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Fostering knowledge construction in university students through asynchronous discussion groups

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Abstract

Does collaborative learning in asynchronous discussion groups result in enhancing academic discourse and knowledge construction? This general research question has been researched in a study involving 300 students, working during six months in 38 electronic discussion groups. The transcripts of the discussions were coded and analysed to test hypotheses related to the impact on knowledge construction. Coding of the units of analysis was based on the models of Fahy, P. J., Crawford, G., Ally, M., Cookson, P., Keller, V., & Prosser, F. (2000). The development and testing of a tool for analysis of computer mediated conferencing transcripts. *Alberta Journal of Educational Research*, 46(1), 85–88 and Veerman, A., & Veldhuis-Diermanse E. (2001). Collaborative learning through computer-mediated communication in academic education. In P. Dillenbourg, A. Eurelings, & K. Hakkarainen (Eds.), *European Perspectives on Computer-Supported Collaborative Learning. Proceedings of the First European Conference on CSCL*. Maastricht: McLuhan Institute, University of Maastricht. The results confirm that students in the discussion groups are very task-oriented and that higher proportions of high phases of knowledge construction are observed. Significant increases in the cognitive interaction, task-orientation and higher phases of knowledge construction are detected. Group size is a significant interaction variable. Discussion in smaller groups reflects larger proportions of higher levels of knowledge construction. The results point at the critical impact of structure in the task environment. In the discussion section, methodological issues are presented. The article concludes with directions for future research and some implications for instructional practice.

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1. Introduction and general research problem

Research on cooperative and collaborative learning represents a vast body of theoretical and empirical studies. In their review and meta-analysis of research, Johnson and Johnson (1989, 1996) document hundreds of studies about cooperation. They come to the conclusion that "The research (...) has an external validity and a generalisability rarely found in the social sciences" (Johnson & Johnson, 1996, p. 1021). Their analysis also considers in detail the impact of technology to foster cooperation and they point at the promise of groupware environments. At the same time, they ask for more research in this field. The present study is a response to the latter request. It researches the impact of a specific type of groupware: asynchronous discussion groups. In the literature, this type of groupware is also referred to as *computer supported collaborative learning environment* (CSCL [1]).

The asynchronous discussion groups researched in this study are a component of a large scale curriculum innovation at the Faculty of Psychology and Educational Sciences of the Ghent University. The innovation focusses on the implementation of social-constructivist principles, such as active learning, self-reflection, authentic learning, and collaborative learning. The innovation is continuously monitored with research activities. Earlier studies focussed on the way students perceive and experience the innovation and to what extent innovations are in line with student learning styles and capabilities (Schellens & Valcke, 2000). The actual research reports on the third phase in the re-design of the course "Instructional Sciences". This course introduces students to a large variety of abstract theories and conceptual frameworks related to learning and instruction. The asynchronous discussion groups were established to foster academic discourse and active individual knowledge construction. They were expected to further mental model construction and help students to apply the mental models in dealing with authentic problems. This brings us to the central research problem for this research paper. Does collaborative learning in asynchronous discussion groups result in enhancing academic discourse and knowledge construction?

In the literature, a variety of concepts is used to refer to learning in group settings. In the present study, *collaborative learning* is used to refer to relatively stable groups that work together during a semester on shared tasks that invoke academic controversy. The collaborative work requires bringing together information, ideas, solutions, and opinions that are not always compatible with one another. Each student in the group is expected to present their own position, and an argumentation that states their position in relation to other group members to solve the problem or answer a key question.

[1] In the literature different concepts are used to identify the educational use of ICT to support cooperative learning: cooperative learning environment, computer supported collaborative learning environment, computer supported intentional learning environment, collaboratory notebook, web based learning environment. In the present article we consistently use the concept computer supported collaborative learning environment (CSCL). This conceptualisation is most commonly found in the literature.

2. The theoretical and empirical base of CSCL

Collaborative learning is central to the constructivist learning paradigm (Duffy & Jonassen, 1992; Salomon & Perkins, 1998). Information and communication technologies (ICT) present new and challenging ways to foster this collaborative learning. CSCL researchers refer explicitly to theoretical frameworks that build on social-constructivist principles; e.g., cognitive apprenticeship (Wilson & Cole, 1996), situated cognition/learning (Brown & Duguid, 1993), anchored instruction (Young, 1993), problem based learning (Moust & Schmidt, 1998), etc. A second group of researchers also builds on concepts derived from cognitive psychology to account for the way collaborative learning fosters: e.g., cognitive flexibility theory (Spiro, Feltovich, Jacobson, & Coulson, 1988), distributed cognition (Hutchins & Klausen, 1996), and distributed constructionism (Kafai & Resnick, 1996).

Despite the growing adoption of CSCL-tools in current instructional practice, research does yet not present consistent evidence that founds the assumptions related to the use of CSCL. This research builds on a variety of methodologies: self reporting, interviews, conversation analysis, content analysis and discourse analysis. A number of authors point at specific weaknesses that account for the non-conclusive results of the studies (Archer, Garrison, Anderson, & Rourke, 2001; Fahy, 2002; Fahy et al., 2000; Gunawardena & Duphorne, 2000; Potter & Levine-Donnerstein, 1999; Rourke, Anderson, Garrison, & Archer, 2001; Saba, 2000). We can summarise these critiques as follows. First of all, critiques point at the frail link between the empirical design and the theoretical base. This is e.g., demonstrated by the fact that research instruments are but weak operational translations of the theoretical base. From a methodological point of view, researchers also question the reliability of the research instruments and research procedures. In addition, they stress the lack of information in the research reports about this issue. Others point at the restricted numbers of students involved in the studies, or the limited number of discussion sessions or the short time span of the study. This affects the generalisability of the results. Since a number of studies are set up in authentic study environments, they mention the problem of controlling student characteristics (e.g., differences in prior knowledge, differences in involvement, differences in the number of messages, etc.). Discussions about the research design reflect concerns about the lack of including control groups. A number of studies is descriptive in nature and does not result in data that are helpful to test hypotheses.

This short overview reinforces the need to continue to study CSCL. Moreover, it puts forward clear guidelines for the design of our empirical study. In the context of the present study, special attention will be paid to the following methodological issues:

(1) Discussion in CSCL-environments results in written messages. But what will be the *unit of analysis*? The unit of analysis is to reflect in an exhaustive and exclusive way a specific construct (Rourke et al., 2001). In the literature a variety of choices is discussed: a sentence, a paragraph, a theme and the illocutionary unit (the complete message). Each choice presents advantages and disadvantages. Opting for each individual sentence or paragraph as the unit of analysis results is an objective and reliable choice but research experience indicates that this unit is too small to represent individual theoretical constructs, such as referred to in the analysis models. Opting for themes as the analysis unit helps to counter the latter disadvantage but presents problems in terms of the reliable identification of each individual theme, resulting in

subjectivity and inconsistency (Garisson, Anderson, & Archer, 2000). The best choice is to opt for each complete message as an individual unit of analysis. According to Rourke et al. (2001) this results in the objective identification of all units of analysis. Second, the number of observed units is under control and can be managed for analysis purposes. A third advantage is that the researcher works with the unit as it has been defined by the author of the message.

(2) Most CSCL-research entails the coding of the units of analysis on the base of a theoretical model. Researchers have to ensure the reliability of this coding strategy. Gunawardena and Zittle (1997) criticise available CSCL-research in three ways when discussing reliability. First of all, too few studies report explicitly about this psychometric quality. In their overview, only half of the studies state reliability figures and/or procedures to guarantee high reliability (see also Rourke et al., 2001). Second, they focus on the method to determine the reliability. Majority of studies adopt a 'percent agreement statistic' that determines the percentage of agreement for the total number of categories coded by the researchers (Holsti, 1969). But this approach neglects the *change agreement* between researchers when they gradually adapt their coding approach to the opinion of the other coders (Capozzoli, McSweeney, & Sinha, 1999; Krippendorf, 1980). Alternative approaches are *chance*-*corrected*, such as Cohen's Kappa, but researchers consider them to be very conservative and restrictive.

A separate discussion in this context is related to the optimal reliability figure that is acceptable. Riffe, Lacy, and Fico (1998) suggest 80%. Garisson et al. (2000), together with Hillman (1999) and McDonald (1998) suggest Kappa-values between 0.74, 0.96, and 0.67. But according to Rourke et al. (2001) it is still too early to impose concrete reliability levels.

Next to methodological questions, empirical research about cooperation also puts forward the discussion about the nature of cooperation in groups. Johnson and Johnson (1996) refer to a number of clear design guidelines that help to guarantee that true cooperation will be observed in groups. They refer to (a) positive interdependence. This implies that the group shares a common goal, strive after mutual benefit, have a long term perspective and have a shared identity. (b) There is an individual and a group accountability; both the group and each individual will be evaluated. (c) Intertwine face-to-face and CSCL-interaction. (d) Take care of the development of interpersonal skills. (e) Also focus on the group processing next to academic achievement. These empirically founded guidelines will have to be considered when setting up the research in this study.

3. Theoretical framework of the present study

How can we describe, explain and predict the impact of collaborative learning in a CSCL-setting on knowledge construction? Fig. 1 gives a graphical representation of the theoretical base for the present study. It integrates social constructivist principles and concepts derived from the information processing approach to learning (see comparable approaches of Baker (1996), Doise & Mugny (1984), Erkens (1997), Kreyns & Bitter-Rijkema (2002), Petraglia (1997), Savery & Duffy (1996) & Veerman, Veldhuis-Diermanse & Kanselaar et al. (1999)).

The centre of the Fig. 1 represents the learning process at the individual level (student X). "Learning" is considered as an information processing activity. This builds on the central assump-

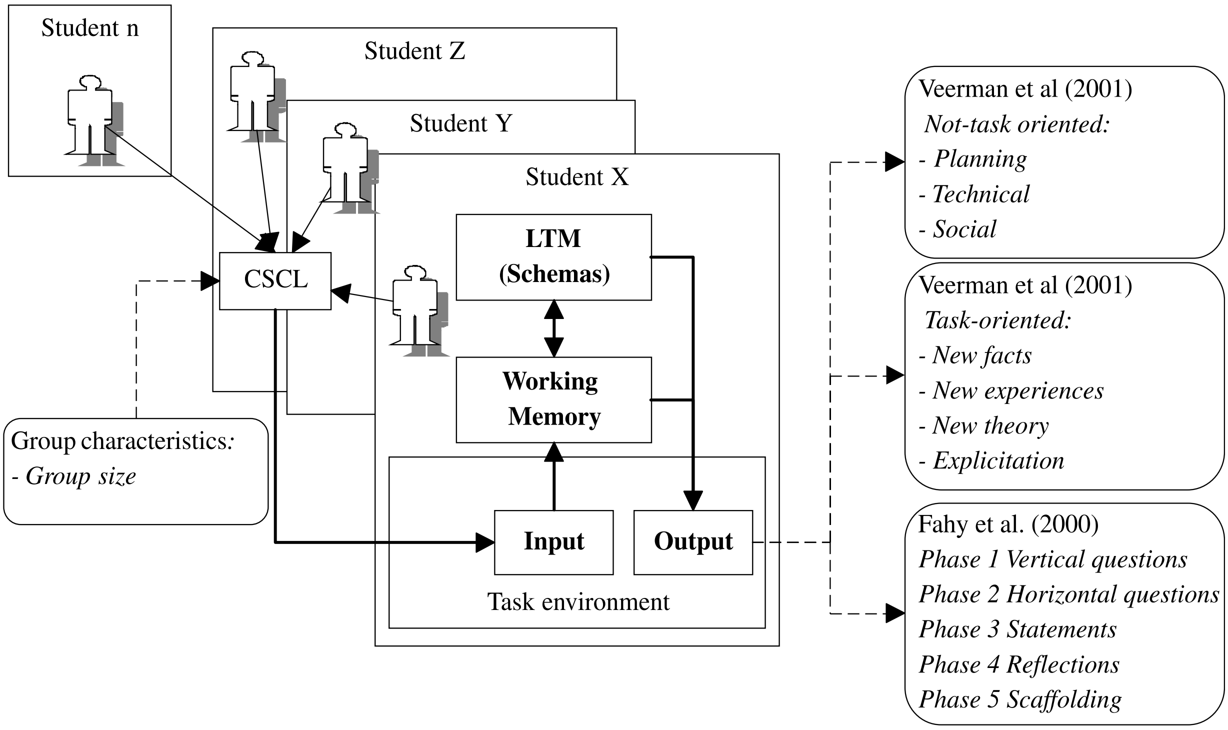

Fig. 1. Graphical representation of the theoretical base.

tion that learners engage actively in cognitive processing in order to construct mental models [2] based on their individual experiences. New information is in this way integrated with existing cognitive structures. This *active processing assumption* invokes three types of processes: selecting, organizing, and integrating (Mayer, 2001). The mental models are stored in and retrieved from long term memory (LTM). The processing activities are triggered by the task put forward in the task environment. The structure and theme of the task are therefore considered to direct these activities. Research of De Wever, Valcke, Van Winckel, and Kerkhof (2002) supports the importance of task structure to foster the knowledge construction process.

The task is put forward in a collaborative environment. This invokes *collaborative learning* that builds on the necessity of the learner to organise output that is relevant input for the other learners (Student Y to *n*). This exchange at input and output level is considered to reflect a richer base for the further cognitive processing at individual level. This assumption is central in the cognitive flexibility theory of Spiro et al. (1988). Given the importance of the "group" in the CSCL-setting, characteristics of the group such as group size, are of importance.

The output is a key element in the theoretical base of the present study. The asynchronous nature of the discussion environment forces the learner to communicate the output in an explicit way. All the written communication in the CSCL-environment is therefore considered as relevant (cf. the concept of *entire Gestalt* of Gunawardena, Lowe, & Anderson (1997)). The output mirrors the

[2] Authors in the field of cognitive science adopt a variety of concepts to refer to the cognitive structures that learners actively build and store in long term memory: mental model, cognitive structure, mental model, etc.. In this article we adopt the concept "mental model".

concrete processing activities. Individual processing is slowed down by the complexity of the complete problem since learners have to cope with both selection, organisation and integration processes. As a consequence, learners experience the *limited capacity* of their working memory (Mayer, 2001). Other authors refer to *cognitive load* in this context (Sweller, 1988, 1994). But learners in a collaborative setting can profit from the processing effort of others. The output of each individual student is organised since it is derived from his/her own mental models. The assumption is that this output is therefore more easily accessible by other learners in the collaborative setting. Since the input of other learners is more organised, students are expected to experience lower levels of cognitive load.

During the discussion processes, students working on the real life problems present output that evolves along stages in the cognitive process. In Fig. 1, different types of output are identified. We build on the work of Fahy et al. (2000, 2001) and Veerman and Veldhuis-Diermanse (2001) to identifying the types. The typologies will be used to analyse the transcripts of the written communication. The specific choice for these two models is based on available information about the psychometric qualities of both models.

The *transcript analysis tool* (TAT) of Fahy et al. (2000) identifies interaction about questions, statements, reflections and scaffolding: The typology is based on the analytic model of Zhu (1996).

(1) Vertical questions: These questions assume there is a specific correct answer, for example, "*Are the students involved in the selection of the criteria*?"; "*Do you give them a grade at the end of the course*?".
(2) Horizontal questions: In these cases, there is not a single correct answer, but a variety of plausible alternative reactions can be accepted, for example: "*Only because we put a course online does that mean that we have to forget about the weekly working sessions and the course reader*?"; "*After all what makes a tool Constructivistic*?".
(3) Statements: This type of communication imparts facts or information. A reaction/answer of other learners is not expected. Values or beliefs are not stressed and kept very implicit, for example, "*I read that 9 out of 10 students failed for such courses*"; "*We found that keeping content practical kept the attention of the participants*".
(4) Reflections: This type of communication reveals argumentations, negotiations, thoughts, opinions, judgments, doubts, beliefs and transfer of personal information. The learner expects reactions that vary from understanding/acceptance (scaffolding) to additional questions and other reflections, for example, "*I personally think that this way of working is good but not for all kids, because you need a certain base before you can start*".
(5) Scaffolding: These are contributions that foster the further collaborative learning process. Learners acknowledge one another, encourage, recognise contributions, thank, and greet.

We add to the typology a hierarchical structure (see Fig. 2). The first four types of communication are considered to reflect consecutively higher order cognitive processes in the selection, organisation, and integration of mental models. The fifth type represents social cognitive processes. In the context of this study, we hypothesise that the CSCL-environment will foster the higher types of communication, thus promoting the construction of mental models.

The analysis model of Veerman and Veldhuis-Diermanse (2001) builds on social-constructivist principles. The typology is more general than the model of Fahy et al. (2000) since it also focusses

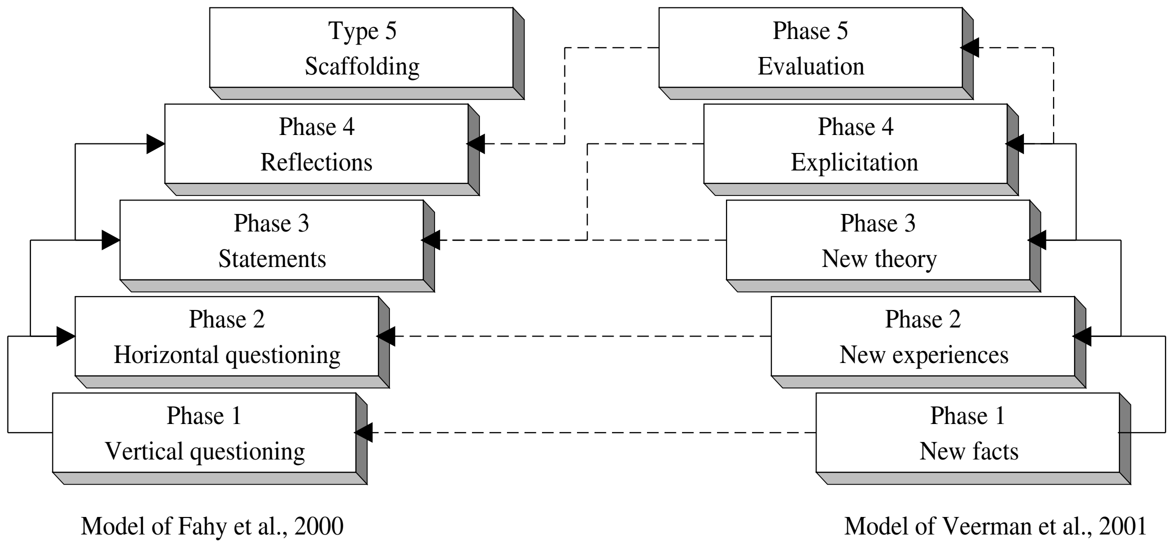

Fig. 2. Hierarchical structure in CSCL-communication as related to cognitive processing and theoretical relationships between both typologies.

on non-task related activities. But the authors also present a clear relationship between types of collaborative activities and knowledge construction (see also Veerman et al., 1999). They distinguish between task-oriented and not-task-oriented behaviour. This distinction helps to control for explicit interpersonal monitoring activities in the output and to check the balance between not-task-oriented and task oriented communication. They differentiate four categories of not-task-oriented communication: (a) Planning: "Is it OK to discuss the arguments first"?; (b) Technical: "How can we get rid of the delete-button on the screen"?; (c) Social: "Good job!" and (d) Non-sense: "Who joins in to go to the movies"? Considering our focus on the impact of CSCL on cognitive processing, we assume that social and planning behaviour are of central importance to foster cognitive processing. We expect that CSCL-settings will promote these types of communication.

Within task-oriented communication, they consider three basic cognitive processing activities:

1. Presentation of new information. Learners present information that is new in the context of the discussion. Further distinction is made between the presentation of information on:
   (a) facts, for example, "*On the internet you can find some examples of exercises and you get the solution if you click on the following link...*",
   (b) experiences or opinions, for example,"*I personally would choose to explain to the other students why we accepted these students with emotional disabilities...*",
   (c) theoretical ideas, for example "*I found a definition of constructivism,constructivism means active learning...*".
2. Explicitation. This is a type of communication that reflects a further refining and/or elaboration of earlier ideas, for example, "*I know that A. already mentioned that adding some links to the learning environment would make it a more constructivistic one.I would like to go further into this by giving a few examples of the kind of links that I think could be useful...*".

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3. Evaluation. This type of written messages corresponds to a critical discussion of earlier information or ideas. It goes beyond a simple confirmation or negation and reflects argumentations, reasonings, justifications, for example "*I cannot fully agree on this one.I know B. argued that because of these specific features one can assume that this is a constructivistic learning environment.But I would like to refer to what we discussed in the working sessions,we then agreed that there had to more than* 2 *or* 3 *features...*".

We add again a hierarchical structure to the typology of task-related communication. The consecutive types of communication represent higher levels of knowledge construction. This is represented in Fig. 2. Comparable to the assumption put forward in relation to the model of Fahy et al. (2000), we hypothesise that collaborative work in the CSCL-setting will foster knowledge construction, resulting in the observation of higher number of explicitation and evaluation types of communication.

The adoption of two different typologies to analyse knowledge construction in the discussion groups presents some advantages. First of all, hypothesis testing about the impact of collaborative learning in CSCL can be based on two different data sets. Second, since the two typologies are clearly interrelated, the analysis results are helpful to validate the individual typologies. The relationship between both typologies is also represented in Fig. 2.

4. Research section

4.1. General research question and hypotheses

The central research question of the present study is the following: Does collaborative learning in asynchronous discussion groups result in enhancing academic discourse and knowledge construction? Building on the theoretical base, we put forward the following hypotheses to research this general question:

(1) The proportion of task-oriented communication is larger than the proportion of non-task-oriented communication.
(2) Communication in the discussion groups will become more task-oriented instead of non-task-oriented.
(3) In the context of non-task-oriented communication, more 'social' and 'planning' communication will be observed, at the expense of interaction in relation to 'technical issues' and 'nonsense' interaction.
(4) The CSCL-environment fosters higher proportions of higher phases of knowledge construction.
(5) At the end of the research period, more communication reflecting higher phases of knowledge construction will be observed.
(6) The size of the discussion group affects the collaborative learning activities. In smaller groups, we observe larger proportions of task-oriented communication and higher proportions of the higher phases of knowledge construction.

4.2. Research setting

As stated in the introduction to this article, the research was set up in the Faculty of Psychology and Educational Sciences and related to a freshman course on "Instructional Sciences". This course is supported with an on-line learning environment that presents additional resources, links, planning information, calendar, news, self-assessment, etc. (http://allserv.rug.ac.be/~mvalcke/Onderwijskunde/index.htm). At the start of the academic year 2000–2001, electronic discussion groups were added to this on-line environment. The discussion groups ran during a complete semester. Each three weeks a new discussion theme was introduced. The objectives pursued in the discussion groups did not differ from the weekly face-to-face activities: active processing of the new domain knowledge, presented during the weekly face-to-face working session and application of this knowledge while solving an authentic case. The only difference was that in the discussion groups, students were actively engaged in working towards these objectives.

The asynchronous discussion groups were implemented with the tool Web Crossing conferencing server (http://webcrossing.com/). This tool allows students to manage their own contributions and the discussion structure (threaded discussion).

4.3. Research design

The experimental study was set up in the ecologically valid setting of a first year university course. This specific choice presents some threats. Although we tried to check a large number of research variables, the full complexity of the context cannot be completely under control. The research population is heterogeneous, variables and processes outside the research context can influence the collaborative activities (e.g., a group work organised in the context of another course). In the next sections, we will describe in detail how a research design was elaborated that helped to cope with the complexity of the setting.

4.3.1. Participants

Students in this study were enrolled for the course "instructional sciences", as part of the first year programme for psychology and educational sciences. All first-year students ($N = 850$), registered for this 7-credit course could – next to the weekly face-to-face sessions – opt for participation in formally organised online discussion groups. As stated earlier, the discussion groups focussed on the same learning objectives as the face-to-face sessions.. At the start of the course, all students ($N = 850$) were randomly assigned to a discussion group and after one trial session, lasting three weeks, the students could make a choice to participate further in the electronic discussion groups or not. It was understood that opting for the discussion groups was a formal choice. Participation was scored and accounted for 25% of the final score for this subject. Students who did not choose to participate in the discussion groups were solely evaluated on the basis of the final written exam that was to be taken by all students.

Over one third of the students opted for further participation ($n = 300$). We researched whether student opting or not opting differed in a certain way. Students did not differ in their attitudes towards computers, experience in working with computers and prior educational level. Therefore, the research sample was not considered to differ from the entire population. The students in the

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discussion groups worked in 38 different discussions groups. None of these 300 students dropped out of their group during the research period. They continued their activities during four months, while working on six consecutive discussion themes. Due to the initial possibility to opt out of the discussion groups, the sizes of the groups differ. Control for this variable resulted in a specific research hypothesis (H 6) and gives the possibility to research the impact of group size in the theoretical model.

4.3.2. Procedure

During the first face-to-face session of the semester, a demonstration was given of the CSCL-environment. Extra information was made available in the on-line environment. A number of strict rules was stated that defined the nature of expected student participation in the discussion groups. These rules helped to meet to a large extent the design guidelines of Johnson and Johnson (1996) that were discussed earlier in this article: (a) Participation in the discussion groups was – once students opted for the discussion groups – obligatory and a formal part of the curriculum. Therefore participation was scored and stood for 25% of the final score. (b) Successful participation implied that each student entered at least one primary reaction to solve the case, while making active use of the resources presented in the course reader. Second, each student was expected to reply at least once to the work of another student, again argumented and based on the available resources. (c) The moderator intervened at least once a week. He/she does not give concrete content feedback but rather structural feedback (scaffolding): e.g., your reactions was not based on clear arguments, and not based on specific resources; or "Most of your ideas neglect key features of the theoretical model presented by Bandura". At a quantitative level, all students met the minimum requirements of participation in the discussion groups.

In the on-line environment extra information was made available for students to get a clear understanding of the rules about minimum participation and instructions about good quality contributions. All contributions had to be based on a clear argumentation. The argumentation had to be derived from the knowledge base presented during the weekly face-to-face sessions. Students could refer to a chapter or paragraph of the course reader. Their contributions had to reflect the theoretical framework, the terminology and the propositions of the course reader also when to reacting to other students. Next to the course reader, student were advised also to refer to useful websites, well described personal experiences, and other books or articles than those referred to in the course reader.

The experiment was set up at the start of the academic year. The freshman students did not know each other personally and because of the size of the entire student group ($N = 850$) they scarcely had opportunities to meet fellow group members in person. Since the collaboration was set up in the context of the asynchronous discussion groups, it hardly made sense to start working together outside the on-line learning environment for this specific task. The students did not get any specific instructions about establishing social connections. In the context of other courses, the students had also to work together in collaborative settings. But the grouping was again organised ad random.

Students not opting for participation in the discussion groups, had no access to the CSCL-activities. They only attended the face-to-face sessions. There were no differences in the learning objectives pursued in the setting researched in this article and the normal classroom activities.

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4.3.3. Discussion themes

In line with constructivist principles, the discussion themes were based on real-life authentic situations; e.g., a case study in which a teacher education institute implements digital portfolios or a position paper of the Ministry of Education about a school reform, or the implementation of a new curriculum for nurses. Students got the opportunity to work during three weeks on a case. After these three weeks they did no longer have access to the former theme or their input. A new discussion theme was presented in their discussion group. To control for a possible interaction between the content of a discussion theme and cognitive processing, the developers elaborated for each discussion theme 15 alternative discussion tasks.

4.3.4. Selection of the research data

The transcripts of the output of 300 students, in 38 discussion groups for six different themes represent a massive amount of research data. For the purpose of the present study, a subset of data was selected from the larger data set. The transcripts of nine groups were selected. The ad random selection of the groups was based on group size: three smaller groups ($n = 8$, 9 or 10), three average size groups ($n = 11$, 12 or 13 participants) and three large groups ($n = 15$, 17 or 18 participants). For each individual group, all the communication submitted in relation to the second, fourth and sixth discussion theme was used for analysis purposes.

4.3.5. Choice of the unit of analysis

Each complete message was chosen as the unit of analysis for the coding. This choice created some problems during the coding process. As for the model of Veerman and Veldhuis-Diermanse (2001) we were obliged – in a number of cases – to split up an entire message into two or three messages. This was the case when, e.g., the first part of a message was not-task related (e.g., a remark about a meeting with some other students the day before) and the second part of message was clearly task-related. In a number of other cases the message contained clearly two completely different contributions. The determination of the unit of analysis was carried out in connection to the actual coding of the units. The reliability of this approach was controlled for (*Cronbach* $\alpha > 0.8$). A total of 1752 units of analysis could identified in this way.

4.3.6. Coding of the messages in the transcripts

Each unit of analysis was coded according to the two analysis models discussed in the theoretical section. Three independent researchers carried out this task. Every transcript was coded by each individual researcher. Atlas-Ti® was used as the coding tool. The researchers received training in the use of the package and had plenty of time to exercise with the tool. Sample data were used for training. Group discussion helped to get acquainted with the particularities of the models and to reach mutual agreement about the coding category to be selected.

After the coding of the first transcript of a discussion by each individual researcher, the quality of the coding was assessed by determining *Cronbach* α. A value of 0.7 was put forward as a criterion for inter-rater reliability. The initial values for the different discussions varied from 0.55 to 0.99. After negotiations, inter-rater reliability varied between 0.88 and 0.99. To check whether its was not always the same researcher changing the coding category, α was also calculated for each individual researcher. The latter represents the agreement between the first and second coding of a unit of analysis. The α value was always >0.7.

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4.3.7. Statistical analysis

Statistical analysis builds on descriptive statistics and χ^2 to test the hypotheses. Considering the fact that the coding resulted in ordinal and nominal scale data, the latter technique is appropriate to test distributions of proportions and changes in proportions of observed coding categories. With the exception of two cells, cell frequencies were never less than 5. To test the hypotheses that put suggest specific changes over time, we compared the transcripts of the first discussion theme with the last electronic discussion theme analysed. This represents a time difference of about four months.

5. Results

5.1. General results

Individual group members posted on average between 8.2 and 15.3 messages. The average per theme and per person varied between 2.5 and 5.1. In six out of the nine groups, the average number of messages per person increased between the first and sixth discussion theme. The majority of students posted more messages than formally required.

It is apparent that the communication in the CSCL-setting was for the most part task-oriented. The following proportions were observed: 88.1% of task-oriented and 11.9% of not-task-oriented communication. These proportions change hardly over time. As to task-oriented communication we observe 88% in theme 1, 76.3% in theme 3 and 87.6% in theme 6. Non-task-oriented communication fluctuates as follows: 12% in theme 1, 9.4% in theme 3 and 12.4% in theme 6.

When we study the distribution of the different types of non-task-oriented communication in the transcripts of the three discussion themes, we can observe some particularities. It is striking that we observe no communication of the type about 'planning' and 'non-sense' in the discussions about theme 3 and 6. Table 1 gives a summary of the distributions of the types of non-task-oriented communication.

Table 2 summarises the distribution of the types of task-oriented communication as discriminated by Veerman and Veldhuis-Diermanse (2001). We can derive from the table that most of the communication is related to the exchange of *new experiences, new theories* and *evaluation*.

Table 1
Distribution of non-task-oriented communication in the transcripts of the three discussion themes (Veerman et al., 2001)

	Theme 1 (%)[a]	Theme 3 (%)[b]	Theme 6 (%)[c]	All themes (%)[d]
Non-sense	4.5	0	0	1.4
Technical	10.6	38.8	5.1	14.6
Planning	7.6	6.1	0	3.8
Social	77.3	55.1	94.9	80.3

[a] $n = 66$.
[b] $n = 49$.
[c] $n = 98$.
[d] $N = 213$.

Table 2
Phases in knowledge construction (Veerman et al., 2001)

	Theme 1 (%)[a]	Theme 3 (%)[b]	Theme 6 (%)[c]	All themes (%)[d]
Phase 1 new idea (facts)	1.1	3	1.6	1.8
Phase 2 new idea (experience)	21.8	16.5	25.8	22.2
Phase 3 new idea (theory)	34.9	28.7	25.6	29.7
Phase 4 explicitation	5	5.8	4.2	4.9
Phase 5 evaluation	37.2	46	42.7	41.5

Note. Not all units of analysis reflect communication behaviour that could be coded along this typology. As a result, the total amount of units of analysis is lower than 1752.

[a] $n = 556$.

[b] $n = 363$.

[c] $n = 620$.

[d] $N = 1539$.

Table 3
Phases in knowledge construction (Fahy et al., 2001)

	Theme 1 (%)[a]	Theme 3 (%)[b]	Theme 6 (%)[c]	All themes (%)[d]
Phase 1 (vertical questions)	0.4	3.7	3.7	2.7
Phase 2 (horizontal question)	8.0	5.4	5.4	6.2
Phase 3 (statement)	36.4	45.1	42.5	41.3
Phase 4 (reflection)	52.0	43.4	47.2	47.6
Scaffolding	3.1	2.5	1.2	2.2

Note. Not all units of analysis reflect communication behaviour that could be coded along this typology. As a result, the total amount of units of analysis is lower than 1752.

[a] $n = 450$.

[b] $n = 408$.

[c] $n = 570$.

[d] $N = 1428$.

Table 3 shows the distribution of communication that reflects the phases in knowledge construction based on Fahy, Crawford, and Ally (2001). Next to the four consecutive phases of cognitive processing, also the proportion of scaffolding communication is specified. We perceive very high percentages of *reflection*, but low levels of *scaffolding*.

5.2. Results in relation to the hypotheses

Hypothesis 1. The proportion of task-oriented communication is larger than the proportion of non-task-oriented communication.

Applying χ^2 to test whether the observed frequencies reflect an equal distribution of the proportions is hardly necessary (χ^2 (1) 939.95, $p < 0.000$). Already at descriptive level, it is clear that we can reject the null hypothesis.

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Hypothesis 2. Communication in the discussion groups will become more task-oriented instead of non-task-oriented.

The very high frequencies of task-oriented communication observed during the first discussion hardly change during the sixth discussion. The changes in proportions are as a consequence not significant (χ^2 (1) 1.85, $p = 0.174$). We cannot reject the null hypothesis.

Hypothesis 3. In the context of non-task-oriented communication, more 'social' and 'planning' communication will be observed, at the expense of interaction in relation to 'technical issues' and 'non-sense' interaction.

Table 1 shows how *planning* and *non-sense* communication is no longer observed during the sixth discussion theme. Chi-Square analysis is therefore only applied to test changes in the proportions of *technical* and *social* communication. We observe slightly lower numbers of technical communication and a minimal increase in social communication. These changes in proportions are not significant at the 1% level (χ^2 (1) 4.47, $p = 0.034$). We are able to reject the null hypothesis, but this only at a lower confidence interval.

Hypothesis 4. The CSCL-environment fosters higher proportions of higher phases of knowledge construction.

We check this hypothesis twice, by carrying out the analysis on the data sets obtained by applying the two different analysis models. Building on the model of Veerman and Veldhuis-Diermanse (2001), we test whether the proportions of communication behaviour that mirror different phases of knowledge construction are equally distributed. Analysis of the descriptive data in Table 3 already suggests that no equal distribution is observed. This is confirmed by the Chi-Square analysis (χ^2 (4) 683.34, $p < 0.000$). We observe significantly less communication related to presentation of new facts and experiences and significantly higher amounts of communication that reflects ideas based on theories and evaluation. In contrast, significantly lower proportions of explicitation are observed. In general, we can conclude that the null hypothesis can be rejected. Application of the same analysis procedure to the data based on the model of Fahy et al. (2001), results in a clearer picture. Table 4 suggests unequal distributions. This is confirmed by the Chi-Square analysis (χ^2 (3) 824.78, $p < 0.000$). We observe to a significantly higher extent phase 3 and phase 4 communication types. Remember that we exclude the category *scaffolding* from this analysis since this type of communication is not a phase of knowledge construction. In view of the results of the two analyses, we are able to reject the null hypothesis.

Hypothesis 5. At the end of the research period, more communication reflecting higher phases of knowledge construction will be observed.

This hypothesis questions whether there is a significant difference between the first and last discussion in the occurrence of communication that reflects higher phases of knowledge processing. Again, the hypothesis can be tested twice considering the two analysis models applied in coding the messages.

When testing the hypothesis on the data based on the model of Veerman and Veldhuis-Diermanse (2001), we expect an increase in the proportions of *new ideas based on theories*, *explicitation* and *evaluation*. The data in Table 2 suggest changes. There is a clear increase in exchanges about *evaluation* and an increase in putting forward *new ideas based on experiences* and *new ideas based on facts*, but a slight decrease in *explicitation*, and a clear decrease in exchange of

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Table 4
Distribution of types of communication in relation to different group sizes

	Small groups (%)	Average group size (%)	Large groups (%)
Not-task oriented	4.8	13.3	15.1
Task oriented	95.2	86.7	84.9
Not-task oriented communication[a]			
Non-sense	0	0	12.3
Technical	17.6	18.3	62.6
Planning	17.6	1.7	0.9
Social	64.7	80	24.2
Task oriented communication[b]			
Phase 1 new idea (facts)	2.4	3.0	0.8
Phase 2 new idea (experiences)	19.5	23.1	21.6
Phase 3 new idea (theories)	33.1	31.3	27.3
Phase 4 explicitation	4.7	5.7	9.1
Phase 5 evaluation	40.2	36.8	41.2
Phases in knowledge construction[c]			
Phase 1 vertical questions	2.3	3.9	2.0
Phase 2 horizontal questions	3.7	5.4	11
Phase 3 statements	44.6	38.7	38.5
Phase 4 reflection	47.7	49.0	40.9
Type 5 scaffolding	1.7	2.9	7.6

[a] $n = 213$.
[b] $n = 1539$.
[c] $n = 1428$.

new ideas based on theories. This change in proportions is significant (χ^2 (4) 27.19, $p < 0.000$). As a result we cannot completely reject the null hypothesis. The hypothesis seems only to be valid when we consider the communication about *evaluation.*

As to the model of Fahy et al. (2000), the results in Table 3 suggest that there is again a change over time that reflects a certain increase in communication that reflects higher phases of knowledge construction. This change in proportions is significant (χ^2 (3) 130.92, $p < 0.000$). But the change is again not completely in line with our expectations. There is an increase in *vertical questioning* and *statements* and a small decrease in *horizontal questioning* and *reflections*. As a result we cannot reject the null hypothesis.

Hypothesis 6. In smaller groups, we observe larger proportions of task-oriented communication and higher proportions of the higher phases of knowledge construction.

The data in Table 4 summarise the distribution of types of communication, considering the differences in group size. The data show how non-task-oriented communication increases in large groups ($n > 14$). This change is significant (χ^2 (2) 24.22, $p < 0.000$). Discussion in smaller groups results in higher levels of task-oriented communication. The null hypothesis is to be rejected in relation to this dimension in the analysis model.

Secondly, there is a clear and significant difference in proportions within the types of non-task-oriented communication (χ^2 (6) 109.00, $p < 0.000$). *Non-sense* communication is observed to a higher extent in large discussion groups, and communication focussing on *social issues* decreases. A striking high number of communication in relation to *technical* issues is observed. [3] As to the distribution of non-task-oriented communication, the null hypothesis can be rejected. Third, there is also a clear difference in the frequencies of task-oriented communication between small, average size and large discussion groups (χ^2 (8) 20.36, $p = 0.009$). The null hypothesis is to be rejected. But, the relevance of the differences is limited since the order in which the 5 phases occur, is not affected. Within each group size, *evaluation* is pre-dominant, followed by *new ideas based on theories* and *new ideas based on experiences*. New ideas based on facts is consistently the least observed type of communication. Considering the model of Fahy et al. (2000), we also observe significant differences in the distribution of proportions between groups of different size (χ^2 (8) 48.76, $p < 0.000$). In relation to each group size, the largest proportions are observed in the two highest phases of knowledge construction. But the relative proportions are especially higher in the small and average size discussion groups. In the large discussion groups, we observe greater proportions of *horizontal questioning*. Building on these analysis results, we can reject the null hypotheses.

In summary, the different steps in the analysis result in a consistent picture: the null hypothesis can be rejected.

6. Discussion

In this first section of the discussion, we put the results in a broader perspective to explain particularities and compare the results with the results of other studies. The latter is constrained by the fact that hypothesis testing is still rarely found in the field of CSCL research. Second, we discuss some methodological remarks in relation to this study.

6.1. Discussion related to the hypotheses

Hypothesis 1. The proportion of task-oriented communication is larger than the proportion of non-task-oriented communication.

The results are consistent with comparable studies of e.g., McKenzie and Murphy (2000) and De Wever et al. (2002). These researchers also observed a large task-oriented communication and this is contrast to earlier studies of e.g., Henri (1994). A first explanation could be found in the design of the task environment. Learners received very operational guidelines to direct their discussion behaviour. This is in line with recommendations of Johnson and Johnson (1996). Strijbos and Martens (2001) suggest in this context to present *roles* to learners in discussion groups or to adapt the technical design of the discussion tool as such that it reflects a specific task structure (see e.g., Suthers, 1998; Veerman, 2000). A second explanation for the results can be

[3] In testing the hypothesis for differences in proportions in non-task-oriented communication, it is important to consider that in two cells, the frequencies are <5.

related to the formal character of the work in the discussion groups. Students were well aware of the fact that the discussions were monitored and evaluated.

Hypothesis 2. Communication in the discussion groups will become more task-oriented instead of non-task-oriented.

Given the very high levels of task-oriented behaviour observed in the first discussion, one can expect that the proportion of task-oriented behaviour hardly increases. This ceiling-effect masks potential changes in the distribution. Although the null hypotheses cannot be rejected, we can state that at least the level of task-oriented communication did not decrease, but remained as high as before.

Hypothesis 3. In the context of non-task-oriented communication, more 'social' and 'planning' communication will be observed, at the expense of interaction in relation to 'technical issues' and 'non-sense' interaction.

The analysis results indicate that we can reject the null hypothesis only at a lower confidence interval. ($p < 0.05$). Nevertheless, the results are in line with an earlier study of McKenzie and Murphy (2000). They also observed large numbers of *social* communication at the end of the discussion period. There might be a specific explanation for the drop in interaction about *planning*. The discussion themes were presented in a very operational way. Students were presented with a clear prescription about the way to solve the cases. This might have affected the need for group members, at the end of the four-month discussion period, to discuss in detail planning issues in relation to the last discussion theme. An alternative explanation could be related to the statistical analysis technique. We applied Chi-Square analysis to compare the sixth discussion theme with the first discussion theme. This might neglect differences that could be observed on the occasion of the second discussion. Table 2, shows e.g., apparent levels of communication focussing on "technical" issues during the discussion of the third theme.

Hypothesis 4. The CSCL-environment fosters higher proportions of higher phases of knowledge construction.

Considering the model of Fahy et al. (2000), we could clearly reject the null hypothesis. As to the model of Veerman et al., the results were comparable, but not in line with our predictions. Lower levels of *explicitation* have been observed.

The other results in relation to this hypothesis are comparable to the results of the study of De Wever et al. (2002). This research team, building on alternative analysis model of Gunawardena et al. (1997), could also confirm the hypothesis that group discussions result in communication that mirrors higher phases of knowledge construction.

The results of this analysis can also be used to control the content validity of the two analysis models applied to test this hypothesis. Given the interrelationship between both models (see Fig. 2), the congruent results of the statistical analysis underpin the theoretical position of both models that identify phases in knowledge construction.

Hypothesis 5. At the end of the research period, more communication reflecting higher phases of knowledge construction will be observed.

The results do not completely support the hypothesis. Considering the model of Veerman et al. (2001), the analysis results indicate that the hypothesis looks only valid when we consider the

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changes in proportions in communication about *evaluation*. Considering the model of Fahy et al. (2000), the initial high proportion of the communication about *statements* and *reflection* (88.4%) is also present in the sixth discussion (89.7%). It is possible that testing this hypothesis is restrained by the high percentages already observed on the occasion of the first discussion. This ceiling effect is more clear if we limit our analysis to the changes in proportions of e.g., the two highest phases of knowledge processing *explicitation* and *evaluation* in the first analysis model. The change in proportions is not significant (χ^2 (4) 0.004, $p = 0.949$).

A clear point of discussion is the low frequencies observed in the category *explicitation*. A further refining or elaboration of earlier ideas seems to be observed to a lesser extent. A possible explanation for these low frequencies can again be related to the explicit structure presented to the students in the task environment. Students were asked to ground their contributions in the resources made available but they were not explicitly asked to refine or elaborate on earlier ideas. If this explanation is true, this is of importance for instructional designers and developers of learning environments that focus on the use of discussion groups. Liaw and Huang (2000) and Northrup (2001) determined that in a learning environment, interaction does not just happen, but must be intentionally designed into the instruction. This should be taken into account for future research.

On the hand, the present study shows how a clear task structure fosters specific task-oriented communication, but on the other hand, the results also suggest that a too rigid task structure might inhibit the occurrence of specific types of cognitive processing. A careful balance should be respected between open and closed structure of the discussion tasks.

Hypothesis 6. In smaller groups, we observe larger proportions of task-oriented communication and higher proportions of the higher phases of knowledge construction.

The results of the analysis were very clear. Group size clearly affects the types, structure and phase of knowledge construction in asynchronous discussion groups. Smaller sized groups perform at a quantitative and qualitative higher level. This is in line with the findings of comparable studies (see e.g., Mennecke, 2002; Veerman, 2000).

Most researchers suggest a group size of 10 to 12 participants to guarantee a sufficient critical mass to direct the discussion. A large group size ($n > 12$), causes participants to have to deal with a too high number of messages and invokes extraneous cognitive load. As our research suggests, this could be solved by adding more structure to the task environment by e.g., giving more concrete directions to the participants about the way to tackle the problems (see also Cifuentes, Murphy, Segur, & Kodali, 1997; Harasim, Hiltz, Teles, & Turoff, 1998; Palloff & Pratt, 1999).

6.2. Methodological remarks

In the present study an attempt was made to meet the critical methodological issues that are raised in the CSCL-literature. Nevertheless, a number of methodological remarks can still be made. A first remark is related to the lack of control groups in the research design. A future experimental design with control groups could help to research to a clearer extent the specific differential impact of the group discussion as compared to e.g., students that solve the tasks in an alternative individual way or group setting. Given the authentic instructional context of the pre-

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sent study, this was not possible. Moreover, the ad random assignment of students to different conditions is from an ethical point of view not always acceptable.

A second methodological point of discussion is related to the characteristics of psychology and education students taking a course about "instructional sciences". Given the focus of the course, these students might have been more sensitive to the topic and the research context. But, we tried to minimise negative side-effects by organising the course with freshman students, at the start of the academic year and as part of the "normal" instructional setting.

A third remark can be made about the fact that the 300 students were not selected ad random from the student population. Are the results typical for these 300 students or can they be generalised? A post hoc analysis of student characteristics indicates that the 300 students are not significantly different from the overall student population, considering their *attitudes towards computers*, *experience in working with computers* and *prior educational level*. A fourth comment is related to the content validity of the analysis models applied in the study. The results in relation to hypothesis 4 give some basis to the content validity of the two models. But future research should pay – a priori – more attention to this psychometric quality of the instruments used. In this study we applied Chi-Square to test the hypotheses. This statistical test demonstrates some weaknesses. The technique allows for testing the overall changes in proportions, but is less suited clear to support the changes in relation to changes in specific cell frequencies. Moreover, the multivariate nature of the complex research setting is difficult to research with this non-parametric technique. A final remark is related to the quality of the knowledge constructed by the group and each individual. The present study builds on the central assumption that the quality of the communication does mirror the quality of the cognitive processing that will result in the construction of mental models in LTM. The present study did not control the actual quality of these final mental models by presenting, e.g., a specific posttest.

7. Conclusions

To what extent does working in asynchronous electronic discussions foster knowledge construction? The general results of the present study bring forward evidence that supports the hypotheses put forward in relation to the general research question. Interaction in the discussion groups becomes more intense, stays task-oriented, and reflects high phases in knowledge construction. These results give us sufficient base to ground the frame of reference put forward in the theoretical section of this article. The theoretical model also puts forward the potential impact of the variables *group size* and helps to point at the critical importance of the *task structure*. Clear results could be presented about the impact of group size on the nature and quality of the discussions and the phases of knowledge construction. Small and average sized groups perform better. Higher phases of knowledge construction are observed within these groups. Large groups invoke more communication about *non-sense* topics and *technical issues*. The impact of the variable *task structure* was stated, but remarks were made about the potential inhibiting effect on communication about *planning*. The results were less clear as to the changes over time. We predicted that during the last discussion, the students would communicate more about issues that mirror higher levels of knowledge construction. The results were less clear. We

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pointed at a possible ceiling-effect due to the very high proportions of higher levels observed during the first discussion.

From a methodological point of view, the present study shows characteristics that distinguishes the study from other attempts in the literature: large groups of students have been involved during a long period of time and large quantities of units of analysis have been analysed. Extra attention was paid to guarantee high levels of reliability in the identification of the units of analysis and the coding of the interaction. At a basic level, content validity of the instruments was guaranteed by the link between the analysis models and the theoretical frame of reference. The fact that the analyses based on both models result in comparable results gives adds to the content validity of the models used.

Some critical points were raised about methodological characteristics that should be taken into account in future CSCL-research. We stressed the importance of determining to a better extent the validity of the analysis models. External validity approaches could be adopted. Next, the adoption of an experimental research design was discussed by referring to the use of control groups. But this should take into account the authentic learning setting and respect for the learners as an individual and as a group member.

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