Teachers' collaborative interpretations of students' computer-mediated collaborative problem-solving interactions

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Abstract. Although teachers need to draw on knowledge of students' knowledge in order to engage in a wide range of educational activities, relatively little research has been carried out on what types of student knowledge teachers attempt to acquire, and how they acquire it. We propose an analytical model of teachers' cognitive-interactional activities within an experimental reflective teaching situation. This situation employs a new research method that we term "collaborative interpretation", during which teachers study and discuss a computer generated interaction trace of a dyad's computer-mediated problem solving with a view to engaging the dyad in a pedagogical interaction. Our model of the teachers' activity is based on viewing it as a complex explanation process, involving reconstruction of the students' activity, identification and evaluation of what is to be explained, and collaborative elaboration of all aspects of the explanation process itself. Our long-term research goal is to design innovative computer supported collaborative training techniques for physics teachers that provide different dynamic presentations of students' collaborative problem solving in order to facilitate teachers' understanding.

1. Introduction

In order to carry out educational activities successfully, teachers need to draw on a wide variety of knowledge, such as knowledge of students' knowledge, the curriculum, teaching methods, classroom organization, educational goals, and subject matter [1]. Here we focus on the nature of *teachers' knowledge of students' knowledge* and on understanding how teachers acquire it in a form that is appropriate to the specific activity in which they are engaged. As De Corte, Verschaffel, & Schrooten [2] have pointed out, there is a lack of research concerning teachers' knowledge of what students know. Research that sheds light on such a question could be useful for facilitating educational activities such as error diagnosis [3], explanation [4] lesson planning, as well as some forms of adaptive tutoring [5]. Our main research goal is to understand the activities in which teachers engage when they attempt to interpret students' problem solving activity, with a view to engaging the students in a pedagogical interaction.

We describe an exploratory study in the context of use of a Computer Supported Collaborative Learning environment "CHENE" [6] the aim of which is to develop an analytical model of teachers' cognitive activities in a specific experimental reflective teaching situation. Three physics teachers were asked to collaborate in interpreting three computer generated interaction traces of dyadic problem solving, with a view to subsequently helping

the dyads review their problem solving. The design of this situation was inspired by a two-tiered version of the constructive interaction method [7] [8]. Firstly, student dyads discuss together so that their problem-solving processes and underlying knowledge could potentially be accessible to teachers and secondly, teachers discuss these dyads' problem solving and discussion so that the *teachers'* cognitive activities could potentially be available to researchers. Our general aim was to determine to what extent the discussion between the teachers would enable us to study the processes by which they analyzed the students' activity. Such a situation permits us to construct a virtual world in which the pace of students' problem solving action is slowed down thus allowing teachers time to reflect [9] and *learn* about the way that students think. Our research is analogous to work carried out within the "vicarious learning project" [10] which aims to study how students (rather than teachers) can learn from studying or observing educational dialogues.

We propose that the teachers' activity can be modeled as a complex explanation process, involving reconstruction of the students' activity, identification and evaluation of what is to be explained, and collaborative elaboration of all aspects of the explanation process itself. This study constitutes a first stage of a longer-term research project directed towards the design of innovative computer supported collaborative training techniques for physics teachers based on providing different dynamic presentations of students' collaborative problem solving in order to facilitate teachers' understanding.

2.   Research background

Our main research questions concern the nature of the knowledge that teachers possess and acquire of students in specific educational situations, and the processes by which they obtain it. Existing research has naturally concentrated on understanding teachers' *practice* (in the sense of "praxis", action) in standard classroom situations [11] [12] [13]. Authors differ in terms of general theoretical approaches to studying teachers' knowledge, but do not specifically focus on what teachers know about students' knowledge.

The MIT Teacher Project [9] however, showed the potential benefit of focusing on teachers' views of students' problem solving. Viewing a video of the details of a problem solving interaction between students could elucidate students' puzzling behavior and even make teachers *change their minds* about students' knowledge.

The experimental situation within which our research questions arise shares similarities with such video-clubs whilst differing in several respects from classroom situations.

- Firstly, it is unusual for teachers to have access to students' problem solving processes, especially their dialogue, in the form of a computer generated interaction trace.
- Secondly, teachers have time to reflect on the students' activity, offline.
- Thirdly, the situation we are studying is integrated into a novel situation involving computer-mediated communication, used for the students' own work and for teachers' interactions with them.
- Fourthly, teachers are explaining students' problem solving to other teachers, their peers.

In spite of the differences with the classroom, teachers are nevertheless participating in a cognitive activity in preparation for a form of teaching, an activity specifically designed for gaining knowledge about students' knowledge. We aim to understand the way that teachers bring to bear their professional practice on this new situation, and the extent to which they are able and willing to adapt it to new needs. The following are examples of general questions to which we sought initial answers in this exploratory study:

- Would the teachers only concentrate on correcting the students' final solution, or would they extract useful information from the study of the problem solving process itself? To what extent?
- Would the teachers only be concerned with correcting errors, or also with conceptual understanding?
- Would they be concerned only with students' domain understanding or also with their collaboration?

In the rest of the paper we describe an exploratory empirical study designed to address these general questions, as well as our specific questions concerning teachers' knowledge of students.

3.   Empirical Study

3.1.   Research approach

Our approach to analyzing teachers' cognitive activities in our specific reflective experimental situation comprised two related aspects. Firstly, we developed a set of analysis categories that took into account all teachers' utterances in phase 2 of our experimental situation, involving collaborative interpretation (cf. § 3.3). This was accomplished by hypothesizing possible categories based on a rational task analysis (i.e. of the teachers' task) and previous research results, and then by refining these categories in confrontation with the data (cf. § 3.4). Secondly, we defined an analytical model that described the *relations* between the activities corresponding to the categories — i.e., the manner in which the teachers' cognitive activities progressed throughout their interaction— on the basis of both the analysis and a specific theory of *explanation*. In particular, the model led to redefining new aspects of the teachers' explanation process (cf. § 5).

3.2.   Students' problem solving task

The students' task was to draw an energy chain that represented a battery connected by two wires to a lighted bulb. Each student had a handout describing elements of the energy model [14]. The task was a *modeling* problem and involved establishing relations (see Figure 4) between objects and events (e.g. battery, bulb, electricity), to concepts of the energy model and theory (reservoirs, transformers and transfers of energy).

3.3.   Phases of the study

Three physics teachers and six students (16-17 yrs.) following a scientific curriculum participated in our laboratory study. Our three-phase experiment (see Figure 1) was designed around a teaching sequence on modeling energy in physics [14]. In phase 1, two students worked together for 30 minutes with C-CHENE [6] to exchange typewritten messages at a distance across the Internet and to construct their energy chain.

In phase 2, the energy chains produced by the three collaborating pairs of students, together with their *interaction traces* leading up to them, were printed out and given to the physics teachers. Interaction traces are automatically recorded sequences of time-stamped graphical problem-solving actions and exchanges of typewritten messages. Students were
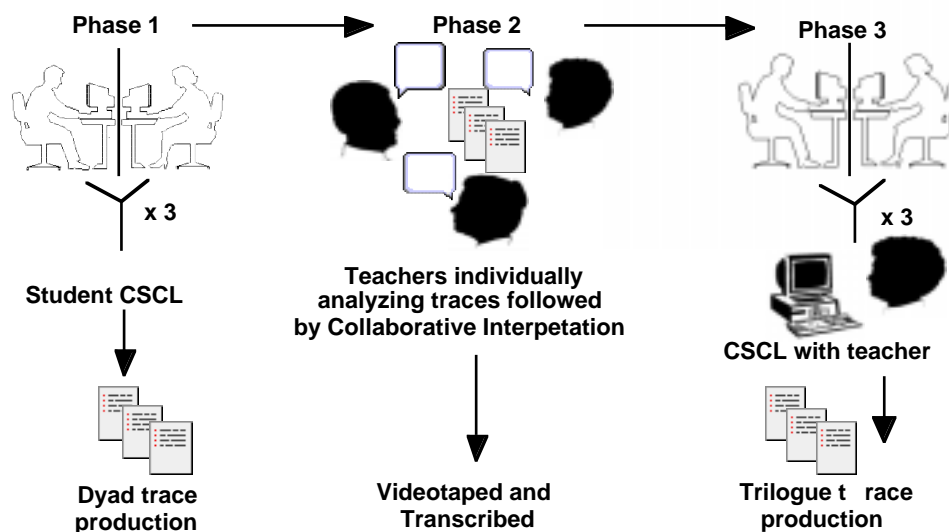

Figure 1. Three dyads problem solving in phase 1, three teachers each analyzing a dyad and then discussing in phase 2 and each teacher going on line with the dyad she analyzed in phase 3.

aware that their exchanges were to be read by the teachers. Previously, the three teachers had practiced analyzing an interaction trace (example in Figure 2). The teachers were asked to perform three analysis activities on paper with a view to working with Prof-CHENE (C-CHENE with a communication space for the teacher) to help their student dyad in phase 3:

1. Note the elements (both dialogical and graphical) in the interaction trace you believe are pertinent in the energy chain your dyad created;
2. For the elements that you marked as pertinent, in your opinion, what are the reasons the students did or said what they did? and
3. Think about how you could use the information gained in 1) and 2) to help your dyad in phase 3.

The teachers analyzed their interaction traces individually for about 20 minutes. Then, each teacher was asked to present the analysis of her dyad to her colleagues. This discussion lasted 45 minutes and was videotaped. The data presented in this paper is this transcribed discussion; its analysis reflects a total of 364 decisions. In the final phase, each of the teachers went on-line with their dyad, everyone on his/her own computer. Each of the three student-student-teacher triads had the student dyad's final energy chain on the screen. They exchanged messages concerning the students' work on the energy chain for 40 minutes.

> [2] [DIALOGUE] [173 s] [Charlie: we can represent the battery by three reservoirs]
> [3] [DIALOGUE] [238 s] [Jon: I'm going to create a reservoir named battery, ok, you do it, ok?]
> [4] [GRAPHIC] [267 s] [reservoir created reservoir 1]
> [5] [DIALOGUE] [377 s] [Jon: how do you want to name the transfers between the different reservoirs of the battery? I think it might be better to just do one reservoir]

Figure 2. Extract from an interaction trace using C-CHENE (translated from original French)

3.4. Corpus collected and analysis approach

A systematic analysis of the teachers' utterances during their collaborative interpretation was carried out, using the set of categories shown in Figure 3. The teacher trilogue was divided into utterances according to the smallest meaningful segment for the given context. For example, a single speaking turn might contain 3 different utterances (see turn 314 in Table 4). Utterances can be multi-functional, eg. both evaluation and identification, although a decision was made to assign each to a dominant category. Brief definitions follow.

- Reconstruction is the process of forming a mental model of the dynamics of the students' problem solving activity by using the interaction trace. This means recognizing the evolution of the energy chain the students built as well as what they said about it and potentially what they thought about it.
- Identification is singling out a graphical or dialogue trace element for explanation. This happens when the interaction trace element satisfies one or more of a set of triggering conditions for explanation (cf. § 5).
- Explanation is the process of generating an answer to an explanation-seeking why-sentence for a phenomenon, event or fact be explained (cf. § 5).
- Evaluation refers to judgmental (either positive or negative) statements concerning student activity
- Projected remediation is what teachers will ask or have do the students during phase 3.
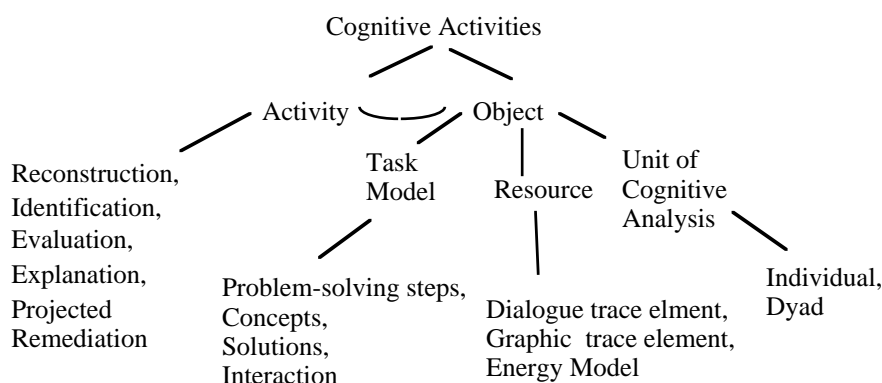

Figure 3. Analysis categories for teachers' cognitive activities.

Each cognitive activity carried out by a teacher is done so in relation to an *object*. An object has three components: a task model, a resource, and a unit of cognitive analysis. The task model is defined by the problem solving steps, concepts, solutions and interactions between the students concerning the modeling of energy. Resources used by the teacher while performing a cognitive activity are either what the students typed to each other (dialogue trace element), the parts of the energy chain they drew (graphic trace element) or the students' energy model handout. Finally, the teacher instigates a cognitive process in relation to either the individual or dyad (i.e. the teachers' "unit of cognitive analysis").

4. Results

4.1 Quantitative

We present quantitative results according to our analysis categories, taking the group of three teachers as a single cognitive unit of analysis. The first aspect that we were interested in was the extent to which the teachers would attempt to *reconstruct* the students' activity and exploit it to its full pedagogical potential. In fact, teachers only attempted to reconstruct about half of the interaction trace elements, whether they were dialogue or graphical actions. (see Table 1).

Table 1. Elements of interaction traces that the teachers attempted to reconstruct

	Trace elements		Graphic elements		Dialogue elements	
	Total N	N reconstructed	Total N	N reconstructed	Total N	N reconstructed
Totals	204	**109**	130	**75**	74	**34**

The second aspect concerns what the cognitive activities teachers engaged in were in relation to, e.g. explanation of concepts or of problem solving steps? Table 2 shows that most of the teachers' utterances concerned reconstruction focussing on students' problem solving. However, 36 % of identifications were in relation to problem solving steps while 56 % were in relation to conceptions. Most strikingly, 20% of explanations were in relation to problem solving steps while 76 % were concerned with conceptions.

Table 2. Relation of cognitive activities to task model elements

	Reconstruction	Identification	Evaluation	Explanation	Proj. Remed.
PS steps	94	16	18	13	6
Conceptions	12	25	18	50	16
Interaction	3	1	1	1	0
Solution	0	2	0	2	1

Finally, we were interested in the possible *patterns* and (co)-elaboration in teachers' cognitive activities (see Table 3). For the present, our results concern only consecutive pairs of activities.

Table 3. Table of relations between consecutive pairs of activities

1st ↓ 2nd →	*Reconstruction*	*Identification*	*Evaluation*	*Explanation*	*Proj. Remed.*
Reconstruction	53	12	15	16	1
Identification	9	5	3	12	2
Evaluation	12	3	4	3	3
Explanation	13	14	4	20	0
Projected Remediation	1	1	3	1	10

Reconstruction appeared to be the most (co-)elaborated activity (53), for consecutive pairs, followed by explanation (20), then projected remediation (10). Excluding (co)-elaboration of itself, reconstruction was mostly followed by explanation (16), evaluation (15) and identification (12). Excluding (co)-elaboration of itself, explanation was mostly followed by

identification (14), and reconstruction (13). Identification was mostly followed by explanation (12). Evaluation was mostly followed by reconstruction (12).

4.2. *Qualitative: an example from the teachers' discussion*

Table 4 shows an extract from the teachers' discussion where the subject is the first energy transfer arrow that the students have labeled "electricity" (see Figure 4).
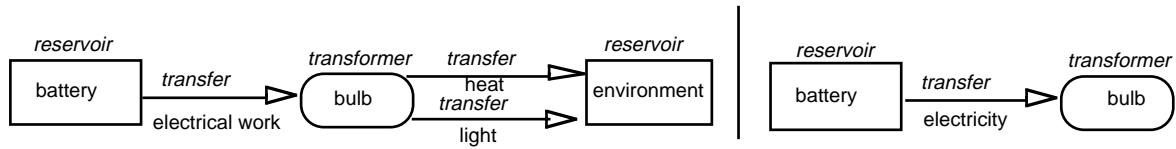

Figure 4. Correct energy chain (left) and student energy chain (right) for the battery-bulb problem

The extract begins (312) with T3 reconstructing the students' problem solving from the following graphic element in the interaction trace: [29][GRAPHIC][link 1 from the battery to the bulb has been called: electricity]. Interestingly, the teachers' unit of cognitive analysis here is the *dyad* rather than the individual student (use of "they"). In 313, T1 identifies what is to be explained: why did the students name the transfer "electricity"? Explanation is 'triggered' by the teachers because they believe that the students' thinking behind the term "electricity" is unclear. Do the students think that if there is a global displacement of energy, there is a global displacement of electrons (misconception)? Or do they realize that there is no global displacement, just local displacement that produces electrical work? The teachers' discussion is not conclusive and one suggests that T3 evoke this potential confusion in phase 3, when each teacher reviews the problem solving of her dyad with the dyad on-line. It is clear in this case, and throughout the rest of the extract, that the teachers are addressing the students' conceptions. We note the alternation of explanation and reconstruction activities in the middle of the extract, followed by an incomplete proposal for remediation.

Table 4. Analysis of teachers' collaborative interpretation: phase 2

Turn	Discussion	Activity	Task Model	Resource	CAU
312aT3	And then they do an arrow, uhh, a transfer	Recon.	Prob. Sol.	Graphic	Dyad
312bT3	and this arrow then that goes from the battery to the bulb they call electricity, so in fact...				
313T1	Why is it electricity?	Ident.	Concept.		
314aT3	Yes, they have, yes, and then they haven't assimilated that it was by mode of transfer, by electrical work, I mean.	Expl.			
314bT3	So then, one of them says: "are you sure that there's a displacement of electrons?"	Recon.		Dialogue	Indiv.
314cT3	So, there is a confusion here, too.	Expl.			
315aT1	Yes, but you see, displacement of electrons...	Recon.			
315bT1	The idea of a transfer of work is present.	Expl.			
316T3	Yes, the idea is there				
317T2/3	the mode is work				
318aT1	Because here, it says that there is displacement of an object, or a part of an object, there is displacement of a charge			E. model	
319aT3	There is the electrical work of the current			Dialogue	
319bT3	Yes, yes				
320T2	We could still evoke...	Proj. Rem.			
321aT3	The idea is still underlying	Expl			

5.   Discussion: towards a model of the teachers' cognitive activity

Three main points arise from the results described above, in relation to our research questions. Firstly, teachers *do* partially reconstruct students' problem solving processes, as well as their degree of understanding of fundamental domain concepts, and do not solely focus on students' errors or on their final results. However, could teachers have better understood students' knowledge by reconstructing actions they missed or ignored? To what extent is reconstruction necessary for explanation seeking? Secondly, there was very little teacher activity concerning students' interaction or manner of collaborating. Thirdly, the processes of evaluating problem solving, identifying aspects to be explained, reconstructing what is to be explained, and elaborating explanations, seem to be complexly intertwined. As a means of modeling the teachers' activity, we propose that it can be viewed as a *explanation process* (see Figure 5). The model draws on our analysis categories, represents complex relations between them (cf. § 4) and defines new elements of the explanation process.
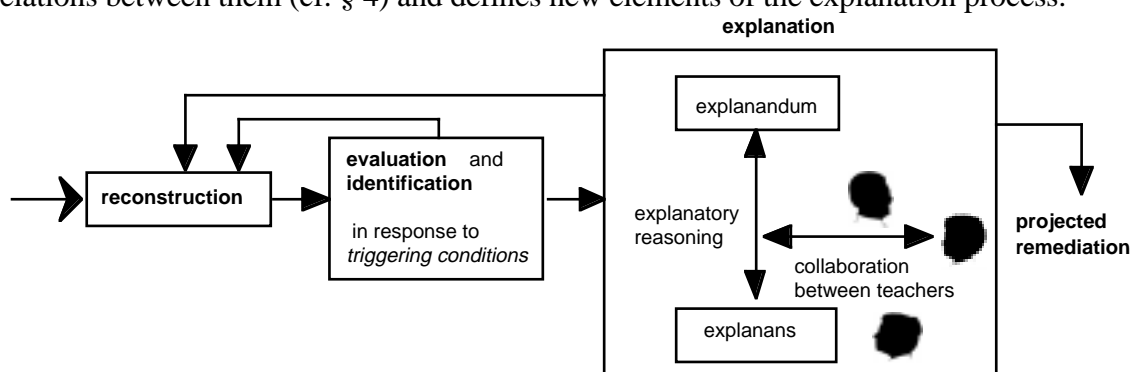
Figure 5. A proposed model for teachers' activity as an explanation process.

Teachers enter the explanation process with a *reconstruction* activity. Subsequently, some of the reconstructed elements of students' problem solving are *evaluated*, and/or lead to *identification* of an explanation need in response to *triggering conditions* [15]. These triggering conditions are related to the teachers' goal of participating in a future pedagogical activity with the students. Our corpus revealed triggering conditions such as surprise, contradiction within students' activities, mismatch with teachers' own previous knowledge, students' errors or correct steps, ambiguity of students' activities, evidence of students' hesitation or differences between students. Next, identifying a need for explanation leads to the interactive definition of an "explanandum" [16] — the entity that is to be explained. Explanation is described as the interactive *process* [17] of finding an "explanans" — the semiotic entity that explains — for an "explanandum". In our case, the explanandum corresponds to aspects of the students' problem solving, conceptual understanding, problem solving steps, the solution or interactions, while the explanans corresponds to an utterance or a sequence of collaborative interaction between teachers. The nature of the explanandum has to be reconstructed or elaborated; its relation with the explanans will usually be negotiated. The explanation process can thus be viewed as a specific type of *restricted* and *local student modeling* that involves collaboratively adjusting and matching *two* sets of representations (explanandum and the explanans). Finally, at variable intervals, teachers suggest projected remediation. When explanation is followed by identification or reconstruction, it signifies a modification of the explanandum or a passage onto new student problem solving elements.

Note that in Table 4, one teacher identifies an initial explanandum (the transfer 'electricity'), a second teacher makes a first attempt at explanation with the explanans (the students have not understood the concept of electrical work). The explanandum is refined ("What *do* the students think about displacement of charge?") by the next reconstruction: ("So then, one of them says: 'are you sure that there's a displacement of electrons?'"). This new explanandum produces conflicting explanans: ("So, here too there is a confusion" vs. "The idea of a transfer of work is present.") that are not completely conciliated.

6. Conclusions and Further Work

On the basis of our exploratory study, we can conclude that our experimental situation, involving collaborative interpretation, is a viable means for studying the knowledge that teachers possess and acquire of students' knowledge. Teachers' knowledge of students' knowledge seems to be locally determined by needs for explanation, in confrontation with their prior knowledge. In future work we therefore require a more adequate understanding of teachers' background knowledge. In the medium term, our analysis approach and model will be applied to a larger corpus of interactions between teachers. Finally, the need for presenting interaction traces to teachers in a form that facilitates their understanding is readily apparent from our research. Teachers need better access to both the dynamics of student problem solving and to its conceptual underpinnings. Obtaining such corpora requires both the use of problem solving tasks that encourage students to make their conceptual understanding explicit and new presentation techniques. Further research will focus on designing a situation using CMC that facilitates teachers' acquisition of students' knowledge. Our aim is to render teachers' models of students' more coherent and complete while emphasizing students' conceptual understanding.

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