Favouring spontaneous production of modellable computer-mediated argumentative dialogues between learners

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Abstract : Although argumentative interactions are potential mechanisms by which learners will be led to render explicit their understanding, reflect upon it and eventually restructure their knowledge, very specific conditions are required so that these interactions will be produced spontaneously in collaborative problem-solving situations. We describe an experimental collaborative problem-solving situation involving computer-mediated communication (CMC), that is designed to favour the production of argumentative interactions and to enable the cognitive changes that they produce to be modelled. Our approach is based on a restricted set of hypotheses, derived from psychological and logico-linguistic studies of argumentation, and involves the following main phases : (i) graphical individual problem-solving with translation of solutions into a linguistic form, (ii) expression of justifications, explanations and attitudes with respect to solution elements, (iii) automatic constitution of dyads and individualised generation of texts describing the verbal conflict situation, (iv) CMC discussion, and (v) individual reconstruction of the agreed solution and justifications. This approach enables us to study learners solutions, justification structures and attitudes, before and after collaborative problem-solving activity, and thus to assess the role of argumentative interactions in students' changes in view. Our results show that the situation is successful in favouring argumentative interactions. Although such interactions do not necessarily lead to an improvement in solutions, and/or conceptual understanding, they can lead students to a better understanding of the nature of the task in which they are engaged (in this case, *modelling* energy in physics).

1. Introduction

A central tenet of recent research on collaborative learning is that certain types of communicative interactions between learners can be associated with specific interactive learning mechanisms (e.g. [6]). In this paper we concentrate on the case of argumentative interactions between learners — interactions that involve the attempt to resolve expressed conflicts of opinions with respect to proposals, by verbal means (expression of justificational structures). A number of mechanisms by which these types of interactions could lead to conceptual change have been described (e.g. [14, 1]). For example, they can lead students to co-construct knowledge, to differentiate concepts from each other, and to produce more articulated and/or coherent individual views. However, a major problem faces research on argumentative interactions and collaborative learning : it appears that very complex and strict conditions are required in order that argumentative interactions can be produced spontaneously by learners [9] in CMC situations [2]. Our aims are similar to those of Hoppe and colleagues (e.g. [10]) in that we also aim to constitute productive collaborative dyads in a CMC situation. However, our work differs from Hoppe and colleagues' work in that our primary aim is to effect cognitive changes via stimulating a specific type of communicative interaction.

Our research addresses two related problems : (1) understanding the conditions for production of argumentative interactions in collaborative problem-solving situations involving CMC, and (2) modelling the cognitive changes produced as a result of engaging in argumentative interactions. We propose a restricted set of hypotheses, based on psychological and logico-linguistic studies of argumentation, and on CMC research, concerning the conditions under which argumentative interactions can be produced. These hypotheses form the basis for design and implementation of a computer-based environment, involving synchronous typewritten CMC. Experimentation of the environment has enabled us to collect a corpus of argumentative interactions that is adapted for the validation of a cognitive model of argumentation in relation to cognitive change. Our experimental collaborative problem-solving sequence involves encouraging students to express justifications and attitudes, translating graphical problem-solutions into a linguistic form as a preparation for debating, automatic constitution of dyads and individualised generation of texts describing the verbal conflict situation, and individual reconstruction of the agreed solution and justifications after CMC discussion. This approach enables us to study learners solutions, justification structures and attitudes, before and after collaborative problem-solving activity, and thus to assess the role of argumentative interactions in students' changes in view. Our results show that the situation is successful in favouring argumentative interactions. Although such interactions do not necessarily lead to an improvement in solutions and/or conceptual understanding, they can lead students to a better understanding of the nature of the task in which they are engaged (in this case, modelling energy in physics).

In the rest of the paper we describe our practical and theoretical hypotheses, then the computer-based environment itself, and the successive phases of our experimental collaborative problem-solving sequence. We then present and discuss results of a study where the learners' task was to elaborate simple qualitative models of energy ("energy chains", [15]). In conclusion we discuss the extent to which this experimental CMC situation has potential as a learning environment.

2. Design hypotheses and modelling constraints

Previous research on problem-solving dialogues between learners has confirmed what teachers have always known : students are not naturally likely to argue spontaneously with each other, at least with respect to the subjects taught in school. Interpersonal conflicts or individual contradictions are not sufficient to provoke the incidence of argumentation, nor the incidence of argumentative attitudes (i.e. relatively stable "pro" and "contra" stances). Nonnon's work [12] partially explain this phenomenon : concepts that are not yet sufficiently mastered (since they are being elaborated, and learned) will not allow students to take risks to defend or attack them. So it appears that, in certain situations, there will be a trade-off between conditions for collaborative learning and for engaging in argumentative interactions.

Our investigations on the situations promoting spontaneous argumentative interactions between learners are structured on one hand by *psychological* hypotheses (H1-H4) underlying studies of psychological obstacles to the production of argumentative texts [9] and by *pragma-dialectical* hypotheses (H4-H8), derived from theoretical studies of argumentation [8]. On the other hand, our approach is structured by *modelling constraints* : we need to be able to study students' views (proposals, justifications and attitudes) before and after argumentative interactions, whilst preserving authenticity of the debate (i.e. the students should be genuinely committed to their own proposals).

2.1 Hypotheses

H1. The concepts underlying the problem-solving task to be solved can be understood by participants.

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Figure 1 : The correct energy chain for the 'battery–bulb' problem

H2. The "argumentativeness" of the task : participants can understand different positions with respect to the problem.
H3. The communication situation (CMC interface) does not prevent the expression of opinions.
H4. The conceptual distance between the two conflictual theses is sufficiently wide and evident.
H5. A minimal common ground is shared, with respect to the topic to be discussed.
H6. A conflict of opinions has been openly declared, and understood.
H7. Participants have enough arguments at their disposal, and commit themselves to the debate.
H8. Participants want to resolve this conflict, whilst defending their own positions.

The first hypotheses (H1-H2) manifest the need for a preliminary task that can help students to gain an initial understanding of the concepts underlying the main problem-solving task, and enable them to "step back" in order to apprehend attitudes, differences of opinions and contradictions. The third hypothesis warns of the advantages and disadvantages of a computer-mediated typewritten discussion. Although such communication channels may facilitate control of emotions or dissimulation, they also impose a particular way of representing concepts, that may be a semiotic obstacle to reasoning. We assume participants will eventually argue, if there is a conflict (H6), that can not be solved by a compromise (H6) : the choice of the opponent in argumentation is the crucial point (H4). The other pragma-dialectical hypotheses stress the importance of conflicts in the debate that can give rise to argumentative resolution procedures. These are specifically needed for the elaboration of instructions, that must explicitly state the particular conflicting points to be discussed.

2.2 Modelling constraints

In order to experiment the potential of such a situation for learning, attitudes and explanations have to be collected just before and just after discussion, in order to have a good representation of the participants' knowledge, of the attitudes they may have during the interaction and of the arguments they may use. An external intervention has to be designed at the boundaries of the interaction in order to collect this information, yet it must alter neither the content nor the progression of the discussion.

Spontaneous emergence of a critical discussion is predicted as soon as the appropriate dialogical attitudes ("pro", "contra") have been expressed and the communication between participants' screens is established. This implies that dyads have already been established, i.e. which students will discuss together in pairs. This does not leave much time for analysing the individuals' solutions in order to automatically constitute dyads (using a matching algorithm). Since the combinatory space that has to be investigated is very large (105 combinations for 8 students), *dyad constitution* that is based on analysis and comparison of individuals' problem solutions *needs to be achieved by a computer*.

3. Description of the experimental collaborative-problem solving situation

3.1 The choice of a task : energy chains

The choice of the problem-solving task involves a crucial compromise : the main topic must be both debatable (in the sense of Golder, op. cit.) and modellable, i.e. it allows automated analysis and dyad constitution. The task chosen was qualitative modelling of energy, using by *energy chains* by high school students (16-17 years old). Energy chains are composed by the following elements : *reservoirs* (that store energy), *transformers* (that transform energy) and *transfers* of energy (work, heat and light). This task also contains a fundamental syntactic rule : "chains must start and finish by a reservoir ; these reservoirs must be different". The

Table 1 : General progression of the experiment.

	Phases	*Achieved by*	*Screens*
1.1	Individual problem-solving	Student	1
1.2	Expression of attitudes and explanations	Student	2a, 2b
2.1	Automated solution & attitudes analysis	System	
2.2	Dyad constitution	System	
2.3	Generation of conflict situation text, specific to each dyad	System	
3	Typed dialogue (CMC)	Dyad	3
4.1	Individual reconstruction of the agreed solution	Student	1'
4.2	Expression of personal attitudes and explanations	Student	2a', 2b'

Nota : 1 & 1' (resp. 2a, 2b and 2a', 2b') are related to the same activities. See screen dumps, presented below.

experimental situation students have to model is the case of a bulb connected to a battery by the mean of two conducting wires. The correct corresponding chain is given figure 1.

The choice of this task is grounded by the following facts. Firstly, students' problem solving strategies are now well known for this task [11, 3, 5]. Secondly, the task implies a wide knowledge space for debate, since students have to their disposal several systems of explanation for this phenomenon, and therefore several conflicting positions may be held and discussed (the electrokinetic model proposes a very different solution to this exercise). Finally, this graphical task is well structured by syntactic rules on a small number of types of elements, which allows automated analysis of students' solutions. Dyad constitution may be achieved by a computer, in a reasonable processing time (10 minutes maximum).

3.2 Successive phases of the experiment

The experiment has been carried out with 8 high school students of a same class, 3 boys and 5 girls, aged from 16 to 18 years old. It involves four main phases : three are achieved by students (alone or in dyad), one is achieved by the system (see Table 1).

Phase 1 : Individual problem solving and attitudes

Description : On the first screen (see figure 2), each individual student must draw the energy chain that models the experimental situation, provided for each student. The experimental situation consists of a battery, a bulb, connected by two electric wires. This material is the same that the students commonly use in labwork.

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Figure 2 : Computer environment for graphical construction of energy chains (*left*) with an automated description of its components (*right*).

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Figure 3 : Attribution of attitudes and explanations. *For each sentence formulated by the system* (left column) *on the basis of the graphical solution, subjects are expected to express their attitude in the local menu* (in the centre column) *and to explain their choice in the reserved place, on the* right.

On this screen, two spaces are available : one graphical window where energy chain elements can be placed (these boxes and arrows can be manipulated from the menu bar) and one text window, updated by the system, that describes chains in a few sentences, as fast as they are elaborated. Students also have a quick access on the screen and on a separate sheet of paper to a description of the model (syntax and semantics of the chain components). Our fundamental hypothesis here is that *argumentation is a language-based activity* : our aim is thus to facilitate the transition between "semiotic registers" [7], from a graphically-based problem-solving activity, to language-based reflection and discussion (cf. [13]). In addition, automated description of diagrams in a linguistic form provides a common way of describing the solutions, that may improve determination of the common ground prior to discussion.

On the second screen (see figure 3), students are proposed sentences (up to ten) by which the system describes their individual solution. Each sentence is displayed in a separate text window, in a column, on the left hand side. On the right of each sentence, students successively find a local menu, from which one of five following attitudes can be selected, then a text window, where subjects are invited to type explanations or justifications with respect to their attitudes.

(1) *I'm sure it's the case.*	(strong commitment)
(2) *Yes, maybe*	(weak commitment)
(3) *I don't know.*	(no commitment)
(4) *Maybe not/yes.*	(weak negation or denial)
(5) *I'm sure, it's (not) the case.*	(strong negation or denial)

A third screen (not included in this document), in principle identical to the previous one, displays a *more complex description* of the solution. It does not describe components separately anymore, but rather "chunks" of the energy chain diagram, composed by two connected boxes and their interconnections, in order to collect more global attitudes and *other types of explanations*. Our hypothesis here is that modelling involves *global* as well as element-to-element matching [5], so justifications for chunks may not be equivalent to the sum of justifications of their components.

Phase 2 : Dyad constitution

An automated algorithm has been implemented for dyad constitution, so that discussions may start as soon as possible after attitudes have been expressed. During the first phase, none of the students (or researchers) knew who would discuss with whom. The choice of the partners is achieved on line, on the basis of the individual solutions, in order to put together subjects who manifested conflictual solutions, in a way that may give rise to potentially rich argumentation. Solutions are analysed, formalised and finally compared.

Three criteria have been selected in order to predict which pairs of students' solutions would lead the students who created them to commit themselves to argumentation :

- *conceptual obstacle* : students should be put together who did not solve the problem the same way. There are three ways of describing the problem (modelling levels, see [15]) : a raw description of the objects involved in the situation (objects level), an electrokinetic model (using knowledge from electrical circuits) and energy modelling (the correct way, expected for this exercise). Research in physics education showed that students' description are homogeneous from the modelling point of view, and they have difficulties in changing the way that they conceive the problem. Therefore, from this conceptual obstacle one can expect strong positions and entrenched commitments. Modelling levels are estimated on the basis of the labels given to components of the chain, and the number and direction of transfers. These subcriteria are weighted by the degree of belief in the corresponding propositions, as expressed in the attitudes.
- *normative obstacle* : a chain that does not conform to rules of the model (circularity and completeness) is expected to give rise to well grounded attacks from the opponent (there is a space of possible counterarguments).
- *solution correctness* : from the principle that a good solution is more convincing than a worse one, one must avoid putting together very inequal solutions, otherwise the worse solution could not compete against the better one. On the other hand, one should also avoid to put together two solutions that obtained a similar mark : they could be so close that there

would not be any conflict left, that may lead not to a valuable argumentation, but rather to a negotiation.

The argumentative potential of each dyad is evaluated on the basis of the previous criteria, and an "argumentative mark" is given. An optimisation algorithm investigates all possible ways of choosing four pairs in a group of eight subjects, and retains the best configurations : no pair must be too weak, most of them must be maximal. In fact, the final choice amongst candidate dyads (e.g. 5 optimal ones amongst 105 possibilities for a group of 8 students) is left to the experimenter's intuition.

Text generation for each conflict situation

Once the choice of dyads is made, one must give specific instructions to each dyad that will lead to an argumentative interaction. In accordance with the rules of pragma-dialectics and our modelling constraints, instructions consist of a natural language description of the conflict situation and the following final phrase : *"Discuss together, each of you defending his/her own point of view, in order to find a common solution to the exercise."*

By the presentation of this text, essential elements of the common ground relating to the conflict situation are established, and positions are declared. Participants can not visualise the opponents' diagram : they only have a partial description of it, in natural language. The students also have at their disposal their own solution diagram, on a separate sheet of paper.

Phase 3 : CMC discussion of the solutions

Once dyads have been constituted, the students sit in front of a computer, so that partners in a given dyad are back to back. Partners share the same computer screen across the network. The connection enables each student to observe all actions of the other on the shared screen, including text as it is being typed.

The screen used for computer-mediated argumentation is divided in two parts (see figure 4). The upper part of the screen displays the description of the conflict situation, and the instruction phrase, described in the previous section. The lower part of the screen is dedicated to communication. Two personal spaces are displayed on both sides of a central dialogue history.

Subjects communicate by the use of buttons in their personal space. Some buttons send short messages to the dialogue history : 'Yes', 'No', 'I agree', 'I don't agree'... These are shortcuts because typing takes a while ; they are also provided to stimulate their use, and so to structure a certain from of discussion. Other buttons (balloon, 'Because...', see figure 4) open

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Figure 4 : CMC environment shared by the subjects of the same dyad. *The upper part displays the conflict situation, whereas the lower part is dedicated to communication. On both side of the dialogue history (*in the centre*) subjects are provided a personal panel for the formulation of communicative acts. A free text typing window can be called by clicking on the balloon. The other buttons send key messages directly to the dialogue history.*

a pop-up text window where free text can be typed. The students send their messages by hitting the TAB key. In this case, their message is added to the bottom of the dialogue history (bottom of screen in the middle) and their text dialogue box closes. The design and implementation of the computer-mediated communication part of this interface was based on previous research [2] carried out within GRIC-COAST.

The shared screen technology induces its own side effects. Subjects have to manage turn-taking and avoid simultaneous typing (overlapping contributions cannot be separated). Subjects do also conform to another implicit social rule, that is not to intrude and use opponent's personal space : the shared screen technology actually cannot tell which computer provoked events such as key strokes and mouse clicks.

Phase 4 : Individual reconstruction of the agreed solution and attitudes

Once students decide that the debate is closed, they call the experimenter to disconnect the screen sharing. Subjects come back to the initial drawing environment for energy chain elaboration (see figures 2 and 3). They are expected to rebuild the energy chain on which they agree at the end of their discussion. As in the first phase, their chain is analysed and descriptive propositions are proposed by the system, on which subjects must express their own attitudes and give explanations.

The design rationale of this phase was that the researcher would be able to access the degree of agreement reached in the discussion, by comparing it with the chains drawn subsequently by individual students of the same dyad. One can also access by the explanations given to new components of the chain, and to the reasons why proposals were accepted or not.

4. Results

On the basis of a preliminary analysis of the corpus, some qualitative conclusions can be made, validating the fact that the experimental situation — including automatic translation of graphical solutions into a textual form, automatic solution analysis, conflict situation texts and, above all, dyad constitution — is able to favour the spontaneous production of modellable argumentative interactions between students.

4.1 General results

Although students communicate through a type-written interface, in phase 3 dialogal (i.e. relatively short interventions, synchronous writing and reading, free turn-taking) and argumentative interactions were produced : the average amount of time spent in argumentation reaches 84% of the interaction duration (58% in dialectical argumentation).

In 3 cases out of 4, argumentation started as soon as the discussion started. The only dyad that had some trouble in arguing (dyad 3) was composed of students having very similar initial solutions. In all cases, there was no problem of mutual understanding, relating to CMC, nor semiotic obstacles. This shows that conflicts and the common ground were correctly established.

The most conflictual task-oriented discussions were obtained with dyads having the greatest conceptual and normative differences (dyads 1 and 4). This corroborates the criteria on which the dyad consitution algorithm was based.

The positions and the arguments maintained in the discussion (phase 3) directly relate to the justifications and opinions given in phase 1.2.

The "common" solution, expressed by separate individuals does reflect consensus at the end of the argumentative dialogue. With the exception of one student who looked over the shoulder of her neighbour, the only differences we can notice between the final solutions are related to items that were not debated.

The evolution from the initial to the final individual solution is a rational function of the argumentative dialogue itself. We can find in the dialogue where changes have been provoked, because the new explanation given in phase 4.2 generally refer to a particular argument of the corpus.

In 3 cases out of 4, students agreed on one initial solution of one of the partners ; only one dyad agreed on a *new* energy chain as a result of the discussion.

Cognitive progression : there is a general progression, but not necessarily towards a better solution, nor better comprehension of concepts, but towards *better model-based reasoning* (i.e. better understanding of what the modelling process is — e.g. it is not the case that there should be one-to-one matching between model elements and entities to be modelled).

These results, especially the first two, confirm the contribution of this research tool as a means of collecting and stimulating argumentative interactions between learners. From result 3 to 5, one can observe a strong relationship between the private expression of cognitive attitudes (phases 1.2 and 4.2) and their commitment to a public debate (argumentation phase). The two last results show that argumentative activity may provoke cognitive changes, in a normative way (critique), but that it does not — of course — necessarily promote better understanding nor better problem-solving. One can explain this result by the fact that the conceptual differences between initial solutions were quite small. A more extensive experiment should be done in order to determine under what conditions argumentation can give rise to more extensive conceptual changes.

4.2 The four dyads

We now briefly expand on these results, summarising the work of the four dyads (table 2).

Dyad 1: *Basil and Romeo*. In this dialogue, two conflicts arose : one concerning the number of reservoirs, the second concerning the number of transfers. Basil convinced Romeo of the necessity to put a second reservoir, following the rule of the model (there must be a final reservoir, different form the initial one). Romeo accepted although Basil acknowledged the fact that in a electrical circuit there is only one battery, and “thus” only one reservoir. Romeo accepted a third transfer (“even” there are two wires), on the reason reservoirs had to be linked (implicit rule). Labels (modes of energy transfer) were not debated. Decisive arguments were based on explicit or implicit formal rules. Romeo’s explanations for his final solution recalls the arguments by which Basil convinced him.

Dyad 2: *Anna and Daisy*. The dialogue between Anna and Daisy started directly on the question whether they should put one or two transfers between the battery and the bulb. They quickly came to the paradox there should be one transfer, but with two wires. Although Anna gave the right reason (the unique transfer is achieved by the two wires), she finaly proposed another solution : they kept only the “positive” wire, because of its direction. Daisy acknowledged her reasoning. Labels were not debated either.

Dyad 3: *Janet and Samantha*. Janet and Samantha took a while before the conflict arose, because Janet did not seem to defend her solution. Samantha made her commit to enter the discussion by beginning to argue. Samantha did not provoke the conflict on the direction of the second wire. The students could have agreed on a three elements solution : one reservoir, one transformer and one transfert (wires) from the battery to the bulb. But Janet agreed for second transfer (i.e. Samantha’s solution). Samantha acknowledged that change, in favour of her solution. Labels were not debated. This dialogue was not conflictual, since no one really defended their solution. Unfortunately, we can not determine the degree of agreement between the students, because Janet did not draw the common solution in phase 4, but the one she saw on Augustin’s screen (her neighbour) instead.

Table 2 : Summary of the students' solutions before and after discussion.
Each solution is given the value of the criteria used by the dyad constitution algorithm : conceptual level (C1), normative level (C2), and solution correctness (C3).

Dyad	Initial solutions		Final solutions	
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2	Anna Ce graphisme de format Encapsulated Postcript (L'impression sera bonne sur une imprimante Pos Nom du fichiAn-avant.eps Titre : A-avant.fig C1 : real C2 : uncomplete C3 : moderate	Daisy Ce graphisme de format Encapsulated Postcript (L'impression sera bonne sur une imprimante Pos Nom du fichiD-avant.eps Titre : D-avant.fig Créateur : fig2dev Version 3.1 Patchlevel 2 Date de créatio Tue Dec 1 14:05:01 1998 Nombre d 0 C1 : electrokinetic C2 : circular, uncomplete C3 : poor	Anna Ce graphisme de format Encapsulated Postcript (L'impression sera bonne sur une imprimante Pos Nom du fichiAn-apres.eps Titre : A-apres.fig C1 : real C2 : uncomplete C3 : moderate	Daisy Ce graphisme de format Encapsulated Postcript (L'impression sera bonne sur une imprimante Pos Nom du fichiD-apres.eps Titre : D-apres.fig C1 : real C2 : uncomplete C3 : moderate
3	Janet Ce graphisme de format En L'impression sera bonne su Nom du fichiJ-avant.eps Titre : J-avant.fig Créateur : fig2dev Version 3 Date de créatio Wed Dec 2 Nombre d 0 C1 : real C2 : uncomplete C3 : moderate	Samantha Ce graphisme de format Encapsulated Postcript (L'impression sera bonne sur une imprimante Pos Nom du fichiS-avant.eps Titre : S-avant.fig C1 : electrokinetic C2 : circular, uncomplete C3 : poor	Janet Ce graphisme de format Encapsulated Postcript (EPS) ne compren L'impression sera bonne sur une imprimante Postscript. Nom du fichiJ-apres.eps Titre : J-apres.fig C1 : real + energy C2 : circular C3 : moderate	Samantha Ce graphisme de format Encapsulated Postcript (L'impression sera bonne sur une imprimante Pos Nom du fichiS-apres.eps Titre : S-apres.fig C1 : electrokinetic C2 : circular, uncomplete C3 : poor
4	Augustin Ce graphisme de format Encapsulated Postcript (L'impression sera bonne sur une imprimante Pos Nom du fichiAu-avant.eps Titre : A-avant.fig C1 : energy C2 : uncomplete C3 : good	Marianne Ce graphisme de format Encapsulated Postcript (L'impression sera bonne sur une imprimante Pos Nom du fichiM-avant.eps Titre : M-avant.fig C1 : electrokinetic C2 : circular, uncomplete C3 : poor	Augustin Ce graphisme de format Encapsulated Postcript (EPS) ne com L'impression sera bonne sur une imprimante Postscript. Nom du fichiAu-apres.eps Titre : A-apres.fig Créateur : fig2dev Version 3.1 Patchlevel 2 Date de créatio Tue Dec 1 14:22:46 1998 Nombre d 0 C1 : energy C2 : complete C3 : good	Marianne Ce graphisme de format Encapsulated Postcript (EPS) ne comprenc L'impression sera bonne sur une imprimante Postscript. Nom du fichiM-apres.eps Titre : M-apres.fig C1 : energy C2 : complete C3 : good

Dyad 4: *Augustin and Marianne*. Augustin attacked Marianne's solution, because he thought one should put only one transfer between the battery and the bulb. Since they did not agree on that rule, they came to another problem : the correct solution needs a second reservoir. They agreed on that necessity, and Augustin proposed an extension of its solution, with a second reservoir called "battery 2". Marianne agreed, and shifted to the conflict concerning labels : she did not agree with his label "travail" (work) and proposed "electrical wire". The conflict opposed two rules : the one written in the model (transfers are either work, heat or light), and the implicit one (chain item must match the objects of the physical experiment). They agreeed on the compromise "electrical work". Augustin asked her if she still agreed on the necessity of a second battery. She accepted, on the basis that those reservoirs should be different. In phase 4, Marianne drew the common solution as it was

discussed ; the explanation for the second battery recalls Augustin's argument. Augustin worked on the undebated label of the second battery, and managed to make his solution more coherent ; his explanations are quite different from the initial ones.

One may wonder why the students did not reach better solutions, especially why they did not manage to escape from the electrical circuit description level (the students often confuse energy with electrical current). All of the students recognised that the bulb gave light and heat, some mentioned it as an explanation in phases 1.2 or 4.2, or during the dialogue as an argument for the bulb being a transformer. One explanation for this phenomenon is that the description given to the students of their solution was restricted to the part of the chain between the battery and the bulb.

Another point concerns the winning arguments : arguments relating to formal rules of the model (implicit or explicit) always won over other arguments based either on physical observations or on electrical considerations. On one hand, this winning argument helped the students to avoid circular solutions and to try to find a second reservoir. On the other hand, promoting formal arguments prevented them from having the "obvious" physical consideration : energy was confused with electricity, heat and light were completely forgotten. To prevent this problem, we should improve their understanding of the task, with a better presentation of the "energy chains" model, insisting more on conceptual considerations, rather than on the formal ones. This should suffice to have more diverse initial solutions, as well as more conceptually-based arguments, that could counterbalance the weight of the formally-based ones.

4.3 From an experimental situation to a potential learning environment

The potential of this experimental situation as a learning environment is based on the three cognitive activities, carried out by learners at different stages of the experiment :

Students have to solve the problem of energy chains in two very different types of *knowledge representation* : graphical diagrams and natural language. In the first phase, they are expected to shift from one to the other, until they come to a stable solution (the system does the automated transcription). Each representation induces its own mode of reasoning [4, 13], and its side-effects. Although it is easier in this exercise to reach a solution graphically, this representation does not stimulate critical analysis (see screens 2a ans 2b). This is better achieved in natural language – and even more in a dialogue –, in which the focus can be more or less reduced. This is why the students are expected to discuss their solution in pure type-written communication channel, with no possible reference to a comman graphical representation of a chain.

The shift between the multiple representations of their own solution (ie. between screen 1 and screens 2a/2b) is intended to stimulate reflection and attitude formation. The choice of an attitude and the explanation to be given promotes critical activity : students are encouraged to distance themselves from their solutions, and to form coherent and explicit views with respect to them. When they are faced with an alternative point of view, they are thus ready to defend their solutions, to deepen the discussion, and to find a common agreement.

In argumentation dialogue, students face another point of view, that may be very different from their own. During this activity, they have to represent the other's solution for themselves (we saw some students drawing the chain on their screen with the finger) to evaluate the validity of what is claimed, and to defend their solution. Students manage quite well in this difficult task, specifically with formal arguments (maybe the most efficient, but also the easiest to find). Argumentation leads them to agree on more model-based and acceptable solutions, but it remains difficult to enable students to find the right arguments that could lead to them produce solutions that are based on deeper conceptual understanding.

5. Conclusions and perspectives

This paper presented an experimental situation for favouring spontaneous production of argumentative interactions between learners, in a CMC situation that is designed for modelling relations between those interactions and specific types of cognitive changes. We described an experimental study that has produced satisfactory qualitative results on a restricted group of learners : argumentative interactions were spontaneously produced that led to better understanding of the nature of the modelling task rather than better solutions and/or conceptual understanding An experiment on a wider group is planned for completing the validation of this protocol and for supporting our main research project : cognitive modelling of argumentation dialogue.

Success in the spontaneous production of argumentation dialogue depends essentially on the degree of commitment of students to their solutions, and on the conceptual distance between their points of view. In the corpus collected during the experiment presented in this paper, students' solutions were too similar, or too "classical", and very much constrained by the electrical model. Further experiments aim to get better argumentative dyads by giving students better information on the energy chain model, so that they understand that a quite different phenomenological description is expected. Hopefully more personal and more diverse solutions could be produced with better conceptual understanding on the part of students. One future aim is to improve the way the initial conflict is described and presented to dyads, for establishing the basic information and the common ground required for the discussion. More linguistic markers for argumentative opposition could easily be introduced. The instruction phrase may also be improved, to encourage students to have more complex argumentative discussions, if they are for example expected to investigate all the differences between their two solutions. We plan to collect a second corpus, using an improved version of the experimental situation and its attendant software, with a larger group of students, which would give subjects more chance of having a better opponent, and enable us to refine the test of the dyad constitution algorithm.

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