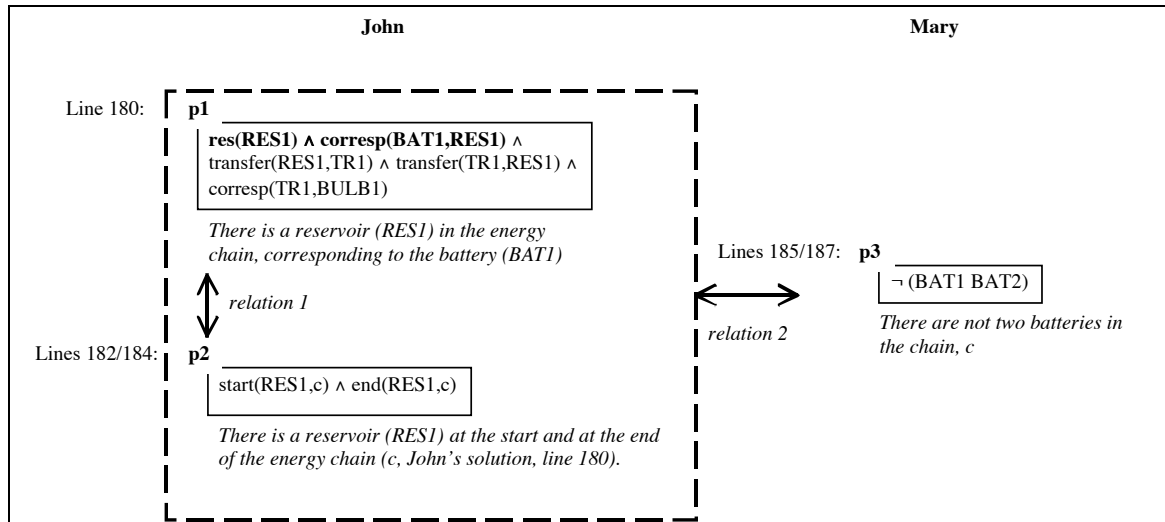


Figure 1. Logical analysis of statements in the Two Batteries example, with relations to be reconstructed.

Let us begin with the first relation, relation 1. John’s p2 refers to a rule for constructing energy chains (relating to the law of conservation of energy) that is given to the students on paper, according to which “A complete energy chain starts and ends with a reservoir”. It can be represented as follows:

$$p4: \forall c[\text{complete-}c(c) \leftrightarrow \exists x \exists y(\text{res}(x) \wedge \text{start}(x,c) \wedge \text{res}(y) \wedge \text{end}(y,c))]$$

So that it appears that John is claiming that his solution (p1) satisfies this rule, and thus that it is a complete energy chain. Substituting for the first two parts of p1 in p4 we have:

$$p5: \text{complete-}c(\langle \text{John's solution, JS} \rangle) \leftrightarrow (\text{res}(\text{RES1}) \wedge \text{start}(\text{RES1,JS}) \wedge \text{res}(\text{RES1}) \wedge \text{end}(\text{RES1,JS}))$$

In other words, the single reservoir RES1 is one and the same start and end reservoir to the energy chain, and this reservoir corresponds to the same battery, BAT1, “corresp(BAT1,RES1)”.

What about the second relation (2), between Mary’s statement and John’s? Mary can derive the fact that there are not two batteries in the circuit (p3) from simple observation — there was only one(!). For the reconstruction, we are obliged to impute several suppositions to Mary. Two possible ones are the following:

$$p6: \forall c[\text{complete-}c(c) \leftrightarrow \exists x \exists y((\text{res}(x) \wedge \text{start}(x,c) \wedge \text{res}(y) \wedge \text{end}(y,c) \wedge (x \neq y)))]$$

This is an implicit refinement of the rule stated in p4, according to which the start and end reservoirs can not be identical, which would alone be sufficient to show that John’s solution is not a complete energy chain, since “RES1 ≠ RES1” is false and there are not two distinct reservoirs in John’s solution. Where do batteries come in to the reconstruction?

Suppose, hypothetically, that there were in fact two distinct reservoirs — say, RES1 and RES2 — in John’s solution so that p6 could be satisfied, and John’s solution could correspond to a complete chain. The students agree that RES1 corresponds to the (or “a”) battery (part of p1), but nothing is said about what RES2 corresponds to. We can only reconstruct the link between Mary’s statement about two batteries and John’s statements if we also assume that she implicitly subscribes to a ‘rule of modelling’, according to which *to every model element, such as a reservoir, there must correspond a tangible and unique object* (otherwise both RES1 and RES2 could both correspond to BAT1, or else RES2 could correspond to nothing at all). We can represent this as:

$$p7: \forall x \forall y[\text{res}(x) \wedge \text{res}(y) \rightarrow \exists p \exists q(\text{object}(p) \wedge \text{object}(q) \wedge \text{corresp}(p,x) \wedge \text{corresp}(q,y) \wedge (p \neq q) )]$$

Assuming in p7 that x is RES1, y is RES2, p is BAT1 and q is a second battery, BAT2, Mary can derive an absurd consequence from John’s statement (together with her suppositions), according to which there are two batteries, that she contradicts with p3, commonly agreed from observation: *reductio ad absurdum*. Mary can thus conclude that if John’s solution were to correspond to a complete energy chain, then an absurd consequence follows (there are two

batteries); so it is false that his solution is a complete chain. It is John’s defense, rather than his proposed solution of it, that is refuted.

To recap, we had to attribute to Mary the following suppositions in her hypothetical reasoning: 1) the start and end reservoirs must be different (p6); 2) to every model element there must correspond an unique tangible object (p6); and 3) an hypothetical second battery corresponds to the hypothetical second reservoir.

Incidentally, John could have blocked this refutation quite easily, by refusing the reformulation of the energy chain rule (the start and end reservoirs can be the same), by refusing the modelling rule according to which every model element must correspond to a tangible object (this is in fact incorrect — see below), or by refusing her suppositions.

We shall return to comment on this reconstruction below, in reference to a wider set of examples. Let us now turn to the Logic of Dialogue, whose system of attacks and defenses can be constructed quite easily now that the logic relating statements is defined. Table 2 below shows such a reconstruction (“M” contains a label for each dialectical move; X’ represents a modified version of X).

TABLE 2. THE LOGIC OF DIALOGUE FOR THE TWO BATTERIES EXAMPLE.

| N.  | Transcr.   | M | John                 | Mary              | Pragmatic character of dialectical move          |
|-----|--|---|----------------------|-------------------|--|
| 180 | There are several to be done. One there.<br>Should another one be put there? | a | <b>A</b>             |                   | John’s solution                                  |
| 181 | Pprrrttt !   | b |                      | <b>A?</b>         | Attack : how do you défend A?                    |
| 182 | You see it leaves from a reservoir and it comes back to a reservoir          | c | <b>B</b>             |                   | Direct defense of A                              |
| 183 | It’s true!?  | d |                      | <b>B?</b>         | Attack : how do you défend B?                    |
| 184 | A reservoir to start and a reservoir to finish                               | e | <b>B’</b>            |                   | Defense of B                                     |
| 185 | Have we got two batteries John ?   | f |                      | <b>C</b>          | Attack on B/B’                                   |
| 186 | No!  | g | <b>concession(f)</b> |                   | Concession of C                                  |
| 187 | Have we got two batteries !?   | h |                      | <b>C’</b>         | Attack on B/B’                                   |
| 188 | No   | i | <b>concession(h)</b> |                   | Concession of C                                  |
| 189 | Then why do you talk nonsense!   | j |                      | <b>refuted(B)</b> | Explicitation of dialectical outcome : B refuted |
| 190 | What have we forgotten then?   | k | <b>concession(j)</b> |                   | Concession of dialectical outcome                |

The dialectical analysis is of course highly idealised. Thus, for example, the mocking “Pprrrttt!” is reduced to a simple attack (request for defense). Line 184 poses an analytical problem, in that the quasi-repetition of B can either be viewed as a direct defense of A (making B more explicit), or else as a defense of B itself, making more clear the reference to the energy chain rule (p4 above). A further problem arises with line 185 (move f), that can be seen not only as an attack on the rule itself (B), but also on its status as a defense of A, i.e. an attack on the *argumentative link*, which is difficult to represent in such dialogic tableaux. One possibility would be to represent move e as “B | - A” (A can be validly inferred from B), in which case C could effectively attack a purported demonstration. Finally, a difference is introduced between conceding a dialectical move (e.g. line 188) and conceding a dialectical outcome (k).

It is important for our future discussion to note that although Mary makes the dialectical outcome relatively explicit — “talking nonsense” is not too far from a claimed *reductio* — John does not in fact explicitly concede the dialogical game, but rather returns to trying to re-solve the original problem.

Given this restricted example, little can be said about the Logic of Intersubjectivity. But it turns out that in the ensuing discussion, since Mary can not provide an acceptable alternative solution, John re-states his solution that had been refuted in this sequence (see Baker, 1996, for details).

On the basis of this illustrative example, we now proceed to a more general discussion of each of the three 'logics' mentioned above, as they obtain in the type of dialogues with which we are concerned here.

## The Logic in Dialogue

Logic in Dialogue concerns the nature of the 'language' of reasoning in dialogue. As we discuss below, in contrast to dialogic logic, the language of students' dialogues, viewed from the perspective of collaborative learning, also needs to be considered along conceptual, epistemological and linguistic dimensions.

### Transformations of the domain of discourse

The first remarkable point about the Logic in Dialogue as analysed above concerns the relative difficulty with which it can be reconstructed. Several propositions needed to be imputed to Mary, and in one case, the proposition was a *spontaneous elaboration* of information provided in the problem situation (the energy rule was written down on paper). In general, what this means is that logical reconstruction can not proceed from the assumption that the problem statement is a set of given and immutable premises, equivalent to the "concessions" of dialogic logic (c.f. van Eemeren & Grootendorst, 1984). It is well known that students continually negotiate the meaning of the problem to be resolved in interaction.

Secondly, logical reconstruction has to take into account the fact that *new knowledge* will be introduced and negotiated in dialogue in a way that is *inherently unpredictable*: students can spontaneously draw on any of their experience in the dialogue situation. Spontaneous dialogues do not operate in a 'fixed world' of discourse, they actively create that discourse world: not only are discursive objects not fixed in meaning, but they are also not fixed in number.

But there are of course other types of transformations that can be performed on the domain of discourse during argumentation dialogue, that are in a sense more fundamental than knowledge refinement and the unpredictable introduction new knowledge into the problem situation. The very way in which the discourse domain is conceptualised, or represented, can be transformed in discussion, and become itself an object of that discussion. In argumentation research, two such important operations have been described by Perelman and Olbrechts-Tyteca (1958/1988): *conceptual association* and *dissociation*. Table 3 below shows an example of each of these *cognitive-linguistic operations* (the term was introduced by Vignaux, 1988, 1990). The examples are taken from a corpus of dialogues collected in a physics classroom, where the students' task was to explain the rebound behaviour of balls of different substances, when released from a given height (Langlois & Tiberghien, 1990).

TABLE 3. EXAMPLES OF CONCEPTUAL ASSOCIATION AND DISSOCIATION.

| <i>Conceptual association</i> |  | <i>Conceptual dissociation</i> |  |
|-------------------------------|--|--------------------------------|--|
| 112 / A                       | yes, elastic impact, there is the total energy that's conserved  | A / 93                         | 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 ... |
| 113 / B                       | yes  | B / 94                         | yes but  |
| 114 / A                       | yes, but there is the friction of the air!   | A / 95                         | so there would be more   |
| 115 / B                       | oh, I don't think that that's especially the air friction that enters into it!                                     | B / 96                         | 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?                                 |
| 116 / A                       | but yes it is, otherwise, it would rebound to the same height  | A / 97                         | <b>yes, but that's only valid in the case of an elastic impact</b>   |
| 117 / B                       | no [it wouldn't]   |                                |  |
| 118 / A                       | yes [it would]   |                                |  |
| 119 / B                       | it's the loss at the moment of impact  |                                |  |
| 120 / A                       | <b>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</b> |                                |  |

In the above example of conceptual association, student 'A' attempts to 'dissolve' the verbal conflict by associating "air friction" and "loss at impact", as specific cases of "friction (with the ground or with the air)". In the example of conceptual dissociation, student 'A' introduces a new distinction into the discussion, between "elastic" and "inelastic" impacts. This enables a type of partitioning of the domain of discourse into two areas, within each of which each student's proposal can be seen as valid.

The reconstruction of the logic in dialogue has to work on the shifting sands of the domain of discourse: it is interactively elaborated, reconceptualised and augmented in ways that are difficult to define in advance, and thus can not be seen as a fixed set of propositions with fixed meanings.

### Students' epistemology

Another feature of the domain of discourse that is important for understanding students' reasoning concerns what could be termed the students' epistemology, or a typology of kinds of *knowledge* with which they function. By this, we basically mean the *origin* of knowledge, in cognitive, situational and social terms. In cognitive terms, a proposition evoked in dialogue could be derived from perception, memory retrieval, reasoning or communication. In situational terms, a proposition could be derived from everyday experience, from previous teaching, from media, and so on. In social terms, the proposition can be more or less legitimated, according to whether it is derived from recognised scientific bodies, teachers or other students. All of these factors influence the extent to which the student can appeal to the proposition in joint reasoning, the extent to which it will be viewed as (un)certain or criticisable, and its perceived *weight* as an argument. In more abstract terms, this factor has been dealt with in the belief revision literature in artificial intelligence, under the rubric of "epistemic entrenchment" (e.g. Gardenförs, 1988), where general rules are given for categorising propositions as being more entrenched than others.

For example, in the two batteries extract analysed above, it is significant that Mary's refutation builds on a personal interpretation of a rule legitimated by the teacher and, finally, on an irrefutable perceptual fact (there is just one battery on the table in front of the students). Table 4 below summarises the epistemological nature of the propositions used in the reconstruction of the students' logic in dialogue for the two batteries example.



TABLE 4. STUDENTS’ EPISTEMOLOGY IN THE TWO BATTERIES EXAMPLE.

| <i>Proposition</i>  | <i>Epistemology</i>   |
|---|---|
| p1: There is a reservoir (RES1) in the energy chain, corresponding to the battery (BAT1)                        | Part of John’s proposed <b>problem solution</b>                         |
| p2: There is a reservoir (RES1) at the start and at the end of the energy chain (c, John’s solution, line 180). | Part of John’s proposed <b>problem solution</b>                         |
| p3: There are not two batteries in the chain, c   | <b>Perception</b> in the current situation                              |
| p4: A complete energy chain must start and end with a reservoir   | General rule of modelling, <b>given by the teacher</b>                  |
| p5: The start and end reservoirs of the chain are the same (RES1)   | John’s statement that his solution satisfies the general modelling rule |
| p6: A complete energy chain must start and end with a different reservoir                                       | Mary’s implicit elaboration of the general model rule                   |
| p7: All reservoirs must correspond to distinct tangible objects in the experimental field                       | Mary’s implicit specific conception about modelling                     |

As we have noted, Mary’s perception is irrefutable. What are more interesting, are her conceptions about modelling itself, and particularly p7. This is in fact inadequate: it is not the case that all model elements must have a directly corresponding tangible object, modelling is about creating more complex matchings between model and experimental field, within the constraints of the model’s syntax (Tiberghien, 1994). In fact, it turns out that the end reservoir of the chain should correspond to a more abstract entity, termed “the environment”.

Any mathematical logic is of course based on the generality of the formal system with respect to the instantiation of variables. Putting problems of intensionality to one side, of course it should not matter whether, in the formula “ $\forall x(\text{red}(x) \rightarrow \text{coloured}(x))$ ”, whether  $x$  corresponds to a flag or to a vegetable, or even how the fact was derived from experience. But, as we have seen, in real problem-solving dialogues, the epistemological nature of the proposition is an important aspect of human reasoning, and an important factor in determining the processes and outcomes of argumentation dialogues.

### Linguistic (re)formulation

The above discussion turned upon the interactive transformation and the epistemology of the universe of discourse of argumentation dialogue. But of course, is universe is expressed in particular languages, and clearly something important is lost in such logical reduction. It is not our purpose here to deal with this question in all its depth. Such an enterprise would take us far afield, for example into questions concerning the differences between logical or argumentative connectors in logic and in natural language, or the way in which the use of certain linguistic expressions are heavily value-laden, and orient the argumentative discussion. We shall simply focus on the phenomenon of reformulation (De Gaulmyn, 1987; Gülich & Kotschi, 1987) of utterances, each of which, although linguistically distinct, can reduce to the same propositional analysis.

For example, in the two batteries extract, the two following successive defenses of John were both analysed as an unique proposition, corresponding to an evocation of the general model rule (a complete chain starts and ends with a reservoir):

- 182 You see it leaves from a reservoir and it comes back to a reservoir
- 184 A reservoir to start and a reservoir to finish

In a sense, “leaving from” and “coming back to” can be seen as propositionally equivalent to “starting “ and “ending: the point from which you leave is the starting point. But such reformulations are highly significant from an argumentative point of view; they are manifestations of what Naess (1966; see also van Eemeren, Grootendorst & Snoeck Henkemans, 1996, p. 85) termed the process of “precization”, or “the making more precise”, in argumentation. Argumentation dialogue is not just about exchanging argumentative moves in a dialectical game; it is also — or rather — about establishing a more precise definition or understanding of the subject of debate (c.f. also Walton, 1992). Thus, John’s reformulation of his

defense, against Mary’s repeated attacks (in both logical and interpersonal senses of the term), can be seen as an attempt to make his position more clear, and this is an important process to be taken into account in analysing interactive processes in collaborative problem-solving situations.

### Validation of logical reconstruction

What *validates* precisely *this* reconstruction rather than another? This is of course a question that has been much discussed, in the teaching of logic — the problem of “missing premises” — and in the argumentation literature (see e.g. van Eemeren, Grootendorst, Jackson & Jacobs, 1993). In the specific case considered here, we have followed simple rules of attempting to base the reconstruction as far as possible on what has been explicitly stated — for example, the reconstruction of Mary’s reasoning crucially builds on the model rule evoked by John — and to impute to students types of knowledge that are already described in a wider corpus of research. Thus, for example, it is plausible to ascribe to Mary, in the above example, an inadequate conception about what scientific modelling is — “all model elements have tangible correlates” — since it is known from a much wider corpus that students commonly think in this way (Tiberghien, 1996).

Such an approach depends on an hypothesis that is so fundamental that it is difficult to defend within a given paradigm: if students’ productions diverge from certain norms, this is not so much due to inadequate quasi-logical reasoning, but rather to the fact that students’ understandings are qualitatively different. *Students are internally coherent*, or rather, researchers who model students’ reasoning are obliged to produce logically coherent models. An additional hypothesis is that coherence will be greater in dialogue, due to interpersonal verification, than in individual reasoning (e.g. Crook, 1994).

Despite these methodological difficulties, as we shall argue in conclusion, such logical reconstruction can, we would argue, be a valuable methodological tool for the analysis of students’ prior knowledge, this being the principal basis on which all learning occurs. If we restrict ourselves more narrowly to ‘what is stated’ in students’ linguistic or diagrammatic productions, whether in dialogues or interviews or questionnaires, then relatively little can be said about their thinking.

## The Logic of Dialogue

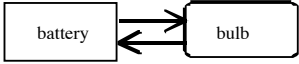
Let us now turn to the logic of argumentation dialogue itself, concentrating on a specific examination of dialectical roles and rules.

### Dialectical roles

A dialectical role is supposed to encapsulate a degree of relative stability in language users’ actions in argumentation dialogue: a person who proposes a thesis is supposed to try to defend it, and is not necessarily expected to attack it.

In the short two batteries example discussed above, roles do appear to be relatively stable: John proposes a solution, that becomes a thesis that he consistently defends (he is the *proponent*) against Mary’s repeated attacks (the *opponent*). But certainly not all of students argumentation dialogues are like this, and for good reasons that we shall explain. Consider the example shown in Table5, taken from the same corpus (and same students) as the two batteries example.

TABLE 5. THE EXCHANGED DIALECTICAL ROLE EXAMPLE.

| <i>N°/Locutor</i> | <i>Dialogue</i>   |
|-------------------|---|
| 192/Mary          | We'll put the transfer. And there, we'll do another one in the other direction, it's the second one<br>          |
| 193/John          | Ah no, no, no, no!  |
| 194/ Mary         | Erm yes we will, but the circuit really has to be closed  |
| 195/John          | And yeah, but the battery   |
| 196/Mary          | Ah yes, but there's no energy that's there's none when, in fact, the bulb doesn't produce energy, so the wire that comes back to the battery, it's just to close the circuit, it's not a transfer |
| 197/ John         | Yeah, but hang on, 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/ Mary         | No, from the positive pole to the negative pole<br><...>  |
| 206/ Mary         | No but look, there really is a second transfer to close the circuit. But in fact, it's not a transfer, it's just to close the circuit, so that the energy can flow through                        |
| 207/ John         | Wait, the current circulates from the positive pole of the battery to the negative pole of the bulb, but that thing there, on the base ...  |
| 208/ Mary         | And after it comes back from the positive to negative or from the negative to positive. Mmm   |
| 209/ John         | positive, negative and to negative ... Well yes there is, it's right, there are two transfers   |

There are many important remarks that could be said about this extract, that clearly shows the students' confusion between electrical current and energy. But what is important for our present discussion is that although at the beginning (line 193) John is a clear opponent of Mary's proposal; when Mary finally retracts her proposal, roles switch round, John becoming the proponent and Mary the opponent.

The explanation for this is quite clear. As Nonnon (1996) has pointed out, in such situations where students are supposed to co-construct new knowledge, they are not in a position to be able to adopt firm stances or dialectical roles: neither 'really knows'. Thus the dialogue will more closely resemble a "forensic debate" (Walton, 1989), or a cooperative search for the 'truth of the matter', than a verbal conflict between fixed positions. Adopting clear dialectical roles requires relative well-elaborated points of view towards which language users can adopt firm commitments, which is not the case of the students here.

Whether students can adopt firm dialectical roles or not also depends on the type of knowledge involved, as we discussed above. In the case of a simple perceptual fact, students can have the degree of commitment required for opponent or proponent roles (the two batteries example). But when different areas of school-learned knowledge — electricity and energy — are concerned, roles can shift and exchange rapidly, as the students 'search around' the problem.

The degree of stability of dialectical roles therefore depends at least on the degree of novelty of the problem, or the extent to which new knowledge needs to be co-constructed, and also on the epistemology of the specific sub-problem.

### Dialectical rules

It is indisputable that for all human beings who are able to communicate adequately in a given culture, some forms of reasoning and argument in communication are viewed as unacceptable. The vast field of research on "fallacies" (see e.g. Hamblin, 1970), since the early beginnings of rhetorical studies, has tried to analyse unacceptable forms of reasoning in communication, as types of invalid reasoning, or else as unacceptable forms of communication (c.f. the famous

“spouse-beating fallacy — “Have you ceased to aggress your spouse? Answer yes or no”, that presupposes spouse-aggression irrespective of the response — or the well-known *argumentum ad hominem* argument).

In dialogical contexts, fallacies reappear in the guise of infractions of rules for rational critical discussion. Three examples of such rules, as mentioned above, can be expressed as the following injunctions: “Do not repeat attacks or defenses”, “All parties should externalise the outcome of the debate” and “Do not attack what you just defended (or the inverse)”. Do students’ argumentation dialogues conform to these rules?

The reconstruction of the logic in dialogue for the two batteries example appears to show clear infractions of both of these rules. Firstly, with respect to the “no repetition” rule:

- John repeats his defense “A reservoir at the start and a reservoir at the end”, and
- Mary repeats her attack “There are not two batteries!”.

However, as we discussed above, in a linguistic sense these are not really strict repetitions: they are more or less reformulated in each case.

Secondly, the way that the sequence ends does not appear to correspond to a direct “externalisation”; Mary seems to triumph in stating that John is incoherent (“nonsense”) and John simply changes the subject:

189      Mary            Then why do you talk nonsense!  
 190      John            What have we forgotten then?

Thirdly, the role switching example shown in Table 5 can of course also be seen as a clear, and double, case of an infraction of *Iipse Dixisti!* As to why these infractions were not mentioned by the students, we discuss this question below.

We might therefore be tempted to conclude — at least from these examples — that students’ dialogues do not conform to dialectical rules. Yet it is not surprising to find examples where students’ dialogues do in fact conform to certain rules, such as in the example shown in Table 6 below<sup>4</sup>.

TABLE 6. AN EXTERNALISATION OF OUTCOMES EXAMPLE.

| N/Loc  | Interaction   |
|--------|---|
| 32 /A: | They [the molecules] don’t move away from each other, they all go towards the second tambourine   |
| 40 /B: | my1:we saw in the film that the molecules were positioned in a certain way spreading outwards, here, tambourine 2, thus creating a bigger space between them than before. OK? YES OR NO |
| 41 /A: | Yes<br><...>  |
| 60 /B: | To my sentence you know, you replied YES: why didn’t you write it in the opinion check boxes. Perhaps you didn’t completely agree.  |

In line 60, student B asks student A why he didn’t make his previously expressed change of opinion explicit in the interface check boxes, and in fact encouraging such explicitation was one of the purposes of that interface.

There are in fact three issues to be dealt with here: 1) does the dialogical game appear to be played out in accordance to the rules or in infraction of them? 2) are infractions of rules

<sup>4</sup> The example is taken from a corpus of computer-mediated interactions, using the CONNECT system (de Vries, Lund & Baker, 2002), where students are asked to express their opinions using check-boxes on the computer interface — “YES”, “NO” or “?” — with respect to segments of their texts written in response to a question about sound in physics. The segment of text they are discussing here is “Sentence 1: *It perturbs the air molecules between tambourines 1 and 2. They move away from each other*”. With respect to this sentence written by student B, student A had originally checked the “NO” box, and student B the “YES” box. The extract is reproduced exactly as the students typed it.

explicitly contested?; 3) what are the rules that could effectively account for what is and is not said, and when?

Consider the analogy with a game that looks, to all intensive purposes, like tennis. Suppose that from time to time one of the players blocks the ball with a part of his body, then hits it with the racket, and that the other player says nothing, the game continuing. We might conclude that there does not exist a rule according to which blocking the ball with one's body is not allowed: if the students play the dialogical game in a certain way and nothing is said to the contrary, then we conclude the absence of a rule forbidding that type of play. If one of the players did, with reasonable regularity, shout "foul play", and the other acquiesced, we might conclude that there was such a rule forbidding that type of play (and similarly for rules requiring a certain type of play, such as serving the ball in turn).

But we can not draw such conclusions in the case of students' dialogues, simply because the 'game' is much more complex, there are other sets of rules than dialectical ones. Thus students' repetitions of attacks and defenses could be related to communication management, or checking that the interlocutor has heard and understood, or more generally, to Gricean (Grice, 1975) maxims of cooperation in communication. So engaging in dialogue in a certain way, and failure to contest infractions of implicit rules, does not prove inexistence of dialectical rules, the dialogical game is simply more complex.

Rather than "rules" in this context, one should perhaps speak of *regularities*. A certain degree of repetition ("Yes it is", "No it isn't", "Yes it is", ... etc.) is acceptable, but in fact usually comes to an end due to recognition of the futility of the dialogue. The hypothesis that dialectical rules have something to contribute to the study of real argumentation dialogues is tenable, provided they are not viewed as absolute injunctions, but rather as describing flexible and largely implicit regularities in any form of collective activity. Suddenly shifting dialectical position, repeating attacks or failing to admit defeat is not logically coherent, it simply reveals a lack of respect for the time and effort of one's interlocutors, since, as dialectical models propose, the dialogue could be seen as a waste of time and effort of all concerned (c.f. Allwood, 1976).

## The Logic of Intersubjectivity

What does argumentation dialogue change about what the participants believe? What role do the theses that are refuted or successfully defended play in the ensuing dialogue? Can cognitive changes resulting from dialogue be studied as a type of logic, or intersubjectivity (mutual understanding and acceptance)?

Although the restricted examples we have discussed here do not enable us to reply to such fundamental questions, a relatively stable result is now emerging across several much larger corpora (Baker, 1996, 1999, *in press*). This result is that in collaborative problem-solving situations requiring the co-construction of new knowledge, argumentation dialogue always leads to *weakening* of initial attitudes with respect to the theses discussed. If the students begin with relative certainty with respect to their proposals, the discussion leads to either refutation (from commitment to its absence) or else from a relatively firm commitment to uncertainly or confusion, and never to strengthening of attitudes. One reason for this was discussed above: since knowledge is undergoing construction, attitudes with respect to it are likely to be neither firm nor stable. Another reason relates to a principle of the type "what is discussed is debatable" ("since we have discussed the question, that shows that neither of us really know the answer"). Finally, the epistemological nature of the thesis is also probably an important factor in determining the extent to which it will or will not be adopted or dropped as a belief. Such changes are not necessarily negative with respect to collaborative learning; they can lead to elimination of unfruitful directions in problem-solving.

There is a case for considering students cognitions in such contexts as *acceptances* rather than *beliefs*, in the sense defined by Cohen (1992): accepting the proposition emerging from the debate does not imply firm belief in it, but rather acceptance that the proposition can be drawn upon in future collective reasoning (Baker, 2000). The extent to which, and the circumstances in which, an accepted proposition leads to a belief in it remain to be determined. A further methodological problem for the logic of intersubjectivity in human psychology resides in the fact that many cognitive changes can take place as a result of dialogue beyond the time of the dialogue itself (Trognon, 1993).

The elaboration of a logic of intersubjectivity clearly needs to draw on the logics in and of dialogue described above. To our knowledge, such a model of the elaboration of cognition in and from dialogue is not presently forthcoming.

## Concluding reflexions

What picture emerges of the logics of students' argumentation dialogues emerges from the preceding discussion, and to what extent can dialogic logic help in drawing it?

The logic of reasoning in dialogue can be fruitfully studied according to the hypothesis that students function with (inter)subjective coherence, on the basis of propositions that diverge in significant ways from established norms in the problem-solving domain. Reasoning in dialogue of course functions on the plane of the nature of what is said, how it is expressed and conceptualised. This does not mean that logical relations between propositions do not obtain, but simply that they must be situated in an open and evolving discursive universe, and thus must themselves be revised as the dialogue progresses. Reconstructing the logic of students' dialogues in this way can be a useful tool for studying the psychology of reasoning and learning in groups.

Similarly, the notions of dialectical roles and rules are useful here, provided that they are reinterpreted as referring to certain regularities in collective and linguistically-mediated action, interwoven with other dimensions of communicative action.

Reconstructing these logics not only enables other dimensions of collective activity to be more clearly defined *a contrario*, but also constitutes a significant step forward for understanding the logic of emergence of cognitions in and by dialogue. Although we have not demonstrated this, there seems to be no reason to think that many of the characteristics of the dialogues analysed here will not generalise to other types of task-oriented dialogues. As for the dialogic logic approach itself, researchers have attempted to extend to other types and genres (Walton & Krabbe, 1995).

Finally, in its application to dialogue analysis, so many elements of dialogic logic models need to be replaced by others — in a manner analogous to the planks of Theseus' ship — that the question can be raised as to whether the logics of students' dialogues are still "logics" in any sense of the term. We would answer: yes they are, but perhaps only (?) in the primordial sense of the term *dia-logue*.

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