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Collaborative learning tasks and the elaboration of conceptual knowledge

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Abstract

In this article we present the results of an experimental study of the influence of task characteristics on the characteristics of elaboration of conceptual knowledge in social interaction. With a pre-test and post-test we measured individual learning outcomes. We constructed a coding scheme that focuses on the communicative functions and propositional content of utterances and on elaborative episodes. The subjects were 40 students who worked in dyads on a collaborative task about electricity in one of four conditions. We compared a concept mapping task with a poster task and investigated the effect of a phase of individual preparation. The post-test scores were significantly higher than the pre-test scores. Individual preparation created better learning results and the asking of more questions. The concept mapping conditions showed more discussion of electricity concepts, collaboratively elaborated conflicts and reasoning, but no higher individual learning outcomes. In the concept mapping conditions, elaboration was related to individual learning outcomes.

1. Introduction

In the first part of this article we will discuss our theoretical framework, beginning by describing different theoretical perspectives on concept learning within the domain of physics. Next, we report the results of previous research on relationships between social interaction and concept learning. Finally, we focus on the role of the collaborative learning task in eliciting the potential benefits of social interaction. In the second part of the article we describe the design and collaborative learning tasks of our study and we present the coding scheme with which we analysed the elabor-

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ation of conceptual knowledge in student interaction. Finally, the results of these analyses will be presented and discussed.

2. Perspectives on concept learning

Researchers in the domain of science education frequently describe concept learning as a process of conceptual change: the transformation of naïve conceptions to more scientific conceptions. Students' understanding of concepts and phenomena is often not consistent with scientific understandings (Chi, Slotta & de Leeuw, 1994; Driver, Guesne & Tiberghien, 1985). For example, students' conceptions of electric current include the non-scientific notions of non-recursive current, clashing currents and current consumption (Osborne, 1983). Strike and Posner (1982) described conceptual change as a replacement of old ideas by new ones. This idea is currently considered too simple by various researchers (Schnotz & Preuß, 1997; Caravita & Halldén, 1994; Chinn & Brewer, 1993; Vosniadou, 1994). They describe concept learning as a process of enrichment, organisation, reorganisation and refinement of knowledge, and as the development of the ability to use scientific concepts and ways of thinking when appropriate. Because everyday contexts do not inform students about the underlying principles of phenomena, students need to reconstruct phenomena with scientific concepts and theories (Caravita & Halldén, 1994) and fragmented knowledge needs to be organised in a coherent structure (Di Sessa, 1993). Chinn and Brewer (1993) stress the importance of explicit comparison of preconceptions with new information, because students do not easily abandon or modify their naïve beliefs.

Until recent years, the learning of concepts was mostly viewed as the construction and transformation of individual knowledge that is represented in memory schemata or mental models. Recent perspectives emphasise the social and situated nature of knowledge. Within the socio-cultural perspective, concept learning is described as a process of transformation through participation in socio-cultural activities (Rogoff, 1998). Although the different perspectives have contradictory points of view on the epistemological level of describing the nature of knowledge and the process of concept learning, we agree with Schnotz and Preuß (1997) and with Salomon and Perkins (1998) that considering the different perspectives is more promising than disregarding one of them or merely contrasting them. In our own research, we view concept learning as the transformation of the way students use concepts that are embedded in theoretical frameworks. We suggest that the level of conceptual understanding is reflected in the way students participate in activities that require the use of the concepts. Students have to become able to use scientific concepts to describe, explain and manipulate phenomena in the domain of physics. From the domain-specific theories on concept learning, we draw the conclusion that activities like the explication of personal understanding of concepts and the (re)organisation of knowledge in particular can foster the desired transformations. We believe that participation in collaborative learning activities gives students the opportunity to engage in such activities. In the following section we will discuss some research into the relationships between concept learning and social interaction between peers.

3. Social interaction and concept learning

An important explanation of the positive results of collaborative learning may be the notion that social interaction stimulates elaboration of conceptual knowledge. In a collaborative learning situation, students will verbalise their understanding. Teasley (1995) found that dyads working on a microworld task generated more elaborative talk than students who worked individually and were asked to talk aloud. She found a significant positive correlation between the proportion of interpretive utterances and final hypothesis scores. She suggests that in talking to someone else, knowledge becomes more elaborate because communication implies that you want to be understood by the other, which results in more coherent explanations.

Various researchers have found relationships between elaborative talk and concept learning. Part of this research builds on studies conducted in a Piagetian framework and focuses on the role of conflict (Doise & Mugny, 1984). Brown and Palincsar (1989) explain the important role of conflict and controversy that appears in social interaction by the fact that it can generate explanations, justifications, reflection and a search for new information.

Others have paid more attention to the mutual support that students can give each other and built on the Vygotskian notion of scaffolding. Webb (1989, 1991) found a relationship between giving elaborated help and learning results. Elaborated help stimulates reorganisation, awareness of knowledge gaps and inconsistent reasoning, and results in more elaborated concepts because students create new relations by giving examples, using analogies, reformulating or refering to school or everyday experiences. King (1990) found that higher order questions in particular elicit elaborative answers.

Researchers that emphasise the co-construction of knowledge state that, in a collaborative learning situation, students negotiate meaning. This negotiation or grounding process is also focused on the meaning of concepts (Baker, Hansen, Joiner & Traum, 1999). To achieve agreement, it is often necessary to integrate different points of view. Roth and Roychoudhury (1992) tried to describe in detail how students co-construct a relation between two physics concepts (quantum and photon). They showed that students use verbal, pictorial and non-verbal mediation to understand each other and to reach agreement. During controversy, students referred to prior problems, previous experiences or to some authority (such as a textbook or the teacher). Changes in students' concepts of the physics relation were more likely to occur when the other participant resorted to longer explanations and justifications of their statement.

According to Mercer (1996), students co-construct understanding in both cumulative talk and exploratory talk. Cumulative talk is described as the accumulation and integration of ideas. In exploratory talk, students engage critically but constructively with each other's ideas. Exploratory talk is considered more valuable for learning because there is no automatic consensus (as with cumulative talk) or unproductive dispute (as with disputational talk), but rather, productive argument, questioning and exploration.

We conclude that collaborative learning has a potential to engage students in activities that are valuable in the process of concept learning: verbalisation of their understanding of the concepts, (collaborative) reasoning with scientific concepts, the asking and answering of questions, the elaboration of conflicts and the generation, comparison and evaluation of explanations. However, it is not guaranteed that such a high-quality discourse will always occur in a collaborative learning environment. Student talk can also be characterised by competition, asymmetrical participation and can be focused on finishing the task instead of understanding of the concepts. Kumpulainen (1996) and Bennett and Dunne (1991) found that the quality of students' talk was closely linked with the nature of the task. O'Donnell and Dansereau (1992) and Cohen (1994) state that task characteristics influence the type and amount of processing and will, consequently, affect the outcomes of collaborative learning. In the following section we consider important characteristics of collaborative learning tasks.

4. Collaborative learning tasks

Cohen (1994) and Salomon and Globerson (1989) suggest that, to stimulate conceptual understanding, a free exchange of ideas is needed. Because a task division can hinder such a conceptually oriented interaction, we preferred to work with collaborative peer-work groups. In contrast with co-operative learning groups, students in collaborative peer-work groups try to reach a common goal and share both tools and activities (Webb & Palincsar, 1996). Students are simultaneously involved in the execution of the same task and participants possess a comparable prior knowledge level (in contrast to peer tutoring). According to Cohen (1986), shared goals and tools can strengthen a positive student interdependence.

Collaborative learning tasks can differ from each other in the kind of product that is requested. Concrete products can facilitate interaction because students can use indexical devices such as the words 'this' and 'that', or gestures such as pointing to parts of the product (Roth & Roychoudhury, 1992). They provide a joint working space on which the results of thinking are visible. However, making a concrete product can also hinder a more conceptually oriented discourse. When many concrete actions are needed to construct a product, utterances related to these actions can dominate student talk at the cost of abstract talk (Bennett & Dunne, 1991). Furthermore, open tasks with answers not fully predetermined are believed to be more suitable for collaborative learning (Cohen, 1994).

5. Research questions and design of the study

We set up an experiment to explore the influence of some characteristics of collaborative learning tasks on the quality of student interaction and individual learning results.

We think it is valuable to use both the activities of the group and those of individual students as a unit of analysis. Damon (1991) states that from a developmental point of view it is important to know what individuals bring with them to the interactional setting and what they take away in a lasting sense from such settings. Like Salomon and Perkins (1998) we want to distinguish between effects *with* and effects *of* collaborative learning. The effects *with* are to be found in the process, while students are engaged in collaboration. In our case we focus on the elaboration of conceptual knowledge in student interaction. Effects *of* are the cognitive, social, metacognitive and affective residues of these activities, which affect learning and behaviour in new situations. We wanted to know how participation in the interaction changes the way students use the concepts in a task without the opportunity to interact with another student. Therefore we chose a pre-test/post-test design.

Our study aimed at answering the following questions:

1. Do the collaborative learning tasks that we use elicit elaborative activities during collaboration?
2. How do the characteristics of the collaborative learning tasks affect the occurrence of elaborative activities?
3. Is the amount of elaboration during collaboration related to individual learning outcomes?

6. Method

6.1. Experimental tasks

We decided to work with pairs of students because we expected that this form was most likely to result in an intensive student discourse. Collaboration in a larger group might encourage asymmetric participation or could lead to cognitive overload. We searched for collaborative learning tasks that could encourage elaborative talk and stimulate both students to participate. The task had to function as the start of a new course about electricity in the upper level of secondary school. We chose a concept mapping and a poster task for the following reasons. Concept mapping stimulates talk about meaningful relations between concepts (Roth & Roychoudhury 1992, 1994). A concept map is a network in which concepts are linked with lines that are labelled to specify the relationship between the concepts. Concept mapping, as it is normally used, primarily focuses on abstract relations. It does not focus on the way the concepts and the relations between them are used to describe and explain concrete phenomena or on how they can be represented in formulas, symbols and graphs. However, students are well known to have problems with both types of relations. We extended the concept mapping task by asking the students to map the symbols, formulas and graphs they associated with the concepts and relations, thus integrating multiple representations.

A poster task, on the other hand, we believed to have more potential to elicit talk about relations of concepts with concrete phenomena than a concept map. In the poster task the working of an electric torch had to be explained using given concepts such as current and resistance. As in the concept mapping task, the students were also asked to integrate multiple representations in their poster.

Because we wanted the students to talk about their own understanding of the concepts, we only gave them loose cards showing the concepts of electricity (to be glued down), paper (A2) and pencils.

We thought it might be useful to let the students prepare individually before starting the collaborative activities, because it had been some time since they had worked with the electricity concepts. Palincsar, Anderson and David (1993) used a similar sequence with a collaborative problem-solving task, but did not investigate the effect of it on student interaction. Half the students were to create a concept map and half were to create a poster. All were asked to prepare individually. Individual preparation for the tasks consisted of making a design for the concept map or poster. We expected that individual preparation would increase questioning (because the students would become aware of knowledge gaps or misunderstandings during individual preparation) and conflict (because the students would want to defend their design).

6.2. Subjects and design

The participants were 40 students from two physics classes in different schools, with an average age of 16. Within each class the students were randomly assigned to same-sex dyads, and within each class the same number of dyads was randomly assigned to one of the following four conditions: (1) concept map with individual preparation; (2) concept map without individual preparation; (3) poster with individual preparation, and (4) poster without individual preparation. Five dyads participated in each condition.

6.3. Procedure

Five weeks before students worked together in dyads, they took the pre-test (35 minutes), and one week before they received instructions about making a concept map and a poster. The experiment was carried out in a room in school under the guidance of the experimenter. The session lasted for a maximum of 45 minutes, depending on the time students needed to complete the task. In the conditions with individual preparation, students worked for 5 minutes on a design for the concept map or poster. In the remaining three conditions, dyads received 5 minutes extra to finish the task. We taped student interaction on video (with one of the 20 dyads the videotaping failed). The post-test (35 minutes) was administered in the next physics lesson.

6.4. Pre-test and post-test

Table 1 contains the description and the reliability (Cronbach’s alpha) for each of the three units of the pre-test and the post-test. The problem-solving unit was constructed to test the understanding of the relations between the concepts and the

Table 1
Items, reliability and Pearson Correlation Coefficient for the pre-test and post-test units (*n*=40)

Unit	Pre-test		Post-test		Correlation
	Items	Alpha	Items	Alpha	Pre-test/post-test
Problem-solving	6 mc-items: students have to account for each answer	0.32	6 mc-items: students have to account for each answer	0.20	0.52
Essay question	Explanation of the working of an electric torch	–	Explanation of the working of a flat iron	–	0.17
Concept definition	6 concepts: definition, symbols, formula and drawing for each concept	0.69	6 concepts: definition, symbols, formula and drawing for each concept	0.73	0.76
Total	13 items	0.64	13 items	0.66	0.78

appliance of these relationships to specific circuits. Students had to decide, for example, in which circuit current strength is higher. The essay question was meant to test the ability to use the scientific concepts interrelatedly in the description of a concrete phenomenon. The concept definition unit aimed at testing the ability of students to communicate the meaning of the concepts. One of the six concepts had to be excluded (‘electric circuit’), because apparently students confused it with a switch (in Dutch the two words are almost the same). The problem-solving items and the essay questions of the pre-test and the post-test were designed as parallel items. The concept definition unit of the post-test contained the same concepts as the concept definition unit of the pre-test.

We used the total scores on the pre-test as a covariate in the analyses of variance that were conducted to investigate the effects of the type of product (concept map or poster) and preparation (individual preparation or not) on scores of the post-test. Because of the low reliability of the problem-solving unit, we excluded this unit from the analyses of variance.

6.5. Coding of verbal interaction

Our coding scheme was based on the notion that verbalisation of conceptual understanding, elaboration of conflict, co-construction and the asking and answering of questions are particularly important aspects of student interaction that can contribute to concept learning.

Because we wanted to make a systematic comparison of the quality of talk between dyads working on different tasks, we chose to analyse the transcripts in a quantitative way. We analysed the transcripts on two levels, namely utterances and episodes.

The utterance level: we defined an utterance as an individual message unit that is distinguished from another utterance through a 'perceptible' pause, comma or full stop. The coding scheme to identify communicative functions of utterances was developed in a study by Erkens (1997) and was adjusted on the basis of a pilot study (Van Boxtel, 1997). Our coding scheme contained the following mutually exclusive and exhaustive categories: statements, arguments, evaluations, questions, requests, proposals, confirmations, rejections, repeats, orders and off-task utterances. Some of these categories were divided in subcategories which are described in more detail in Van Boxtel, Van der Linden and Kanselaar (1997). We distinguished, for example, different types of questions and arguments. A different coding scheme focused on the content of the utterances. A proposition was defined as an utterance in which the student makes a statement about the meaning of an electricity concept. We distinguished the following four proposition categories:

- propositions about a single concept;
- propositions in which a concept is related to another concept;
- propositions in which a concept is related to a concrete phenomenon;
- propositions in which a concept is related to another form of representation (such as a magnitude).

The coding was done with a computer program for qualitative data: WinMax Pro '96 (Kuckartz, 1996). Inter-rater agreement (Cohen's Kappa) between two judges for the communicative functions categories reached 0.89 (353 utterances, from a transcript chosen at random, were coded by two judges) and for the content categories 0.83.

Episodic level: coding the protocols on the utterance level does not give a description of the dynamics of the discourse, for example, of the way students construct a reasoning or resolve a conflict. The contingencies of the actions of both partners also need to be categorised (Grossen, 1994). To identify contingencies reflecting elaboration, we analysed the transcripts on an episodic level, making use of the coding on the utterance level. We focused on question, conflict and reasoning episodes.

Question episodes: to identify content-related question-episodes, we selected the utterances which were coded on the utterance level both as a question and as a proposition. To avoid overlapping categories we decided to exclude critical questions that were part of conflict episodes and verification questions that were part of a reasoning episode (for example, when the conclusion of a reasoning has the form of a question: 'Thus, current strength depends on resistance?'). We distinguished between no answer, short answer and elaborated answer. Elaborated answers were defined as answers that contain more information than only 'yes', 'no' or alternatives. Elaborated answers can consist of several words to several sentences.

Conflict episodes: conflict episodes were identified on the basis of non-confirmations, counter-arguments and critical questions. We selected the conflicts that dealt with the meaning or relations of the electricity concepts. A conflict is elaborated when one student explains or justifies his or her statement (individual elaboration) or when both students contribute to the resolution of the conflict through argumentation about the solution (collaborative elaboration). Resolution of a conflict can also be reached without elaboration. For example, when a student accepts the statement or counter-argument of his or her partner immediately. Lack of elaboration of a conflict can also appear when students ignore the conflict and move on to another part of the task.

Reasoning episodes: we describe a reasoning episode as a sequence of utterances in which definitions, observations or hypotheses about electricity concepts (propositions) are related to each other. A reasoning episode contains at least one utterance that is coded as an argument. Reasoning that appeared in the answering of a question or the elaboration of a conflict was not identified as a reasoning episode. An individually constructed reasoning is a reasoning that contains arguments of only one student. Co-construction of a reasoning is defined as a reasoning that is constructed by contributions of both participants.

Four transcripts, chosen at random, were coded on the episodic level by two independent coders for reliability (a total of 1553 utterances). The proportion of agreement was 79%.

7. Results

In this section we first give the results concerning the content and types of elaboration that we identified in student interaction, illustrated by examples (all examples were translated from Dutch). We also report the differences in student interaction between the concept map and poster conditions and between the conditions with and without individual preparation. Finally, we report the post-test scores and the relationships between these scores and the amount of elaboration in student interaction.

7.1. Content and types of elaborations

In this sub-section we report the results of the content analysis on the utterance level. The analyses with the coding scheme of communicative functions are not reported here, because we only used these codings to identify episodes. The results of the episodic analysis are also reported in this section.

7.1.1. Utterance level: content analysis

We expected that students would communicate their understanding of the electricity concepts and that they should talk in particular about meaningful relationships. The propositions categories in the ‘Total’ column of Table 2 show the amount and character of talk about the electricity concepts. The average intensity of talk about concepts was approximately three propositions per minute. Most conversation about relationships concerned those between concepts. The following example gives an illustration of talk about the relationships between voltage, electrons and current strength. It starts with an erroneous proposition and ends with its correction. Relevant codings of the propositional content of the utterances are given between brackets.

Table 2
Means of proposition and episodic categories in ratios[a] in the four conditions (*n* total=19)

	Concept map		Poster		Total
	Ind. prep.	No ind. prep.	Ind. prep.	No ind. prep.	Mean (SD)
Utterance level:					
Total propositions	3.31	4.31	2.77	1.90	3.13 (1.42)
Single concept	0.21	0.14	0.20	0.20	0.19 (0.15)
Relation between concepts	1.63	2.74	0.55	0.42	1.38 (1.24)
Concept related to concrete phenomenon	0.24	0.54	1.48	0.94	0.79 (0.73)
Concept related to other form of representation	1.23	0.89	0.54	0.34	0.77 (63)
Episode level:					
Total question episodes	0.79	0.44	0.53	0.36	0.54 (0.33)
Answered questions	0.56	0.35	0.39	0.28	0.40 (0.23)
—elaborated answers	0.11	0.11	0.17	0.11	0.13 (0.09)
—short answers	0.45	0.24	0.22	0.18	0.28 (0.20)
Not answered	0.23	0.09	0.14	0.08	0.14 (0.13)
Total conflict episodes	0.29	0.22	0.13	0.08	0.19 (0.17)
Elaborated conflicts	0.15	0.17	0.08	0.07	0.12 (0.09)
—collaborative	0.08	0.10	0.03	0.03	0.06 (0.06)
—individual	0.07	0.07	0.05	0.05	0.06 (0.06)
Not elaborated	0.14	0.06	0.05	0.01	0.07 (0.10)
Reasoning episodes	0.19	0.37	0.17	0.09	0.21 (0.17)
—individual	0.04	0.16	0.05	0.02	0.07 (0.08)
—co-constructed	0.15	0.21	0.12	0.06	0.14 (0.11)
Total elaborative episodes	0.45	0.65	0.43	0.27	0.46 (0.24)

[a] Ratio: frequency divided by the time during which the students worked at the task.

Example 1: Talk about relations of concepts (*condition: poster with individual preparation*)

1	Kevin:	Voltage, voltage is the number of electrons per second.	(proposition relation)
2	Kevin:	That is voltage.	
3	Diederik:	Voltage.	
4	Kevin:	The number of electrons that move per second, or is that the current strength?	(proposition relation)
5	Diederik:	That is the current strength (proposition relation).	
6	Kevin:	Yes.	
7	Kevin:	Then I write that down.	
8	Diederik:	The voltage is the power with which	(proposition

		the electrons move forward.	relation)

This example shows the differentiation of concepts through talk about how concepts are related to each other. The definition that Kevin gives of voltage is, from a scientific point of view, a more appropriate definition of current strength. Through the verbalisation of his understanding Kevin becomes aware of a possible confusion of the two concepts (sentence 4). Diederik confirms that the movement of electrons per second has to be related to current strength. He also explains how voltage is related to the movement of electrons (sentence 8).

7.1.2. Episode level: question episodes

Table 2 shows that question episodes appeared more than twice as often as conflict or reasoning episodes. However, most questions did not lead to elaboration. The fact that short answers were more frequent than elaborated answers is probably due to the high proportion of verification questions (59 per cent of all questions). An example of such a verification question is: ‘an electron transports energy, doesn’t it?’ These questions are important in monitoring common ground (Graesser, Person & Huber, 1993) and are used to construct the shared meaning needed in the collaborative tasks. We think the proportion of verification questions is also high because to complete the task students could only use their own and each others’ knowledge—no other information sources were available. The next fragment, Example 2, contains an example of a question episode about the relation between resistance and the cross-section area of a resistor. An open question (sentence 3) is followed by an elaborated answer. The same problem is discussed for a second time a couple of minutes later. This suggests that Selina did not completely understand what Wai man meant, or did not yet agree with it. Apparently she is motivated to understand the relation. In the attempt to explain the statement about resistance, Wai man first refers to her earlier stated theory about molecules (sentences 8 and 9) and then to the results of an experiment they conducted a year ago (sentence 14).

Example 2: Elaborated answer (*condition: poster with individual preparation*)

1	Wai man:	We can use this one, cross-section area of a resistor.	
2	Wai man:	But I don’t know what to write about it	
3	Selina:	Of a resistor, but how do you mean that?	(question).
4	Selina:	I didn’t understand it.	
5	Wai man:	Look, there is a resistor.	
6	Wai man:	If the resistance is high, then U is...	
7	Wai man:	Then something is smaller, but I don’t know what it is.	
8	Wai man:	It is something like this, resistance, when you compress it (gesticulates) then it is more dense, more molecules.	
9	Wai man:	When you enlarge it, the molecules are	

		further away from each other and the current can go more easier through it.
10	Wai man:	It's something like that.
11	Selina:	Oh, oh yes.
12	Wai man:	For example, sometimes you use such a block, okay?
13	Selina:	Yes, that is the resistor.
14	Wai man:	And I don't know if you made that experiment, but we used another kind of material, it was smaller.
15	Selina:	And then it was less shining.
16	Selina:	Oh yes, like that.
17	Selina:	Yes, that is possible.

7.1.3. Episode level: conflict episodes

As shown in Table 2, collaborative elaboration of a conflict occurred as frequently as individual elaboration, but neither was used very often. Example 3 shows a part of a conflict episode about the question whether the cross-section area (of a resistor) is related to electrons or not. First, Claudine and Alexia shared their ideas about the possible nature of the relationship (sentenceS 2–9, not shown), but then Claudine (sentence 10) concludes that the two concepts have nothing to do with each other. The conflict is not elaborated. Claudine and Alexia do not justify or explain their point of view. Although Claudine evaluates that they are not collaborating well, Alexia ignores the conflict and starts gluing the cards.

Example 3: A conflict that is not elaborated (*condition: concept map with individual preparation*)

1	Alexia:	Okay, we will do the larger the cross-section, the more electrons.	
10	Claudine:	No they have nothing to do with each other.	(non-confirmation)
11	Alexia:	Are you sure?	
12	Claudine:	Yes.	
13	Claudine:	If they do have to do with each other.	
14	Alexia:	I think they do have something to do with each other.	
15	Claudine:	No.	
16	Alexia:	Yes they do.	
17	Claudine:	No they don't.	
18	Alexia:	Yes.	
19	Claudine:	No.	
20	Alexia:	Yes.	
21	Claudine:	No.	
22	Claudine:	We can collaborate well.	(ironic)

23	Alexia:	Yes.
24	Claudine:	Where is the gum?
25	Alexia:	(gives the gum)
26	Alexia:	We agree, don't we?
27	Alexia:	We are going to (glues all the cards).

7.1.4. Episode level: reasoning episodes

Table 2 shows that elaboration of conceptual knowledge was somewhat more frequent in the form of reasoning episodes (0.21) than in the form of elaborated answers (0.13) and elaborated conflicts (0.12). Co-construction of a reasoning generally appeared twice as often as individual reasoning. The following example illustrates the process of co-construction of a reasoning. Both students contribute to the reasoning. Ashraf relates the concept of voltage to the voltage source and consequently to the concepts energy and current. Finally, Harun relates the concept of current to the concept of energy.

Example 4: Co-construction of a reasoning (*condition: concept map without individual preparation*)

1	Harun:	An electric circuit has got a voltage source too, hasn't it?	
2	Ashraf:	Yes, actually it has.	
3	Ashraf:	(draws)	
4	Ashraf:	And it consists of (writes)	
5	Ashraf:	The voltage source has, gives, gives...	
6	Harun:	The voltage source gives voltage.	(continuation)
7	Ashraf:	And energy.	(continuation)
8	Harun:	Yes also.	
9	Ashraf:	And current isn't it?	
10	Ashraf:	The voltage source also gives current.	(continuation)
11	Harun:	And due to this current, there is energy.	(conclusion)

7.2. Effects of experimental factors on elaboration

7.2.1. Individual preparation versus no individual preparation

We expected that individual preparation would result in more question asking and conflict. The analyses of variance revealed no significant effect of the preparation on the number of conflicts (F (1,15)=0.64, p=0.44). Perhaps the individual preparation time (five minutes) was too short. The designs were very incomplete and did not explicitly show differences in understanding. Also, many students had no time to label the links, whereas most conflicts turned out to be about the exact formulation of the relationships between the concepts.

There was a multivariate effect on the number of questions (verification questions, disjunctive questions and open questions). Dyads in which students prepared individually did produce more questions (*F* (1,15)=3.53, *p*=0.04). This effect was mainly due to the difference in the number of verification questions.

The analysis of the transcripts showed that individual preparation gave the students an extra tool during the accomplishment of the task. The designs were used mostly in the first phase of collaboration. In this phase students showed and explained their own work. The designs were also used to support proposals, confirmations and criticism, and to choose new topics that had to be dealt with. Individual designs were used as an extra tool on an average of eight times during the interaction.

7.2.2. Concept map versus poster

Here we only expected differences in the type of propositions used. As we predicted, students who made the concept map talked more about relations between the electricity concepts (*F* (1,15)=19.18, *p*=0.00), whereas students who made the poster talked more about relations of the concepts with concrete phenomena (*F* (1,15)=9.07, *p*=0.01). However, we also found some other (unexpected) effects of the product. Students who made a concept map talked more about relations of concepts with other forms of representation, such as formulas or magnitudes (*F* (1,15)=5.59, *p*=0.03). It also appeared that students who made a concept map talked more intensely about concepts (all proposition categories taken together) than the students who made a poster (*F* (1,15)=6.90, *p*=0.02). A closer examination of the protocols revealed that working on a poster resulted in more frequent and longer phases in which students were writing or drawing. Some dyads spent considerable time drawing an electrical circuit inside the electric torch, whereas the concept map only required short sentences describing the relations between the concepts.

Furthermore, student interaction of the dyads that made a concept map contained more collaboratively elaborated conflicts (*F* (1,15)=6.09, *p*=0.03). The product also had an effect on the total amount of reasoning (*F*(1,15)=5.04, *p*=0.04). In dyads that made a concept map, students more frequently constructed reasons.

7.3. Effects of experimental factors on individual learning outcomes

7.3.1. Individual learning outcomes

We expected that participation in elaborative talk about electricity concepts would affect the ability of students to communicate their understanding of the concepts and their relations with other concepts or concrete phenomena. Table 3 shows the scores

Table 3
Mean student scores and standard deviations of the pre-test and the post-test (*n*=40)

	Pre-test	Post-test	*t*-value	*p*
Problem-solving	5.45 (*2.32*)	6.60 (*2.15*)	3.36	0.00
Essay question	2.15 (*1.31*)	1.95 (*1.50*)	−0.71	0.48
Concept definition	9.28 (*4.22*)	12.08 (*4.42*)	6.07	0.00
Total	16.88 (*5.65*)	20.63 (*6.01*)	6.45	0.00

on the different units of the pre-test and the post-test for the four conditions taken together.

The higher score on the problem-solving items reflects that students were better able to recognise correct relationships between the physical quantities and to apply these relationships to concrete circuits. In the concept definiton unit of the post-test, students gave more extensive and better formulated descriptions of the meaning of the concepts. Erroneous propositions that appeared less in the concept definition unit of the post-test especially included the confusion between current strength and voltage and the linkage of some quantities to the wrong concepts. The post-test scores for the essay question were not higher in comparison with the scores on the pre-test. The electric torch question and the flat iron question apparently were not of equivalent difficulty. The explanations that students gave showed that they had many more problems with identifying electric circuit in the flat iron than in the electric torch.

7.3.2. Differences between conditions

An analysis of variance with the pre-test score as a covariate showed a significant effect of the preparation for the task. Students who prepared individually scored higher on the concept definition unit of the post-test (F (1,35)=5.20, p=0.03). We expected that students who constructed a poster would score higher on the essay question of the post-test, since this collaborative task was ‘closer’ to this unit. However, there was no significant effect of the product on this unit (F (1,35)=0.14, p=0.71).

7.4. Relationships between individual learning outcomes and elaborative episodes

We expected positive relationships between the amount of elaboration in student interaction and individual learning outcomes. The frequencies of the indicators of elaboration were attributed to the individual students. The results of the within-group partial correlational analyses (controlling for pre-test scores) are shown in Table 4. In the condition concept map without individual preparation the frequency of elaborative episodes (elaborative answers, reasoning and elaboration of conflict) correlated with higher scores on the concept definition unit of the post-test (r (10)=0.80,

Table 4
Correlations between elaborative episodes and the concept definition unit and essay question of the post-test in the four conditions[a] (controlled for pre-test scores)

	Concept definition unit				Essay question			
	1	2	3	4	1	2	3	4
Elaborative episodes	0.36	0.80[b]	0.07	−0.57	0.45	0.52	0.14	−0.02

[a] 1=concept map with individual preparation; 2=concept map without individual preparation; 3=poster with individual preparation; 4=poster without individual preparation.

[b] $p<0.05$.

p=0.01). This significant correlation was mainly due to the categories: elaborated answers (r=0.77), collaborative elaboration of conflict (r=0.65) and co-constructed reasoning (r=0.83). In the condition, concept map with individual preparation, the correlation between elaborative episodes and the scores on the concept definition unit of the post-test was also positive, but not significant. The correlations with the essay question were in the concept mapping conditions also positive, but not significant. In the poster conditions the correlations were low and were even negative in the condition of poster without individual preparation.

8. Discussion

In the first part of this discussion we will focus on the coding scheme with which we analysed the elaboration of conceptual knowledge in student interaction. Next, we discuss the influence of task characteristics on the quality of student interaction and the relationships between elaboration in student interaction and individual learning outcomes.

The value of our study resides partly in the introduction of a coding scheme with which we can describe elaborating processing of conceptual knowledge as it is situated in social interaction within collaborative learning groups. We have suggested that, in a collaborative learning environment, elaborating processing of the meaning of concepts is reflected in talk about relations, reasoning, giving elaborated answers and elaboration of conflicts. We generated our own coding scheme, because talk that is generated by collaborative learning tasks requires a different descriptive system of analysis than talk that is generated by students who co-operate but do not work on a common product. For example, we could not use the category 'elaborated help' as it was defined by Webb (1989), because with collaborative tasks questions are relevant for the completion of the common product and can be answered by one of the participants or by the participants together. Our analyses on the utterance and episodic level contributed differently to understanding the interaction. The analysis at the utterance level makes it possible to get information about the contribution of each student in the social activity, whereas the episodic level of analysis is more appropriate to grasp the dynamic and co-constructed nature of talk. Aside from analysing the communication aspects, we also took into account the propositional content of the utterances. The coding on the utterance level enabled us to give a clear definition of the different types of episodes we were interested in.

The influence of task characteristics on the quality of student interaction was reflected in the reported differences between the conditions. We compared a concept mapping task with a poster task and investigated the effect of a phase of individual preparation. Although in schools students are sometimes asked to prepare individually for groupwork, there was no empirical data on the effects of such a preparation phase. We found that imposing individual preparation (which only lasted for five minutes) did affect the number of questions the students posed and gave them an extra tool which supported the exchange of ideas.

As hypothesised, the concept map seems to be a better instrument to elicit talk about concepts, elaboration of conflict and reasoning than the poster. The fact that drawing and writing activities in the poster task resulted in less talk about the concepts is in line with the conclusions of Bennett and Dunne (1991) who found similar results with tasks that require concrete actions. It is possible that the need to resolve a conflict was felt more strongly by students who made a concept map. In talking about relations between certain physical quantities, these students had to choose between two opposite alternatives. For example, the current strength is either directly or inversely proportional to resistance. A concept map requires an explicit answer. On the poster students can write a short story about each concept and its link to a part of the electric torch, whereby it is easier to combine different points of view. The occurrence of more reasoning in the concept mapping conditions may be explained by our observation that many dyads who made a poster did link the electricity concepts to parts of the electric torch but did not construct reasoning in which these concepts were related to each other. Students who made a concept map more frequently included different relationships between concepts in one reasoning.

Although the task lasted for only 45 minutes and students could only use each other, the post-test students showed more complete, correct and better formulated definitions of the concepts and were better able to recognise and apply correct relationships between concepts. Students who prepared individually for the group task had higher scores on the concept unit of the post-test. They may have gained more from the conversation because they elicited talk that was relevant to their uncertainties. Although we found more elaboration in the concept mapping conditions, we did not find an effect of the kind of product that was asked for (concept map or poster) on the post-test scores. However, we did find some empirical evidence for the suggestion that the quality of student talk is related to individual learning outcomes. In the condition of concept map without individual preparation, the amount of elaboration in the social interaction correlated with the concept definition unit of the post-test. In this unit the students had to communicate their understanding of the meaning of six electricity concepts. The task may not have been 'strong' enough to affect the ability to use the scientific concepts interrelatedly in the description and explanation of a concrete phenomenon (as was requested in the essay question of the post-test). The fact that we only found positive correlations in the concept mapping conditions suggests that especially elaboration of the *theoretical relations* between the concepts and the appliance of these relations to concrete phenomena contributes to the ability to communicate the meaning of the electricity concepts.

The correlation that we found between collaborative elaboration and individual learning outcomes may suggest that student interaction that can be considered *elaborative* and at the same time *collaborative* is particularly valuable for concept learning. Such interaction is characterised by a focus on understanding and the construction of a shared understanding. This common focus is reflected in collaborative reasoning and collaborative elaboration of conflicts and possibly also in the co-construction of elaborated answers (we did not distinguish such a category in our coding scheme). Then, both students in each dyad are actively engaged in elaborative activities at the same time. They are not only reflecting upon and elaborating their own understanding but also integrating or elaborating the input of their partners.

We think it is important to make a distinction between collaborative learning as a learning environment with a collaborative task, and collaborative learning as a process. The amount and character of learning and collaboration differs between groups and within groups from moment to moment. The social interaction can reflect more or less common effort towards understanding of the concepts. We agree with Schwartz (1999) that it is not the shared understanding that is the most important for learning, but the effort to realise it. Although our tasks stimulated most students to talk about and elaborate on the concepts, they still did not guarantee that all students took the opportunity to participate in a high-quality discourse. Our study has generated some empirical evidence for the influence of task characteristics. But factors such as motivation, student capacities and the availability of supportive tools may also have a role in this. In a follow-up study we will focus on the effects of the availability of such supportive tools on the quality of student interaction during collaborative learning. More research is needed into the complex interplay between aspects of the learning environment, student characteristics and the quality of student interaction that is generated by collaborative learning tasks.

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