Designing computer-mediated epistemic interactions

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Abstract. Whilst certain types of interactions between learners are potential vehicles for conceptual change, favouring production of such interactions in computer-mediated communication situations remains a difficult problem. We describe the CONNECT task sequence and interface for collaborative text writing, whose design aims to promote epistemic interactions involving argumentation and explanation with respect to fundamental domain concepts. Our approach involves pairing students according to semantic distance between their individual texts, encouraging expression of opinions on ideas in those texts, giving appropriate instructions on discussions, and partly structuring interactions. Within an iterative design approach, we present the results of a study in which students were asked to collaboratively write texts across the net on the interpretation of a sound phenomenon in physics. The interactions produced contained a high amount of explanation and argumentation, although communication management remained problematic.

1. Introduction

It is now well attested that, under certain conditions, specific forms of communicative interactions between students can be vehicles of conceptual change (e.g., [1]). We hypothesise that, in order for conceptual change to occur during communicative interactions, students must attempt to ground meanings of terms relating to fundamental concepts in the domain of discourse [2], and they must render explicit their reasoning and critically examine its foundations (cf. the self-explanation effect [3]). Following Ohlsson [4], we term interactions in which these conditions are satisfied *epistemic interactions*. They characteristically involve argumentation and explanation (cf. [5], [6]).

Favouring the production of epistemic interactions, especially in Computer-Mediated Communication (CMC) situations, requires satisfying a complex set of conditions. Firstly, in order to provide a focus for epistemic interactions, the interface should display both the ideas under discussion and students' opinions with respect to them [7]. Secondly, the communication channel should minimise the degree of cognitive-interactional effort required for interaction and communication management [8]. Whilst CMC channels present potential obstacles to conceptual learning, they can also be deliberately structured in order to promote argumentation and explanation

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[9]. Thirdly, the topic of discussion must be sufficiently epistemically-laden and debatable [10]. In order to engage in argumentation dialogue, participants must have well-elaborated views, and clearly expressed and mutually recognised opposed attitudes with respect to the subject of debate [11].

However, these conditions can often be in direct conflict. For example, students are unlikely to adopt firm argumentative stances (pro, contra) with respect to knowledge that is under co-construction [12]. In addition, when collaborating at a distance, there is sometimes a reduction in students' domain-related interaction as compared to side-by-side situations [13]. Achieving a specific balance between these conditions is therefore a very delicate matter. Our present work aims to explore the space of combinations of conditions for a specific class of tasks (collaborative writing of interpretations of physical phenomena) and to study the interactions of students working in such conditions.

We propose an integrated approach to addressing these problems within the framework of the design of a Computer-Supported Collaborative Learning (CSCL) environment for the Confrontation, Negotiation and Construction of Text (CONNECT) used at a distance. Our approach involves pairing students according to semantic distance between their individual texts, encouraging expression of opinions towards the ideas in those texts (thus interweaving task and communication functions), giving appropriate instructions on discussions, and partly structuring the interactions. After presenting the design of the CONNECT task sequence and interface, we present the results of a study involving dyads using CONNECT to discuss and write texts on the interpretation of sound. Finally, we discuss the potential of our approach for favouring epistemic interactions and mention lines of future research.

2. Designing for epistemic interactions: The CONNECT task sequence and interface

We stress the embedding of technology in a teaching-learning situation for favouring epistemic discussions. The specific CONNECT task sequence comprises of seven phases:

Phase 1: Individual interpretation and text writing. Students are given some domain information and subsequently write an individual text on their interpretation of a new problem situation in that domain. The aim of this phase is to allow initial elaboration of students' individual conceptions, arguments and opinions.

Phase 2: Dyad constitution. Students are paired using a technique that maximises semantic differences between individual texts (see section 3 below). Clearly, the aim of this phase is to create a sufficiently wide space of debate and opposed points of view, the verbal confrontation of which can lead to explanation and argumentation.

Phase 3: Expressing opinions. This phase involves using the CONNECT interface (programmed in HyperCard™). The students of each dyad are linked together through the network with screen sharing using Timbuktu Pro™ as a distance technology. Zones for communication and for doing the task each occupy approximately half of the screen (Figure 1). The task interface displays the individual texts segmented into semantically distinct statements. Students are asked to mark their opinions with respect to each sentence of their own and their partner's text using the menu buttons on the bottom left of the screen (*Yes*, I agree; *No*, I don't agree; or *?*, I don't understand or I don't have an opinion). This is specifically the way in which dialogue and task functions are interwoven, since expression of attitudes, usually performed by communicative acts, is integrated into the task interface.

The communication interface is a combination of a dedicated button interface and a chat box free text interface [9]. Here, we restricted the pre-defined buttons to communicative acts required for interaction management: *Yes*, *No*, *OK?*, *I don't agree*, *I'll do it*, *You do it*, *Hello?*, and *Are we done?* Clicking on a button makes its label appear in the dialogue history. Clicking on the balloon makes the chat box for typing a message appear. A dialogue history appears in the middle of the

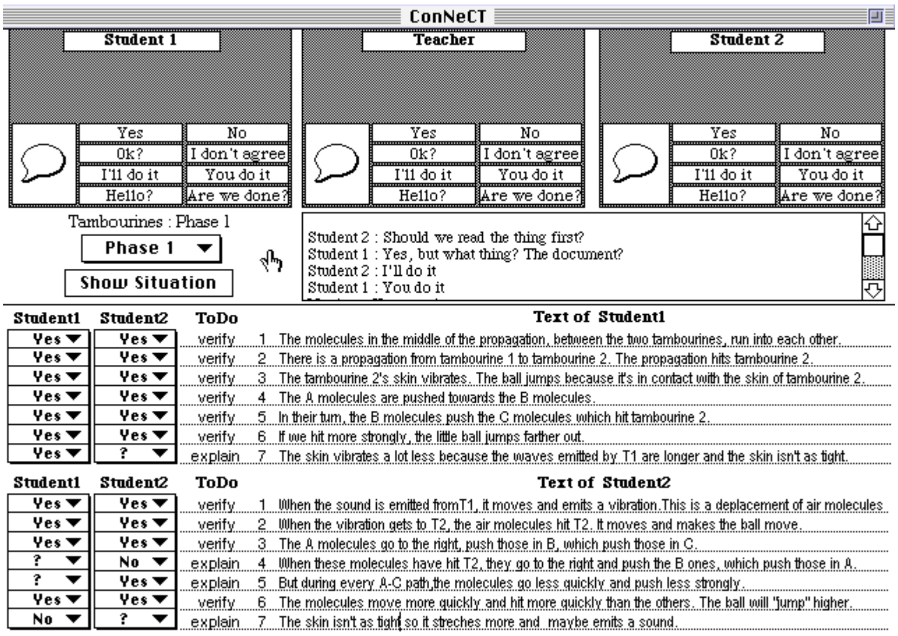

Figure 1. The CONNECT interface for marking opinions and discussing individual texts

screen, and scrollbars allow students to look back at their own dialogue. The aim of phase 3 is both to encourage the students to focus on the content of the texts and to stimulate the formation of positions for subsequent discussion. The rationale of the communication interface is to facilitate interaction management whilst allowing free textual expression of task-related interaction.

Phase 4: Discussion. This phase uses the same interface as above. Depending on the combination of opinions with respect to each sentence, one of four instructions appears next to it. The instruction *Verify* (Yes-Yes, No-No; expected dialogue type: checking) encourages students to check whether they have the same understanding. The instruction *Discuss* (Yes-No; expected dialogue type: argumentation) prompts the students to discuss and try to come to an agreement. The instruction *Explain* (Yes-?, No-?, expected dialogue type: explanation) suggests that one of the students explains the sentence to the other. Finally, the instruction *To be seen* appears when both students don't know or don't have an opinion, and suggests that students try to see what is meant by the sentence. The students are told to follow the instructions next to each sentence preferably starting with the sentences marked *Discuss.* It is stated that in such a complex topic, there is no right or wrong answer, but that any opinion contributes to the discussion. In the course of discussion, students are allowed to change their opinion markings in order to reflect their changing of opinion. The aim of this phase is to focus students' attention on the differences that exist between their individual interpretations and to give guidance as to what type of discussion is appropriate given these differences.

Phase 5: Collaborative text writing. Students are asked to write a common text on the basis of their previous discussion. The communication interface for this phase is identical to the one

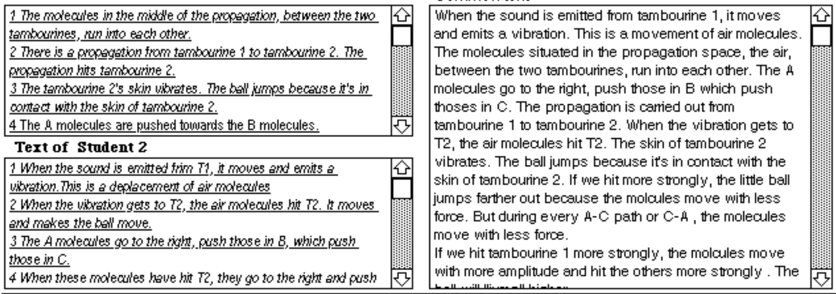

Figure 2. The CONNECT task interface for collaborative text writing (translated from French)

described above. The task interface provides a space for editing this common text and spaces showing all the original (individual) sentences in two boxes (see Figure 2). Clicking on an agreed (underlined) or a non-agreed sentence causes it to be copied into the text editing space (and turn into Italics). The text editing space allows a number of operations such as adding, changing, and deleting text. The main objectives of this phase are to materialise students' mutual understanding of the problem in the form of a common text and to allow discussion of any unresolved issues, misunderstandings, and conflicting interpretations. In addition, prior knowledge of the requirements of this phase gives the students all the more reason for discussing their individual texts in phase 4.

Phase 6 and 7: Teacher study of student interactions and tutoring session. In phase 6, a teacher studies the trace of a dyad's interactions in order to prepare for a tutoring session. Phase 7 involves a tutoring session in which the teacher and two students all communicate at a distance. Although not further discussed in this paper, the rationale of these phases [14] is important for the sequence as a whole. Firstly, the fact that the students know that they will interact with a teacher means that more is at stake in their discussion; and secondly, students most likely will not be able to resolve all conflicts without outside help.

3. Students' use of CONNECT to discuss the topic of sound in physics

The main reason for choosing sound lies in the diversity of student conceptions and linguistic meanings regarding this topic providing opportunities for epistemic interactions. Students were shown a video [15] describing a particular model of sound that explains sound propagation using a microscopic representation (propagation, perturbation, and vibration of gas molecules). They were then asked to use the model to interpret a new situation (see Figure 3). The question concerning movement of A, B, and C molecules forces students to give a more precise microscopic interpretation.

On the basis of previous research on students' conceptions of sound [16, 17], we developed initial hypotheses on students' conceptions of the situation in Figure 3, as follows: a) initial model, all molecules (A,B,C) move from left to right, from tambourine 1 to tambourine 2; b) synthetic model, A molecules hit B molecules, hit C molecules, which hit tambourine 2 (domino effect); c)

There are two identical tambourines. We delicately put a little ball hanging from a string in contact with the skin of the second tambourine. When hitting tambourine 1 with a stick, it emits a sound. Directly after, the little ball in contact with tambourine 2 starts bouncing. Using your knowledge and the knowledge of the video, explain what happens in the air so that the little ball in contact with the second tambourine starts to bounce.

What happens to the molecules near tambourine 1, the molecules in between the two tambourines, and the molecules near tambourine 2 (A, B, and C in the figure)? What changes in the behaviour of the little ball when tambourine is hit harder with the stick? Using two tambourines with a lower sound having a skin that is much less tight, what changes in the behaviour of the skin of the second tambourine when hitting the first?

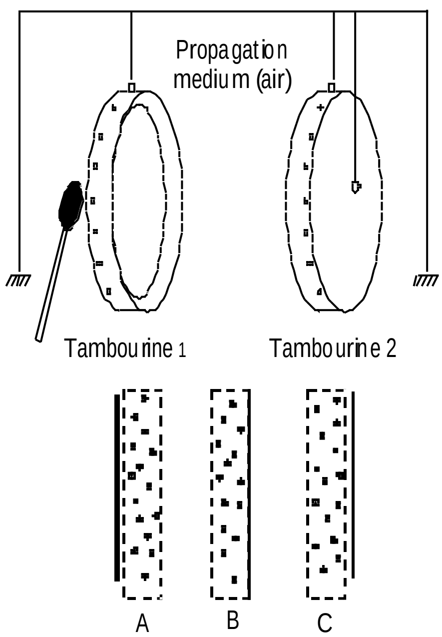

Figure 3. The two-tambourine situation that the students were asked to interpret

extended synthetic model, as b), with a specification of what happens after impact with tambourine 2, e.g. that the same process takes place in opposite direction. The main difference between a) and b) is that in a), students conceive of sound as a travelling entity, whereas in b), a more abstract property, such as a vibration is propagated. In c), by contrast with b), the students provide more general descriptions that go beyond what happens to tambourine 2.

The study was carried out with students of a class at the high school level, who had not yet had a course on sound as part of their normal curriculum (age 16-17). 15 students of this class volunteered to participate in the study. Phase 1 took place in their classroom. Students also wrote a small text on the topic of censorship on television that served as a practice text for learning to use CONNECT. In phase 2, the texts were analysed in order to form seven dyads out of the 15 students (105 possible pairs of two students, more than two million ways of creating seven pairs). The aim was to create a homogeneous set of dyads with maximum (but comparable across dyads) semantic differences between the texts. The texts were jointly rated by three researchers on seven aspects related to different descriptions of sound phenomena. For example, describing the situation in terms of movement of molecules was taken as one sign of model a), whereas using the term propagation was taken as a sign of a more elaborated model. A matrix was calculated with the cumulated differences between student texts. The student with the lowest maximum distance (9 points) with the remaining 14 students was excluded. Starting with the second lowest maximum distance (13 points), seven student pairs could be formed (26 out of the 105 possible pairs showed a distance equal to or higher than 13). The distances of the selected pairs were 13 (four pairs), 14 (one pair), and 15 points (two pairs). In addition to maximum distance between the wording of the student texts, the chosen student pairs differed regarding the main source of potential disagreement between students, i.e. their basic models. Six of the seven dyads came into the laboratory for a practice session with CONNECT and carried out phases 3 through 7. All dialogue and task actions were written automatically to a logfile.

4. Main results

We present two main types of results: quantitative (opinion pairs expressed using CONNECT, types of dialogue produced) and qualitative characteristics of the interactions.

4.1 Quantitative analysis

As a result of phase 2, all dyads consisted of students with different conceptions of the two-tambourine situation. Phase 3 then allowed the students to express their opinions on their own and their partner's texts. Table 1 shows the six dyads with the different combinations of initial, synthetic and extended models as well as the opinions marked by the students. The table shows that the students overtly disagreed in very few cases (4% of sentences, $N_{\text{Yes-No}} = 3$). Rather, students more frequently called into question their partner's text (23% of sentences, $N_{\text{Yes-?}} = 19$). In fact, the students actually agreed on 70% of all sentences ($N_{\text{Yes-Yes}} = 58$ and $N_{\text{No-No}} = 1$).

These results show a tendency to agree or to ask for clarification, rather than to overtly disagree with the partner. Table 1 also shows the common model as expressed in the text written in phase 5. A shift to the more evolved model was observed in four of the six dyads, whereas two dyads adhered to the more simple initial model in their common text.

Table 1. Individual and common models, and opinion pair types for each dyad

Dyad	Individual model	Opinion pair type: Verify Y-Y	Verify N-N	Explain Y-?	Explain ?-Y	Explain N-?	Explain ?-N	Discuss Y-N	To be seen ?-?	Common model
1 Brenda	Initial	6		1						Initial
Mary	Extended	5		2						
2 Ellen	Initial	5		2						Initial
Carol	Synthetic	3		4						
3 Ann	Initial	4	1					2		Synthetic
Franck	Synthetic	6		1						
4 Daphne	Initial	2		5						Synthetic
Lydia	Synthetic	4		2					1	
5 Andy	Synthetic	7								Extended
Jerry	Extended	6						1		
6 Claud	Synthetic	6		1						Extended
Martin	Extended	4		1		1	1			

The principal goal of our analysis of the corpus was to determine the amount and the type of epistemic interactions as a function of the overall design of CONNECT. We distinguished four main categories: Explanation, Argumentation, Problem resolution and Management. Explanation involved attempting to give one's partner a clearer understanding of the meaning of a concept or why an event happened, as well as expressions of (non) understanding. Statements were categorised as argumentation only if a clear disagreement could be identified either in the opinion marks on the interface (Yes-No) or in the dialogue itself, and if at least one attack and one defence of a thesis could be identified. Proposing or evaluating a solution element, e.g., a sentence in the common text, fell into the problem resolution category. The management category contained units dealing with the co-ordination of the interaction and of the task, as well as social or off-task units. The three authors jointly analysed the whole corpus (a total of 492 decisions in six dialogues).

The type of dialogue produced is shown in Table 2 for both opinion marking and discussion phases (3 and 4) and the collaborative writing phase (5). The amount of explanation and argumentation in phases 3 and 4 is high, 33% and 23% respectively. As a comparison, in most CMC collaborative problem-solving situations, the level of epistemic interactions is generally low, for example less than 10% in our own previous research on a task involving graphical construction of a solution to a problem in learning physics [9]. Even when taking into account that discussion was the main task in phase 3 and 4, the cumulated amount of explanation and argumentation (56%) is higher than we expected *a priori* (35%, binomial (221; .35), $p < .001$). Phases 3 and 4 of the task sequence itself did not involve problem solving, and the type of dialogue observed reflected this (3% of the interaction). Phase 5 contained relatively little explanation (2%) and argumentation (6%). This means that most conflicts seem to have been resolved in phases 3 and 4, but some issues nevertheless still come up in phase 5 when agreement on a common text was required. As can be expected, this phase contains a considerable amount of interaction concerned with problem solving, i.e. proposing and evaluating the common text (42%).

A closer inspection of the management category, the most important category, shows that the larger portion concerned co-ordinating the interaction rather than the task in both phases (Table 3).

Table 2 Type of dialogue for each phase (mean frequency and percentage)

Type	Phases 3 & 4 f	Phases 3 & 4 %	Phase 5 f	Phase 5 %
Explanation	12.2	33	0.8	2
Argumentation	7.0	23	2.3	6
Problem resolution	1.5	3	19.3	42
Management	16.2	41	22.7	50

Type	Phases 3 & 4 f	Phases 3 & 4 %	Phase 5 f	Phase 5 %
Management				
Interaction	10.2	63	17.3	76
Task	5.0	31	4.7	21
Off-task	1.0	6	.7	3

Tasks that involve construction of some solution demand more interaction management due to the turn-taking not only between partners dialoguing, but also due to alternation of task and dialogue turns (I speak, you speak, I act, you act). Our results show that computer-mediated dialogue, even when focussing on specifically discussion, still demands considerable amounts of interaction management.

4.2 Qualitative analysis.

We briefly mention three phenomena that illustrate possible mechanisms relating epistemic interactions to conceptual change.

Missed opportunities for confronting and elaborating mental models. Even when opportunities for confronting and discussing different conceptions present themselves, students do not necessarily take them up [6]. For example, in one dyad a conflict between an initial and a synthetic model was mutually recognised by the students, but this was avoided by a superficial concession (on the 'linguistic surface') that revealed no evidence of change of conceptions.

Learning needs revealed, understanding what you do not understand. Part of gaining understanding is, arguably, beginning to realise what you do not understand, or when your understanding is inadequate. In one dyad, as a result of an inconclusive discussion, the students recognised that neither of their views was very clear or convincing and that they would have to ask their teacher for extra information.

Conceptual differentiation. Argumentation dialogues between students are sometimes driven by the attempt to differentiate concepts from each other [18]. In one dyad the discussion turned on the differentiation of the notions of "movement" and "vibration" of the tambourine's skin. This reveals an important mechanism by which argumentation dialogue, and thus epistemic interactions, can lead to conceptual change: conflicts are 'dissolved' by operations on underlying concepts, rather than 'resolved' in a dialogical sense (see [5]).

4. Discussion, conclusions and further research

The design and study of CONNECT has enabled us to explore part of the space of complex conditions required for production of computer-mediated epistemic interactions in relation to conceptual change. Despite a marked preference for agreement and avoidance of overt domain-related conflict, the students' discussions were epistemic to an extent that surpassed our expectations, notwithstanding the high degree of effort required for computer-mediated interaction management. Moreover, our qualitative analysis revealed ways in which epistemic interactions could and could not relate to conceptual change.

Two main issues emerge from this work: students' marked preference for agreement and avoidance of disagreement; and the high degree of cognitive-interaction effort required for management. Whilst the two issues are related, managing CMC leaves less opportunities for emergence of epistemic interactions, there are clearly inherent difficulties in the production of argumentative and explanatory interactions by students in situations designed for conceptual change. These difficulties concern the dynamic nature of students' knowledge and understanding, and the social dimensions of interaction, i.e. friendship relations may inhibit free expression of disagreement.

Our further work on CONNECT will concentrate on addressing the difficult problem of facilitating interaction management, on improving students' mutual awareness and understanding of socio-cognitive conflicts, on improving their understanding and competence with respect to epistemic interactions, and on supporting production of such interactions within a human-computer co-operation involving teachers.

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