ISSA Proceedings 1998 – The Function Of Argumentation Dialogue In Cooperative Problem-Solving

1. Introduction
The aim of the research described in this paper is to understand the functional role of argumentation dialogue in cooperative problem-solving, and ultimately, to understand how argumentation can give rise to cooperative learning. By cooperative learning, we mean the type of learning that occurs specifically in virtue of cooperation between people in performing some activity. We propose refinements of known cooperative learning mechanisms on the basis of analyses of cognitive-interactive processes that are at work in argumentation dialogues, for the specific case of a corpus of cooperative problem-solving dialogues in the domain of school physics problem-solving.
Firstly, the study of argumentation dialogue is situated within recent tendencies in cooperative learning research. Then three hypotheses concerning the way in which argumentation dialogue could lead to cooperative learning are discussed: knowledge explicitation, attitude revision and co-elaboration of meaning in relation to conceptual change. An approach to analysing the extent to which these mechanisms are at work in argumentation dialogue is proposed, based on five interrelated dimensions: dialectical, rhetorical, epistemological, conceptual and interactive. Results of analysing these dimensions in a specific corpus are summarised. The analyses reveal the relations between participants' reasoning and the types of knowledge expressed during argumentation, the way in which argumentation outcomes function with respect to changes in attitudes, and the argumentative contexts in which meaning is co-elaborated and conceptual change occurs.

2. The study of verbal interaction in cooperative learning research
During the last decade, the efforts of many researchers have been directed towards identifying specific forms and phenomena of verbal interactions between

learners that correlate with learning effects, under certain specific conditions. This *interactions paradigm* (Dillenbourg, Baker, Blaye & O'Malley 1996) can be represented as follows : conditions -> interactions -> effects ["->" symbolises causality]. However, when one considers real cooperative learning situations, that usually extend in time over an hour or more, this linear schema turns out to be too simple.
Firstly, once learners become more competent at solving a given type of problem, and they have learned how to cooperate together better, then the form of their interaction usually changes (i.e. there is a backward arrow from effects to interactions).
Secondly, what is important for explaining learners' activity is not so much the set of objective conditions, but rather the way in which these conditions are understood by the subjects themselves. There is thus also a backward arrow from interactions to conditions, to the extent that subjects' understanding of the problem-solving situation is continually negotiated during verbal interaction. Given these facts, it is difficult to use existing quite general (neo-Piagetian and Vygotskian) theories of cooperative learning, that have often relied on a simple distinction between cooperation and conflict, in order to identify the precise interactional phenomena that can be correlated statistically with learning effects. What is required is the development of more specific and local models of cooperative learning (Mandl & Renkl 1992) that will enable us to understand how three types of processes interact dynamically: dialogue, cooperation and problem-solving. Cooperative learning will then be viewed as emerging from the complex interaction of these three processes.

It is within this research paradigm that we pose the question of the role, or *function*, of one specific type of dialogue – argumentation dialogue – with respect to cooperative problem-solving. If we could understand the way that argumentation functions in cooperative problem-solving, then this should help to gain better understanding of how and when cooperative learning occurs. There are number of reasons for singling out argumentation for special scrutiny in the study of learning within the context of formal schooling.
Historically, argumentation or debate is one of the cornerstones of the teaching provided in occidental universities. One would expect that the ability to argue with respect to a specific point of view reveals a deeper form of understanding of the domain of discourse. More recently, a number of hypothetical cooperative learning mechanisms associated with argumentation can be abstracted from

research on learning in different domains of cognitive science.These will be discussed later in the paper.

3. Understanding the functions of argumentation dialogue in cooperative problem-solving

In cooperative problem-solving, differences of opinion can arise on several levels – for example, with respect to local sub-goals of problem-solving, alternative solutions to problems, methods to be adopted, and ways of conceptualising the domain. In many cases, the participants may not be aware of these differences. In other cases they may be aware of them, but may simply 'let the matter drop' without argumentation. In the most infrequent case, participants may mutually recognise that their different proposals can not all be accepted, and engage in argumentation. When learners do engage in argumentation, there are a number of different reasons why they might do so. Thus Walton (1989) has proposed a typology of argumentative discussions according to the participants' subjective goals, such as attempting to persuade each other, to hit out at one's opponent, to cooperatively search for the truth of the matter at hand, or even to demonstrate to oneself that one's position is at least defensible. Clearly, all or any of these possibilities could obtain in specific argumentations between learners, although in practice it is difficult to identify which goals subjects are pursuing.

Here we adopt an approach to understanding the function of argumentation dialogue in cooperative problem-solving that depends on considering the dyad as a cognitive unit of analysis, on defining situational constraints and describing how argumentation functions with respect to the learners' overall activity. In other terms, instead of inquiring as to individuals' motivations, we inquire as to how argumentation influences the overall course of the learners' activity, how it contributes to its overall aims. Of course, individuals' motivations to argue may be in accordance with overall cooperative goals ; but they may, locally, diverge from them.

Elsewhere, we have described cooperative problem-solving activity as a process of negotiation (Baker 1994, 1995) on the level of the problem-solving domain, as well as on that of managing the interaction itself. The overall goal of the activity is to reach agreement on a solution to a problem, under constraints relating to the knowledge domain (e.g. a solution expressed in terms of physics rather than biology may be required) and the social-institutional situation (e.g. the solution must satisfy the learner's conception of the teacher's expectations). The principal means by which this overall goal can be achieved is by successive refinement of proposed solutions, methods, sub-goals, … during the interaction. Negotiation can take place with respect to different objects, using different strategies simultaneously. For example, an argumentation that occurs on the level of attitudes towards a proposed problem solution can be accompanied by successive refinement of the meaning of terms used in the statement of the contested solution(s). Our aim is thus to understand the function of argumentation within such a negotiation process, oriented towards agreement with respect to a solution to a given problem.

Intuitively, there are a number of possible functions of argumentation with respect to cooperative problem-solving. One is that argumentation functions as a type of *decision procedure* with respect to the "common ground" of dialogue (Clark & Schaefer 1989). Thus, in the case where participants A and B propose, respectively, partial problem solutions p and q, and A and B mutually believe that both p and q can not be accepted, the proposition that emerges as the winner from the argumentation (e.g. p is successfully defended, q is refuted) is the one that is added to the common ground, and which forms part of the basis of subsequent joint activity.

According to this possibility, argumentation would have basically an *additive* function with respect to the common ground. Similarly, argumentation might have a *subtractive* function, in the case where a previously mutually believed proposition is removed from the common ground once it has been refuted in argumentation.

A second possibility would be the case where argumentation functions as a *verification procedure*: as a result of argumentation, the foundations of a given proposal are better established. Thirdly, argumentation could fulfil a *clarification function*: argumentation with respect to a proposal obliges the participants to co-elaborate a more precise meaning for it ("precization", in the sense of Naess 1966).

We explore possible functions of argumentation by working backwards from possible cooperative learning mechanisms and attempting to determine the extent to which they could be triggered by correlate interactive processes, using an approach to argumentation analysis that is adapted to achieving these objectives.

4. Argumentation and cooperative learning mechanisms

Very little research exists on the study of spontaneously produced argumentative interactions in cooperative learning situations. Most research on argumentation and learning has been concerned with either the generation and evaluation of argumentative texts (e.g. Voss, Blais & Means 1986, Voss & Means 1991), or else on argumentative interactions that are provoked, in situations that were not designed to promote learning (e.g. Resnick et al. 1993). In our view, this state of affairs is largely due to methodological constraints that have excluded the study of spontaneous interactions in learning situations. This is illustrated by the long line of research that has been carried out within the "socio-cognitive conflict" paradigm (Doise & Mugny 1981).

Blaye (1990) has shown that, for a matrix classification task, although the number of socio-cognitive conflicts that occurred was not predictive of cognitive progress, results could not indicate whether or not argumentation related to learning. Our re-interpretation of this, and other, work is that the types of problem-solving tasks studied were not sufficiently complex in order for them to be *debatable*, i.e. argumentation dialogue, as a possible object of study, was effectively excluded from the experimental situation. Debatability requires a certain degree of complexity in the task domain, and the existence of different possible viewpoints from which to debate. In much research, these types of tasks, as well as spontaneous verbal interaction, are excluded since it is difficult to propose experimental measures of individuals' competence with respect to them. It seems that argumentation is most probably related to a particularly elusive form of learning – a greater degree of understanding in the task domain (Ohlsson, 1995).

Three main types of cooperative learning mechanisms, that could be triggered by argumentation dialogue, can be abstracted from the cognitive science literature: knowledge explicitation, attitude change and co-elaboration of meaning and knowledge in relation to conceptual change. We discuss each in turn.

In any argumentation dialogue, the participants will need to generate arguments (defences) in favour of their own proposals (theses), and counter-arguments (attacks) with respect to their opponents' proposals. In argumentations that occur in cooperative problem-solving situations, the arguments that are generated could be considered to correspond to the (often implicit) reasoning that underlies the problem solutions that are proposed and debated. This process of *explicitation* of reasons or arguments is one possible mechanism by which argumentation may lead to cooperative learning, given that it relates closely to what has been termed the "self-explanation effect" (e.g. Chi, *et al*., 1989 ; Chi & VanLehn, 1991).

Chi, VanLehn and colleagues demonstrated that subjects who were asked to "self-explain" their solutions to physics problems had improved problem-solving performance. In other words, the subjects who verbalised their understanding, when prompted by the experimenter, had better problem-solving performance than subjects who did not verbalise. Webb (1991) confirmed the effect by showing that the explanations produced had to be quite elaborated in order for the explainer to learn, which shows that it is the cognitive activity of producing explanations, perhaps involving restructuring of knowledge, that is important in learning. It should be noted that in these experimental situations, the subjects were in fact explaining to another person – the experimenter. To that extent, the self-explanation results could also apply to the situation where subjects make their reasoning and understanding explicit in argumentation dialogue. The basic mechanism at work here is in fact meta-cognitive (e.g. Brown 1987): learning may occur since explicitation of knowledge stimulates reflection and obliges a greater degree of coherence in a subjects' knowledge. In an argumentative interaction, the constraints on individual coherence might be expected to be even greater than in the case of self-explanation, since each participant can also impose these coherence constraints on their partners.

Whilst the explicitation mechanism makes appeal to the process of argument generation and evaluation during argumentation itself, a second possibility is that argumentation *outcomes* have some influence on the participants' cognition. One possible case would be the following: participant A believes that p, and proposes p as a possible solution to the common problem; B calls p into doubt, and an argumentation ensues, the outcome of which is that p is mutually recognised to have been refuted; this refutation leads to the effect that A no longer believes that p.

This is of course an idealised case: as Dennett (1981) has pointed out, it is quite possible to be obliged to accept the conclusion of an argument, but not to believe it. Clearly, there are many other possible links between outcomes of argumentation dialogue and changes in attitudes, such as belief. These possibilities can be explored more systematically by linking research on argumentation dialogue with research on *belief systems*, that has been carried out in linguistic philosophy (Harman 1986) and in artificial intelligence (e.g. Doyle 1979, DeKleer 1986, Gardenförs 1992). Belief revisions may also occur during argumentation itself, as a result of the explicitation mechanism mentioned above.

A third type of interactive learning mechanism that may be linked with the process of argumentation itself relates to the fact that in order to evaluate a proposal, to attack it or defend it, one often has to inquire into, or make refine, the precise *meaning* of the proposal.

Thus argumentation may be associated with negotiation of meaning and knowledge, and the refinement of concepts. Cooperative learning could occur by the internalisation (in the sense of Vygotsky) of these more refined meanings and concepts.

In summary, on the basis of existing research in cognitive science, there appear to be three basic mechanisms by which argumentation dialogue could lead to cooperative learning: explicitation of reasoning during argumentation leads to knowledge restructuring, argumentation outcomes lead to attitude changes, and negotiation of meaning during argumentation leads to better understanding in the domain of reference.

5. An approach to analysing argumentation dialogue in cooperative problem-solving situations

Given that our aim is to understand the functions of argumentation dialogue in cooperative problem-solving, within a theoretical framework that enables us to link these functions to possible learning mechanisms, we have seen that the following types of dimensions need to be analysed: the process of argumentation itself, including the generation of attacks and defences leading to determinate outcomes, attitudes underlying argumentation dialogue, together with changes in them, the domain of reference of the debate, the way it is conceptualised, and the way in which conceptualisations are refined during the interaction. We therefore propose an approach to analysing these types of dialogues along five dimensions: dialectical, rhetorical, epistemological, conceptual and interactive.

Along the *dialectical dimension*, argumentation is viewed as a verbal game to be lost or won. It is analysed here using the dialogic logic of Barth and Krabbe (1982) as a description language, and as a means of predicting argumentation outcomes (who has won and who has lost). Trognon (1990) has demonstrated the relevance of this dimension to the study of human cognition, since argumentation outcomes as predicted by dialogic logic generally correspond to human intuitions.

The *rhetorical dimension* is understood here not in the classical sense of the attempt to persuade an auditorium, possibly by non-rational means, but in the more general sense of the set of cognitive effects of sequences of argumentative speech acts (cf. Van Eemeren & Grootendorst 1984) on speakers as well as on hearers.

Taken together, the dialectical and rhetorical dimensions correspond generally to pragma-dialectics (Van Eemeren & Grootendorst) ; we distinguish the two

dimensions here in order to study the relations between them (see discussion of attitude changes above, section 4 of this paper).
The *epistemological dimension* refers to the analysis of the nature of knowledge that is appealed to in argumentation, and which underlies it. This is important for the study of the types of argumentation considered here – and perhaps for many other types – for two main reasons. Firstly, certain arguments carry more 'weight' than others, in virtue of the type of knowledge that they appeal to.
For example, an appeal to commonly known facts, or to facts of perceptual experience, is usually difficult to refute. Secondly, it has been shown for teaching-learning domains such as physics, that certain types of knowledge are more firmly anchored in subjects' minds, and thus more difficult to change than others (DiSessa 1988). This aspect is also dealt with in belief revision research under the term *epistemic entrenchment* (Gardenförs 1992). In the teaching and learning of physics, we distinguish types of knowledge according to an epistemological approach to physics teaching and learning (Tiberghien 1994, 1996) – knowledge of theories, models and experimental fields –, according to domains of physics knowledge as it is taught (e.g. electricity, energy, mechanics, …), the social situation in which knowledge was acquired (at school, in the home, …), and the social position of a person from whom the knowledge was acquired (a teacher, a parent, an expert seen on television, another student, …). Thus, for example, from the point of view of learners, knowledge of a physics model acquired from a teacher may give rise to an argument that carries more 'weight' than one that draws on knowledge derived from reasoning carried out by another learner.

Whilst the epistemological dimension deals with the nature of knowledge, *the conceptual dimension* is concerned with the form of representation of knowledge, the way that it is conceptualised. In this case, what is crucial is not so much the way in which individual concepts are defined, but rather the way in which concepts are *differentiated* from each other (Vignaux 1988, 1990). In argumentation theory, this corresponds to what Perelman and Olbrechts-Tyteca (1969) have termed "argument by dissociation".
Suppose that two people argue with respect to the question as to whether it is better for humanity to expend resources on growing plants to eat, or else on breeding animals. The way that the concepts "plant" and "animal" are differentiated may turn out to be crucial to the debate (in fact, the basic difference lies in the way in which each obtains energy – via photosynthesis or else via digestion).

Another important conceptual operation in this context is *generalisation*. Thus Walton (1989) has described how most debates have a tendency to move towards discussing more and more fundamental or general issues (he gives the example of a debate on the desirability of tipping that transforms itself into a discussion on the role of the state in regulating commercial affairs). In an analogous fashion, we might expect similar processes to operate in debates between learners, who should be led to discuss the fundamental conceptual framework underlying their activity.

Finally, the *interactive dimension* operates on the epistemological and conceptual dimensions, within a dialectical and rhetorical framework. It is concerned with the successive refinements of meaning and knowledge that occur in argumentative interactions.

These phenomena have been dealt with in linguistics by the study of reformulations (e.g. de Gaulmyn 1987; Vion 1992). In Baker (1994) we have analysed these successive refinements in terms of a general set of *transformation functions* that operate on the knowledge expressed in cooperative problem-solving interactions.

There are four classes of transformation functions:

extensional (the previous proposal is extended in some way, new information is added, elaborated, or derived by inference), contractional (the inverse of extension, where the content of the previous proposal is restricted in some way), foundational (the second proposal provides justification or explanation for the previous one) and neutral (the previous content remains unchanged, as in repetition or linguistic reformulation; this function thus works on the level of maintaining mutual understanding and agreement, rather than on problem-solving itself). Our basic hypothesis is that argumentative interactions impose a special type of *interactive* and *interactional pressure* (Bunt, 1995) on participants (to resolve the verbal interpersonal conflict, to be internally coherent, to preserve face, …) that may force meanings and knowledge to be refined.

In performing analyses along these dimensions, the dialectical dimension is primary. Precisely because it is extremely reductionist, it allows us to isolate more clearly those aspects of the argumentation dialogue that are not taken into account by this dimension. Similarly, we can use the normative dialectical model as a starting point for determining the dialectical rules to which learners' argumentations conform, within the context of a real interaction.

For example, although repetition of attacks may be proscribed within an ideal dialectical model, such repetitions may be performing other functions, such as ensuring that one's interlocutor has adequately perceived and understood the attack. The dialectical dimension is also primary to the extent that the other dimensions are only studied in terms of their relation to it. For example, the rhetorical dimension is studied in so far as it relates to (dialectical) argumentation outcomes, we must first isolate an utterance as an argumentative attack before asking the question as to its relative 'weight' along the epistemological dimension, and so on.

6. Presentation of the corpus and summary of results of the analysis

6.1 The corpus and the physics problem-solving task

The analysis techniques described above have been applied to a corpus of verbal interactions**(i)** collected in a physics classroom in the Lyon area (students aged 16-17 years). The corpus consists of transcriptions of four verbal interactions between pairs of students, seated side-by-side, each interaction having lasted approximately 45 minutes. The students' task was to draw "energy chains" for simple experimental situations – for example, a bulb is connected to a battery by two wires; a weight is attached by a string to the axle of a dynamo, which is also connected to a bulb by two wires (when the weight falls, the axle turns and the bulb lights up). Energy chains are simple qualitative models of energy storage, transfer and transformation; arrows correspond to different forms of transfer, and different types of boxes to reservoirs and transformers of energy. Energy chain diagrams must be constructed within constraints of certain simple rules, for example: "A complete energy chain must start and end with a reservoir" (this corresponds to the law of conservation of energy). The didactic rationale of this task (Tiberghien 1994, 1996) is that, by attempting to establish correspondences between the model and the experimental situation, under a set of syntactic rules, the students will be led to co-construct a *semantics* for the model, i.e. to have an understanding of the meaning of the concept of energy.
From the point of view of the study of argumentation and cooperative problem-solving, this task presents a large space of debate, since the students draw on a variety of different types of knowledge – for example, knowledge of other areas of physics learnt in school, such as electricity, and knowledge of energy acquired in everyday life, such as with respect to household electrical appliances. Here we restrict ourselves to summarising results of a systematic analysis of the corpus. Fuller details, with detailed analyses of concrete examples, can be found in Baker (1996a, 1996b, *to appear*).

6.2 Summary of results

According to the explicitation learning mechanism, relating to the self-explanation effect mentioned above, participants in argumentation render explicit the steps of the reasoning underlying the problem solutions that they propose, in the form of defences. In this case, there should be a close correspondence between the type of knowledge that manifestly underlies their problem solving, and the type of knowledge that is expressed during argumentation. This assumption can therefore be evaluated by analysis along the epistemological dimension. Such an analysis produced two main results.

Firstly, students are generally stable and consistent in terms of the type of knowledge used in their argumentations, throughout a given interaction. For example, some students consistently argue in terms of facts of everyday experience – “a bulb connected to a battery will not shine forever” ; “my ear-rings shine but they do not give out heat ; so it’s not true that whenever there is light there is heat”. Others consistently make appeal to the institutionalised knowledge provided by the teacher, such as the rules of the energy chain model – “a complete energy chain must start and end with a reservoir” – or previously taught knowledge of electricity – “there must be a transfer from the bulb to the battery as well as one from the battery to the bulb, otherwise the circuit would not be closed”. Stability of epistemic points of view probably relaes to the spontaneous adoption of specific roles with respect to cooperative problem-solving (e.g. “critic”, “proposer”), as well as to the students’ cognitions.

Secondly, there is often a mismatch between the type of knowledge expressed by a given student during argumentation, and the type of knowledge that manifestly underlies the solution proposed by the student. This implies that the explicitation hypothesis needs to be refined. For example, in one argumentation sequence, students A and B proposed the following energy chains for the battery-wires-bulb experimental situation (Figure 1):

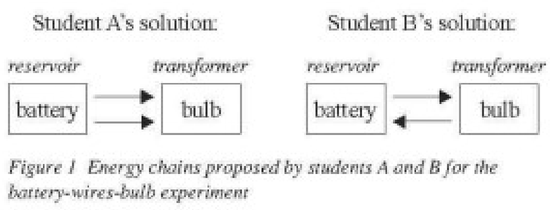

Figure 1 Energy chains proposed by students A and B for the battery-

wires-bulb experiment

From our previous analyses of students' problem-solving in this domain (e.g. Devi, Tiberghien, Baker & Brna 1996) it was clear that B's reasoning was based on a confusion between knowledge of electricity and knowledge of energy: in his solution, the energy transfer arrows between battery and bulb go round in a circle, like the standard representation of electrical current in a circuit. However, in terms of energy, there should be a single transfer of energy, in the form of electrical work, from the battery to the bulb. Student B argues for his solution solely in terms of the rules of the energy model ("the chain starts with a reservoir [battery] and ends with a reservoir [the same battery], so it satisfies the energy model rule"), and not in terms of electricity. In this case (and others) therefore, the student's argumentative behaviour does not correspond to simple explicitation. In the case of student A however, she argues in terms of linear causal reasoning ("the energy is produced first by the battery, then flows along the two wires to reach the bulb"), which does correspond to the solution she proposes.

The conclusion that we can draw with respect to the explicitation mechanism is therefore that argumentation does not always stimulate explicitation of reasoning underlying proposals.
Rather, it may trigger the search for other forms of knowledge that are available in the problem-solving situation, which may be used in argumentation. There may be a number of explanations for this phenomenon. In some cases, beliefs underlying proposals may not be available to conscious inspection ; in others, the type of knowledge that is searched for may be viewed as providing stronger argumentative support than the knowledge underlying the student's original problem-solving processes. From this analysis we can propose a different mechanism by which argumentation could lead to cognitive change: the search for new knowledge sources as arguments may *widen the epistemic field of verification of proposals*, and thus lead to improvement in the quality of solutions.

In order to study attitude change as a result of argumentation outcomes, we first analysed all argumentation sequences along the dialectical dimension, thus predicting outcomes (successful defence or refutation; in some cases, a non-dialectical compromise outcome was produced, or even no clear outcome). We then analysed the dialogue following the argumentation sequence in order to study students' verbal behaviour with respect to the conflicting theses and the outcomes. The criteria for attitude change used were quite simple: if a student asserted a proposition p, or its negation not-p, he or she was assumed to believe it, or its negation. For example, if student A's proposal p was refuted, yet A continued to assert p in the subsequent dialogue, this was taken as evidence for A's continued belief in p. In the case where p is no longer mentioned by A, then no interpretation could be made. For each argumentation sequence, and for each student, we constructed a belief system (a network of propositions linked to justifications) relating to the propositions expressed during the sequence. We could thus attempt to hypothesise the belief revision principles upon which the students operated, in relation to argumentation.

The results of this analysis were quite unequivocal: students were *falsificationist* with respect to proposals of their partners, and *confirmationist* with respect to their own proposals. In other words, in the case where there was at least one commonly accepted counterargument to a thesis T, then T would not be commonly accepted, irrespective of argumentation outcomes (for example, even if T was successfully defended). It appeared that a proposal/thesis had to be 'flawless' in order for it to be a candidate for the "collectively valid" (Miller 1987). Conversely, and again irrespective of argumentation outcomes, provided that a given student had at least one commonly accepted argument in favour of his or her proposal/thesis, then this was sufficient for that student to retain belief in that proposal (even if refuted in the argumentation). We can therefore say that the function of argumentation in the context of cooperative problem-solving (at least for this corpus) is not an additive one. Rather, argumentation functions as a means of eliminating 'flawed' proposals from consideration, as a means of eliminating certain candidates for addition to the common ground. The students' rationality seemed to be: "if there is something wrong with it, then that can't be the right solution". The remaining case is the one where for both of two conflicting proposals/theses, each has one or more arguments in favour of it, as well as some in its disfavour. In this case, the students always attempted to find a compromise, by combining elements of each solution.

Finally, we analysed argumentation sequences along the conceptual and interactive dimensions, within a dialectical framework, in order to determine the dialectical contexts within which knowledge is co-elaborated, and its meaning transformed. Such transformations of knowledge and meaning take place in two contexts: as part of the argumentation process itself (the exchange of argumentative moves, attacks and defences) and as part of the process of finding an outcome to the argumentation.

Significantly, transformations of meaning and knowledge that took place during the argumentation process were often implicit (i.e. not expressed explicitly), and most often led to refinements that were positive, from a normative point of view. For example, with respect to the argumentation situation illustrated in Figure 1, student A's counter-argumentation with respect to B's proposal may be summarised as follows: "There are not two batteries in the experimental situation, so what you say is absurd."
Implicitly, this counter-argumentation (which was in fact fully mutually understood, and led to concession by B) works via an implicit *reductio ad absurdum* that includes an implicit elaboration of the meaning of the energy chain rule (R1): "A complete energy chain must start and end with a reservoir". In A's view, R1 should be reformulated to (R1') :"[R1]… and the beginning and ending reservoirs can not correspond to the same object". Assuming R1', then, if B's chain is complete, and the reservoirs correspond to "battery", then there must be two batteries in the experiment (!). But since there is clearly only one battery, then B's proposal is absurd. Interactive transformations that took place as a means of resolving the argumentation were, however, often superficial combinations of solutions on a purely linguistic level. For example, in the case where one student proposed that an energy transfer corresponded to "mechanical work", and another that it corresponded to "force", then the students juxtaposed elements of each solution, agreeing on the superficial compromise "mechanical force". As mentioned above, however, the desire to search for a compromise was always rationally motivated by the existence of opposed proposals, each of which had something in their favour and something in their disfavour (the desire to extract the 'grain of truth' from each).

The principal conceptual operation that was at work in these argumentations was *dissociation* of concepts, and domains of knowledge, the most important case being dissociation of concepts relating to *energy* from those relating to *electricity*. In the battery-wires-bulb experiment, this dissociation process was triggered by the attempt to determine the meaning of the term "transfer", for the case of the transfers between battery (reservoir) and bulb (transformer).
Typically, as the result of a protracted discussion, the common interpretation

could be summarised as : “I agree that there must be a second transfer from the bulb to the battery [see B’s solution in Figure 1] in order to close the circuit ; but it’s not really a transfer of energy”. In this way, argumentations were not so much *resolved* as *dissolved*, by redefinition of the universe of reference.

This process of dissociation of concepts is potentially important for conceptual change in physics. In fact, the problem in this case is not to replace students’ everyday conceptions with physics conceptions, but rather to enable them to dissociate the fields of appropriate application of concepts.

7. Conclusions

The basic question addressed here was as follows: what is the function of argumentation dialogue with respect to cooperative problem-solving? We understand this question as referring to the influence that argumentation has on the overall course of cooperative problem-solving activity. Our results indicate three basic functions for argumentation dialogue in this context. Firstly, argumentation functions as a *trigger for information search* within the problem-solving situation, as a means for evaluating the acceptability of different proposals. In this way, the process of verifying solutions could be improved. Secondly, argumentation functions as a *filter of defective proposals*, rather than as a means of identifying the most acceptable, or best supported, proposals. Thirdly, argumentation functions as a provider of a *special interactive pressure to co-elaborate meanings* of concepts in the domain of discourse.

In order to fully understand the implications of these results we need to recall an important feature of the argumentation situation studied here. The didactic situation is designed so that the elaboration of new understanding (of the concept of energy) is at stake for the students. The students therefore engage in argumentation with respect to concepts that they themselves do not yet fully master, and in the absence of help or arbitration from a person who does fully possess the requisite understanding (their teacher). Given these considerations, it is understandable that students search for information in the problem-solving situation that can help resolve the conflict of opinions, that they reject defective proposals, and that they attempt to gain a better understanding of the domain of discourse (the didactic objective of the situation itself, from the point of view of the teacher and researchers).

These results are at present restricted to the corpus described above. Our ongoing work is concerned with applying the analysis method described above to other problem-solving domains, and to situations involving computer-mediated argumentative interactions (cf. Baker & Lund 1997). In our view, the way forward in understanding the function of argumentation in cooperative problem-solving situations is to elaborate a more systematic analysis of didactic and argumentative situations themselves (cf. Golder 1996). This should enable us to design situations that allow the emergence of argumentation dialogues that are productive from the point of view of learning.

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NOTE

i. The corpus (in French) is publicly available at: http://www.ens-lyon.fr/~lund/DRED/

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