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Learning in asynchronous discussion groups: a multilevel approach to study the influence of student, group and task characteristics

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The research reported in the current article studies the impact of learning in asynchronous discussion groups on students' final exam scores and levels of knowledge construction. Multilevel analyses were applied to uncover the specific influence of student, group and task variables. The results indicate that the impact of student characteristics on both dependent variables is of higher significance than characteristics of the discussion group students are allocated to. With regard to levels of knowledge construction, task characteristics also appear to be of importance.

With regard to final exam scores the analyses reveal a significant impact from student learning style, attitude towards task-based learning, the number of student contributions and the level of knowledge construction in these contributions. No significant group characteristics were observed.

As to levels of knowledge construction, the analyses revealed that the amount of contributions and the attitude towards the online learning environment are significant predictors. The intensity of the interaction in a group had a significant impact. As to task characteristics, significant differences were found between consecutive themes. These disappeared when taking into account task complexity.

Keywords: Computer-mediated communication; Cooperative/collaborative learning; Interactive learning environments; Post-secondary education

1. Introduction

There is a growing body of empirical research that grounds theoretical assumptions about the impact of computer-supported collaborative learning (CSCL) on motivation, social processes and cognition. Studies confirm that student involvement is more intense and equally distributed among group members in CSCL environments as compared with face-to-face sessions (Cooney 1998, Kang 1998). CSCL promotes metacognitive processes (Alavi 1994, Ryser *et al.* 1995), reflective interaction (Baker and Lund 1997), and problem solving (Jonassen and Kwon 2001). Students are more interested and more intrinsically motivated (Reiser 2001, Wolters 1998). Finally, it appears that high levels of cognitive knowledge construction are reached (Schellens and Valcke 2002) and critical thinking and inquiry is promoted (Duffy *et al.* 1998).

The present study focuses on the impact on knowledge construction and academic performance. It builds on preceding research that already identified a positive and significant impact of CSCL on knowledge construction (Schellens and Valcke 2002, 2005). But the actual research especially focuses on the identification of key variables that help to account for the positive impact of CSCL. Research about collaborative learning has moved beyond the question of whether collaborative learning is effective and focuses now on the conditions that define the efficacy and efficiency of CSCL. Moreover, since CSCL does not systematically produce positive learning outcomes (Dillenbourg 2002, Lockhorst *et al.* 2002), the reorientation is helpful to shed light on possible explanations for the lack of a positive impact in some CSCL studies. Researchers report large variations in the quality of interaction and learning outcomes (Häkkinen *et al.* 2001, Lehtinen *et al.*

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1999). Some of these differences are due to the result of differences in length of studies, technology used or differences in research methodology, but might also be the result of the quality of the group processes (Shaw 1981, Strijbos *et al*. 2004). Therefore, the present study will especially focus on the impact of student, group and task characteristics on dependent variables.

After a short description of the research context and a description of the potential impact of student, group and task variables, the theoretical framework of the study is presented. The major part of the article centres on the in-depth description of a multilevel analysis of the research data. The conclusions focus on the implications of the research results and directions for future research.

2. Context of the present study

The study is set-up in the context of a seven-credit, first year university course 'Instructional Sciences' that is part of the academic bachelors' curriculum 'Pedagogical Sciences' at Ghent University. This freshman course introduces students to a large variety of complex theories and conceptual frameworks related to learning and instruction. The innovative redesign of this course has been studied and monitored since 1999/2000 and focuses on the implementation of social-constructivist principles, such as active learning, self-reflection, authentic learning and collaborative learning (Schellens and Valcke 2000).

The asynchronous discussion groups, studied in the present study, were a formal part of the course. Students participated in the discussion groups during a complete semester (October – January). Every three weeks a new discussion theme was introduced. The aim of introducing discussion groups was to form communities of practice, where students come together to help out each other, solve problems, and share and create knowledge collaboratively (De Laat 2002). The objectives of participation in the discussion were communicated to the students: active processing of the theoretical base that was introduced during weekly face-to-face working sessions and application of this knowledge while solving authentic cases.

3. Theoretical exploration of student, group and task variables

Learning in CSCL settings can be considered as a specific type of collaborative learning. The theoretical and empirical studies in this area present convincing empirical evidence to ground collaborative learning in a large variety of instructional settings. Taking the review studies and meta-analyses of Johnson and Johnson (1994) and Slavin (1995) as a starting point, a concrete list of design guidelines for collaborative learning can be put forward. Analysis of some of these guidelines helps to determine and to position student, group and task variables, which will be taken into account in the present study.

Two basic guidelines stress the need for 'positive interdependence' and 'individual accountability'. Positive interdependence implies that team members need each other to succeed (Johnson *et al*. 1998). Individual accountability refers to the measurement of whether or not each group member has achieved the group's goal. The literature also presents concrete suggestions to guarantee the implementation of the guidelines. In relation to positive interdependence, they refer to specific strategies, such as presenting challenging tasks, which stimulate learners' intrinsic motivation and collaborative skills (Cohen 1994), assigning the group a clear, measurable task and finally blending positive goal interdependence with other types of positive interdependence (Johnson *et al*. 1998). In relation to individual accountability, authors advise to keep the size of the groups small, to present individual tests to each student or control for understanding, and to observe each group and group member and keep track of students' contribution to the group's work, assessing both the quality and quantity of individual contributions (Johnson *et al*. 1998).

Analysis of the guidelines results in the following implications for CSCL that help to account for student, group and task variables. With regard to task characteristics, the guidelines suggest to put forward a very clear and measurable task. However, not all authors agree as to this issue. Cohen (1994) for example states that a strong structuring of the task might hamper the collaborative process. Recent research in CSCL settings suggests that a clear task structure is needed to foster cognitive processing and academic performance (Dillenbourg 2002, Roschelle and Pea 1999, Weinberger *et al*. 2003). Research also points at the need to explicitly state directions, guidelines and types of expected cognitive processing that lead to a qualitative discussion and intended outcomes (Cifuentes *et al*. 1997, Harasim *et al*. 1998, Palloff and Pratt 1999, Schellens and Valcke 2005). Hakkarainen *et al*. (2002) also indicate the need to prompt students to articulate their conceptual understanding to promote learning and knowledge building. More research is, however, needed to obtain a better understanding of the impact of task features (Thatcher and De La Cour 2003). Therefore, task complexity will be considered as a key research variable in the present study.

In relation to group characteristics, prior research has stressed the importance of fostering intensive group interaction (Dillenbourg *et al*. 1995, Schellens and Valcke 2005). These authors also point at the relationship between levels of interaction and group size. More specifically, they argue that a smaller group size, with 8 to 10 students, results in the highest level of group interaction. This is, however, not consistent with the opinion of others researchers. Most are in favour of groups that consist of four to five students, because larger groups do not provide an opportunity for all members to participate and enhance their skills (Cooper *et al.* 1990, Johnson *et al.* 1998, Nurrenbern 1995, Slavin 1995). The literature also centres on group composition as an important group variable. Research results, however, are rather contradictory. Some studies emphasize that groups should be heterogeneous (Cooper *et al.* 1990, Johnson *et al.* 1998, Nurrenbern 1995, Slavin 1995). Other studies contradict this position (Felder *et al.* 1995, Rosser 1997, Sandler *et al.* 1996). In the context of the present study, group size will be kept constant (8–10) and group composition will be randomized, to obtain heterogeneous groups. Intensity of the group interaction will be controlled and used as a research variable.

Regarding the characteristics of individual students, the cooperative learning literature hardly gives indications whether specific characteristics advance or hinder cooperative learning; but authors do report about interaction effects (Johnson and Johnson 1994, Slavin 1995). The same applies to research in the field of CSCL. Variables such as gender, age and appreciation are mostly considered as background variables. Hakkarainen and Palonen (2003), for example, report about the impact of gender on students' interest in CSCL, which might influence learning outcomes. Kreijns *et al.* (2003) have identified student learning styles as a factor that influences the effectiveness of collaborative learning. Schellens and Valcke (2000) found that consistency between the requirements of the online learning environment and learning styles is important. In the same study, they also pointed at student satisfaction, which interacts with the impact on cognitive outcomes. This is in line with the findings of Desmedt (2004) who states that learning styles play their role as individual difference variables within the full complexity of the learning process.

In the context of the present study the following variables will be considered in the theoretical base: learning styles and attitude towards studying in the CSCL environment.

In the following section, the task, group and individual variables discussed will be integrated into a broader theoretical framework to ground our hypotheses about the impact of CSCL on knowledge construction and academic performance. In the research design and analysis of the results, these three clusters of variables will also form the basis of a multilevel analysis to study their specific and interaction effect on the dependent variables.

4. Theoretical framework of the present study

Figure 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 (for comparable approaches see Baker 1996, Doise and Mugny 1984, Erkens

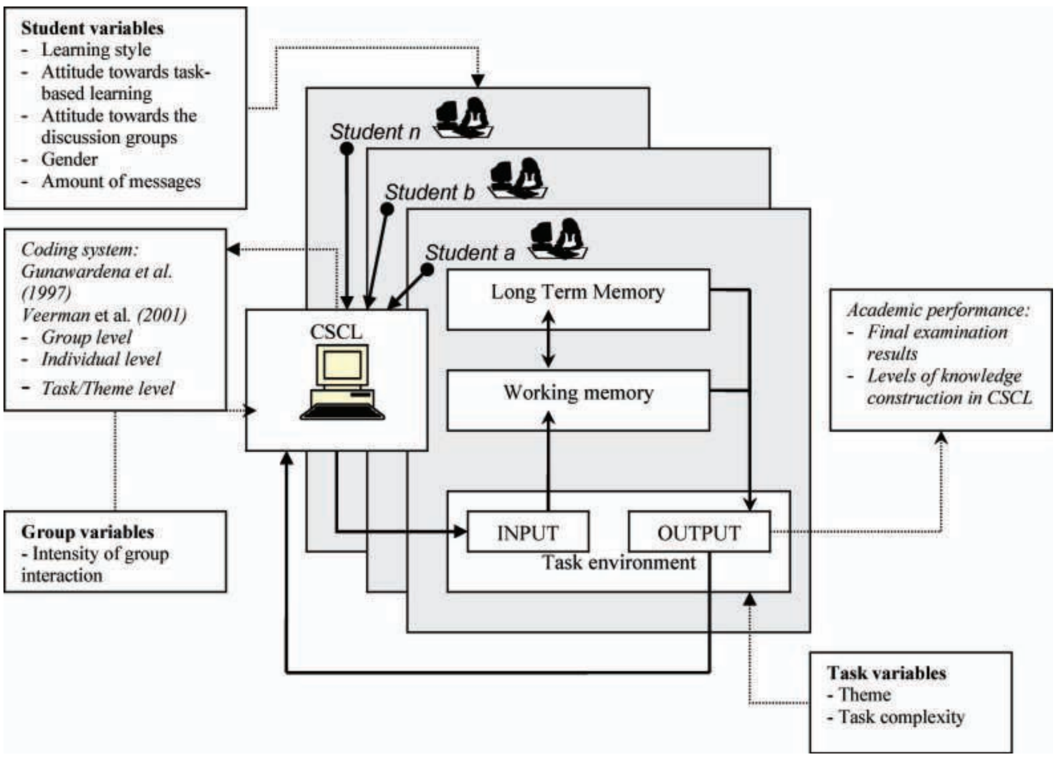

Figure 1. Graphical representation of the theoretical base for the present study.

1997, Kreijns and Bitter-Rijkema 2002, Petraglia 1997, Savery and Duffy 1996).

The figure depicts three key substructures: (1) the individual learning process of a student; (2) the task put forward in the CSCL environment; and (3) the group dimension in the CSCL setting. The learning process of an *individual student* (student a) is presented at the centre. 'Learning' is considered as information processing activity, building on the assumption that learners engage actively in cognitive processing to construct mental models (or schemas), based on individual experiences. In this way, new information is integrated into existing mental models. The *active processing assumption* invokes three types of processes in and between working and long-term memory: selecting, organizing and integrating information (Mayer 2001). The mental models are stored in and retrieved from long-term memory. Because of the importance of individual experiences and the pre-existing cognitive structures, characteristics of the individual learner, such as attitude towards the learning environment and the group discussion, gender, and learning styles are considered of importance. Moreover, it is hypothesized that the more students express their line of thought, the more the construction of mental models is facilitated. Therefore, the amount of individual contributions is regarded as relevant.

A second substructure points at the impact of *the task* put forward in the learning environment and discussed in the CSCL setting. The assignments trigger the cognitive processes of the individual students. The content and complexity of the task are considered to influence the nature of the cognitive activities, resulting in output that reflects certain levels of knowledge processing.

Finally, a third substructure refers to the importance of *the group* in the CSCL setting. An important characteristic in this respect is the intensity of interaction. The task is put forward in a collaboration environment. This invokes *collaborative learning* that builds on the necessity of the learner to organize output that is relevant input for the other learners (student a to n). The exchange at input and output level is assumed to reflect a richer base for the cognitive processing of each individual group member. This assumption is essential in the cognitive flexibility theory of Spiro *et al.* (1988). The output is also a central 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. In this respect, Gunawardena *et al.* (1997) use the concept of *entire Gestalt*. The written student output mirrors their concrete processing activities. Individual processing is slowed down by the complex nature of the tasks since learners have to cope with selection, organization and integration processes. As a consequence, learners experience the limited capacity of their working memory (Mayer 2001), also referred to as cognitive load (Sweller 1988, 1994). However, learners in a collaborative setting can profit from the processing effort of other group members. The output of each individual student is organized since it is derived from his/her own mental models. Therefore it is assumed that this output is more easily accessible for other learners in the collaborative setting. Since the output of other learners is organized, students are expected to experience lower levels of cognitive load when using this output as input for their own individual cognitive processing. This subsequent output is expected to be of a better quality, thus reflecting a higher level of knowledge construction. In the present study, we build on the work of Gunawardena and her colleagues (1997) to identify students' levels of knowledge construction.

The content analysis scheme of Gunawardena and colleagues (1997) has been developed following a grounded theory approach. It proposes a typology to evaluate knowledge construction through social negotiation. The authors developed an interaction analysis model that discriminates between five phases in the negotiation process during a social constructivist learning process. Every phase corresponds to a typical level of knowledge construction. In the long run, every learner is expected to progress to the highest phases in this negotiation process:

(1) *Phase 1. Sharing/comparing information:* In this phase, typical cognitive processes reflect observation, corroboration, clarification and definition.
(2) *Phase 2. Dissonance/inconsistency:* In phase 2, cognitive processes focus on identifying and stating, asking and clarifying, restating, and supporting information.
(3) *Phase 3. Negotiating what is to be agreed (and where conflicts exist)/co-construction:* This type of message is about proposing new co-constructions that encompass the negotiated resolution of the differences.
(4) *Phase 4. Testing tentative constructions:* The newly constructed structures are tested, and matched to personal understanding and other resources (such as the literature).
(5) *Phase 5. Statement/application of newly-constructed knowledge:* This is related to final revisions and sharing the new ideas that have been constructed by the group.

5. Research design

5.1 *Participants*

All students enrolled for the seven-credit freshman course 'Instructional Sciences' participated in the present study ($N = 230$). Students were randomly assigned to one of the 23 discussion groups. Approximately 10% of the freshmen were male students. The largest part of the students (88%)

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just finished secondary education; 12% already possessed a diploma of higher education.

5.2 *Procedure*

After a trial discussion session of three weeks, students participated in four consecutive discussion themes. The entire experimental treatment lasted four months. Students were flexible as to time and place to work on the discussion assignments, within the three-week time frame.

During the first face-to-face session of the semester, a demonstration was given of the CSCL environment. Extra information was made available in an online learning environment. A number of strict rules, which defined the nature of expected student participation, were stated

(1) Participation in the discussion groups was a formal part of the curriculum. Participation was scored and represented 25% of the final score.
(2) Successful participation implied that each student posted at least one primary reaction to solve the case, making active use of the course reader. Second, each student was expected to reply at least once to the work of another student, with arguments based on the course reader.
(3) The moderator followed the ongoing discussions and restricted interventions to giving structural feedback (scaffolding).

After three weeks, students no longer had access to a particular theme since a new discussion theme was presented.

At the start and at the end of the course, a number of instruments were administered and a questionnaire had to be filled out by the students. The questionnaire helped to gather data about the student characteristics: age, gender, and educational level. Next, a special section was added to measure the student characteristics 'attitude towards the task-based learning environment' and 'attitude towards the group discussions'.

Furthermore, the Approaches and Study Skills Inventory for students (ASSIST) was presented to the students to gather information about the student characteristic 'learning styles'. Reported reliability for the ASSIST is high, with Cronbach's α between 0.80 and 0.87 (Entwistle *et al.* 2000).

The information about the group characteristic 'intensity of interaction' was derived from the analysis of the contributions to the discussion groups. The task characteristic 'task complexity' will be explained when giving information about the discussion themes.

5.3 *Hypotheses*

Central in the present research is the question to what extent the impact of CSCL on academic performance and knowledge construction is influenced by student, group, and task variables. The consecutive hypotheses research step-by-step sub-questions in relation to this general research question.

(1) Hypotheses related to the impact of CSCL on academic performance as measured by the final examination.
    (a) *Impact of student characteristics*
        (i) More intensive and active participation in the discussion groups will have a significantly positive impact on the final exam scores.
        (ii) Students who achieved high levels of knowledge construction during the discussion groups will obtain significantly higher final exam scores.
        (iii) Students with a deep or strategic learning style will obtain significantly higher final exam scores.
    (b) *Impact of group characteristics*
        (i) Students who participate in a discussion group with intensive discussion activity will obtain significantly higher final exam scores.
(2) Hypotheses about the impact of CSCL on academic performance as reflected in the levels of knowledge construction.
    (a) *Impact of student characteristics*
        (i) More intensive and active participation in the discussion groups is positively related to students' level of knowledge construction.
        (ii) Students with a positive attitude towards task-based learning at the beginning of the academic year will reach significantly higher levels of knowledge construction.
        (iii) Students with a deep or strategic learning style will obtain significantly higher levels of knowledge construction.
    (b) *Impact of group characteristics*
        (i) Being part of a group with intensive discussion activity will lead to significantly higher individual levels of knowledge construction.
    (c) *Impact of task characteristics*
        (i) Students will reach higher levels of knowledge construction as the discussion progresses.
        (ii) The complexity of the task has a significant impact on the level of knowledge construction.

5.4 *Discussion themes*

In weekly face-to-face lectures, students were introduced to a large variety of complex learning theories and conceptual frameworks related to learning and instruction (behaviourism, cognitivism, constructivism, . . .).

Parallel to the lectures, active processing of the theoretical base and application of the knowledge introduced in the face-to-face sessions was stimulated by working in the discussion groups.

In line with constructivist principles, the discussion themes were based on real-life authentic situations. Simplified examples of assignments were: developing an online learning environment for a particular higher education students, starting from a behaviouristic approach to learning and instruction; visiting a virtual museum, discussing whether it is a constructivist learning environment, developing a checklist and suggesting adjustments to improve the museum in view of a more constructivist approach to learning and instruction; discussing the advantages and disadvantages of the different evaluation approaches in view of specific criteria. These tasks were supported with useful links to websites and additional questions were presented to structure the task completion.

The task complexity was controlled for since it was a key variable in the research design. The degree of complexity of the tasks showed an upward trend, with the third assignment as the most complicated. In the initial tasks students only had to deal with a limited number of questions. Moreover, the assignments were supported with all the necessary information (clustered on the same web page), documented with the conceptual base and a solution procedure was suggested in the learning environment. The tasks presented during the third and fourth discussion theme were more comprehensive (information on different web pages) and complex, the conceptual base was not completely given and/or clear, additional information had to be looked up using different sources, and the solution procedure was not completely prescribed. A lot of information was given in English as a foreign language and more supplementary questions had to be answered.

The 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 threaded discussion structure. Figures 2 and 3 illustrate the threaded discussion and show an excerpt of the discussion.

5.5 *Analysis of the transcripts of the discussion groups*

The transcripts of the output of 230 students for four different themes represent a massive amount of research data. For analysis purposes, eight groups were randomly selected from the 23 discussion groups. All communication submitted in relation to the four discussion themes was used for analysis purposes.

5.6 *The unit of analysis*

In line with the suggestion of Rourke *et al.* (2001), the complete message was chosen as the unit of analysis for the coding. In a limited number of cases, messages were split into subparts. Reliability of this approach was controlled for (percent agreement > .80). A total of 1428 units of analysis were distinguished.

5.7 *Coding of the messages in the transcripts*

Each unit of analysis was coded by three independent research assistants. Atlas-Ti® was used as the coding tool. The research assistants were trained extensively by using sample data. Group discussion helped to become acquainted with the particularities of the schemes and to reach mutual agreement about the coding category to be selected. Assessment of inter-rater reliability resulted in quite high percent agreement measures. The initial value was 0.81; after negotiations, percent agreement was 0.87. To check whether it was not always the same research assistant changing his/her coding, percent agreement was also calculated for each individual research assistant. All values were larger than 0.70.

5.8 *Statistical analysis*

The research design was set up in an authentic setting with an entire first year student population randomly assigned to different discussion groups. A particular characteristic of the study is that no control group is used in the design. From an ethical perspective it was not acceptable to exclude a group of students from the formal learning process. Moreover, considering the nature of the research question a traditional control group is not needed.

Because in the present study the students ($N = 230$) are divided in a number of groups ($N = 23$), the problem under investigation has a clear hierarchical structure. The individual observations are not completely independent because of what individuals share in the group setting (Hox 1994, Stevens 1996). The critical position of statistical analysis techniques has only recently been raised in CSCL research. Traditional analysis techniques that consider individual student measures as the base for analysis are questionable because assumptions about independence of residual error terms are violated. Moreover, cross-level interactions between explanatory variables defined at different levels of the hierarchy can influence the individual outcome variable (Hox and Kreft 1994). Because of this joint modelling of individual and group variables, we took a multilevel modelling perspective on analysing the data, as these models are specifically geared to the statistical analysis of data with a clustered structure. Applying multilevel analysis results in more efficient estimates of

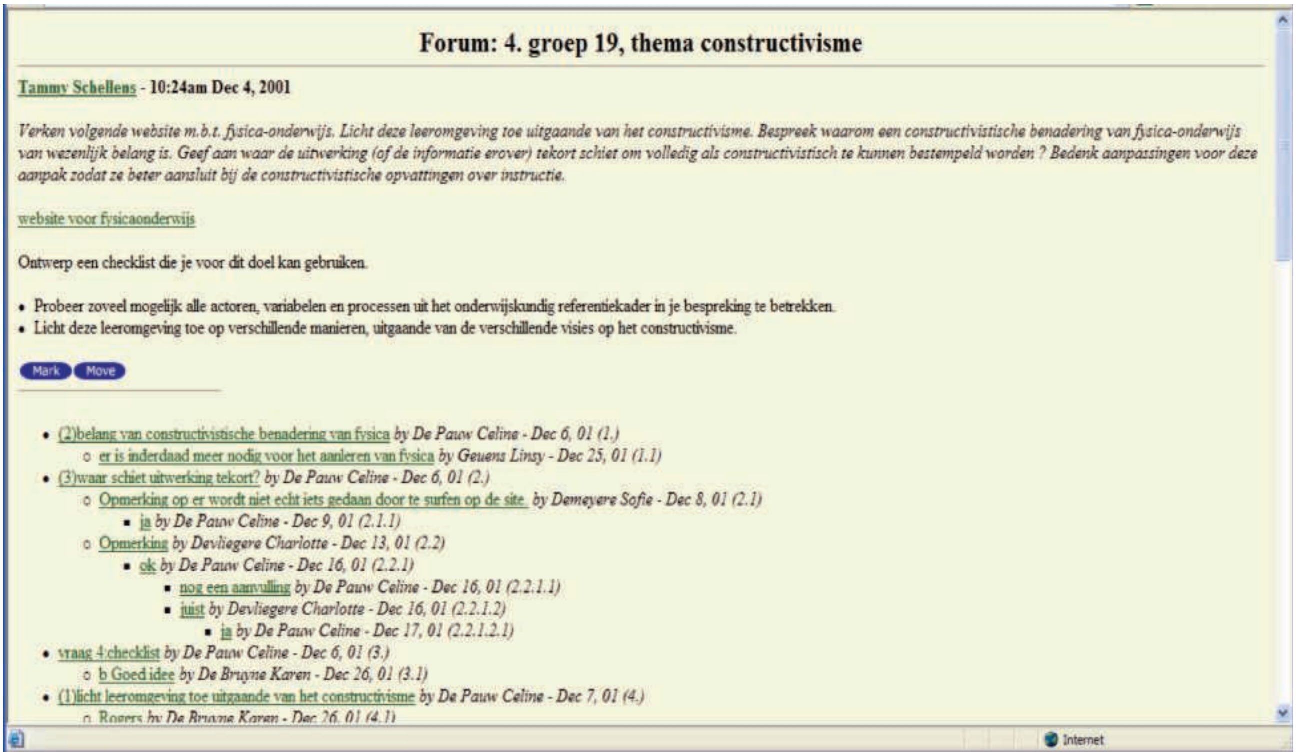

Figure 2. Threaded discussion.

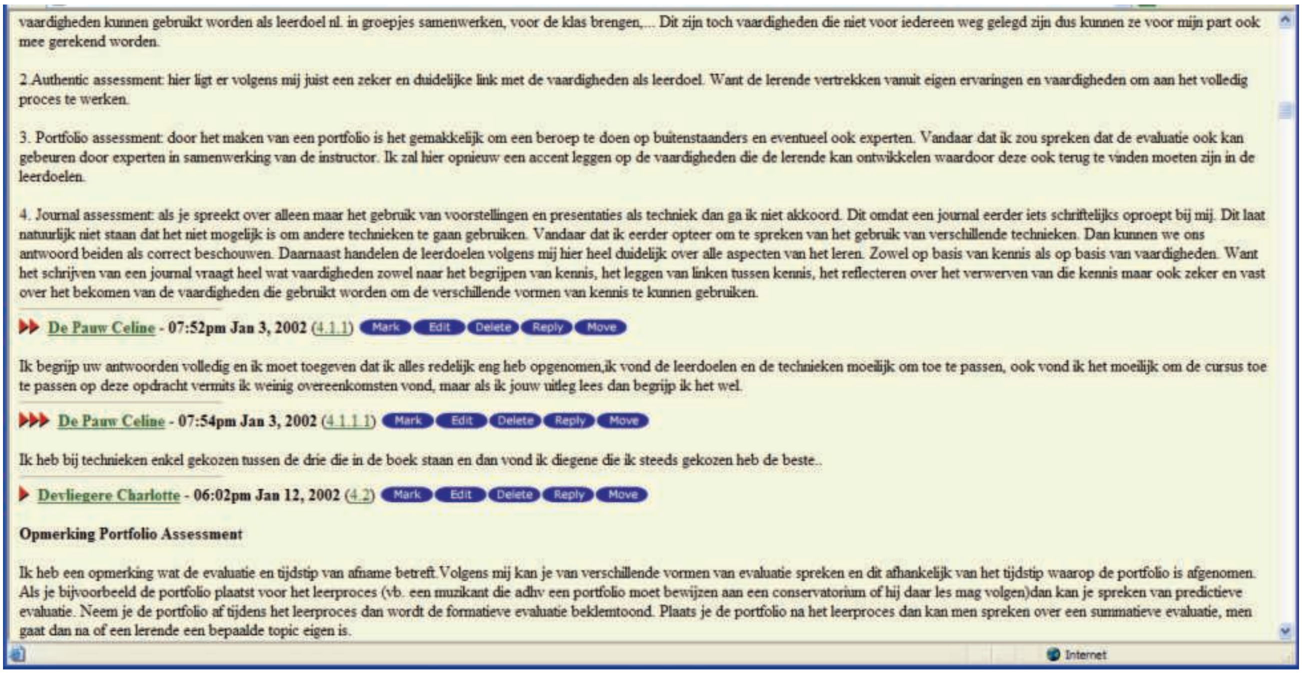

Figure 3. Excerpt of a discussion.

regression coefficients, and more correct standard errors, confidence intervals, and significance tests, all of which will generally be more conservative than the ones obtained when ignoring the presence of clustered data (Goldstein 1995). To analyse the data, MlwiN for multilevel analysis was used (Rasbash *et al.* 1999).

6. Results

6.1 *Hypothesis testing procedures*

To test the hypotheses about the impact of CSCL on the final exam score of the students, a two-stage procedure was followed. The first stage consisted of the estimation of a two-level null model, with students (level one) hierarchically nested within discussion groups (level two), only including the intercept and initially no explanatory variables. This model served as a baseline with which subsequent more complex models are compared. The model also partitions the total variance of the dependent variable (i.e. exam scores) into two components: between-groups and between-students within-groups variance.

The second stage in the analysis consisted of entering the variables at group or student levels, which were hypothesized to affect the dependent variable. Continuous independent variables were centred around the grand mean to facilitate interpretation of the intercept. The student characteristics gender, learning style, students' attitude towards task-based learning, level of knowledge construction during the discussions, and the amount of messages posted were added to the model. With respect to group characteristics, the intensity of interaction (the amount of original contributions and reactions to the discussion per group) was included in the model. Initially, all variables were included in the model as fixed effects, assuming that their impact did not vary from student to student or from group to group. Afterwards, this assumption of a fixed linear trend was verified for each explanatory variable by allowing the parameter coefficients to vary randomly across groups and across students within groups.

Table 1 presents the gradual construction of the model, using the iterative generalized least squares (IGLS) estimation procedure. In this table the model is presented with students' level of knowledge construction as an explanatory variable. To guarantee a full understanding of the analysis procedure, all intermediate steps in the construction of the most appropriate model will be explained.

To test the hypotheses regarding the impact of CSCL on the levels of knowledge construction, a similar two-step procedure was followed. The different analyses focused on (a) the students' mean level of knowledge construction for each discussion theme and (b) on the highest level of knowledge construction attained per theme. Since multilevel models are very useful for analysing repeated measures (Snijders and Bosker 1999), a special kind of hierarchical modelling was defined with regard to the levels of knowledge construction data as collected during the four consecutive discussion themes: measurement occasion (discussion theme 1 to 4) nested within students. In this way a three-level structure arose: measurement occasions (level one) are clustered within students (level two) that are nested within discussion groups (level three). Tables 3 and 5 respectively present the results of the final best-fitting models for students' mean level and for students' highest level of knowledge construction, using the IGLS estimation procedure (see later).

6.2 *Hypotheses with regard to the final exam scores*

As stated earlier, to test this first cluster of hypotheses about the impact on student final exam scores, a full description is given of the stepwise procedure to construct the best fitting models.

The first step in our analysis was to examine the results of a fully unconditional two-level null model (model 0). The intercept of 9.53 in this model represents the overall mean of the final exam scores of all students in all discussion groups. This initial analysis entails the estimation of the total variance of the dependent variable (9.11), the sum of the level-one and level-two variance components. The total variance is further decomposed into between-groups and between-students variance. The random part of the null model reveals that only the variance at student levels is significantly different from zero ($\chi^2 = 120.50$, $df = 1$, $p = 0.000$). Only 6% of the overall variability in the final exam scores can be attributed to group-level factors or between-group differences, and 94% of the variance is owing to differences between individual students within the discussion groups. In other words, the estimates suggest that the differences between students in exam scores within the groups far outweigh the differences between groups. However, to be consistent with the following analyses and to be able to compare the results, we still decided in favour of multilevel analyses.

To test the hypotheses, explanatory variables were included in the analysis. Since parsimonious models are preferred, only significant predictors ameliorating the model were retained. In table 1 models that were not retained for further analysis are represented in grey. First, the '*amount of messages*' was introduced into the model as a student-level explanatory factor. As model 1 in table 1 reveals, this variable appears to be a positive and significant predictor ($\chi^2 = 13.23$, $df = 1$, $p = 0.000$) of final exam scores. As it is feasible that level 1 and level 2 variances in exam scores differ according to the number of messages posted, we next allowed the parameter estimate of this predictor to vary randomly across all discussion groups and students. No significant complex variances were found, which indicates that the variances in the final test scores are fixed and independent of the amount of individually posted messages.

Next, '*gender*' was added to the fixed part of the model (model 2a). As can be derived from table 1, the inclusion of this variable results in a significant improvement of Model 1 ($\chi^2 = 115.84$, $df = 1$, $p = 0.000$). Moreover, table 1 shows that girls significantly outperform boys on the final exam scores ($\chi^2 = 4.51$, $df = 1$, $p = 0.034$).

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Table 1. Summary of the model estimates for the two-level analyses of the final exam scores.

	Model											
Parameter	0	1	2a	2b	3	4	5a	5b	5c	5d	5e	6
Fixed												
Intercept	9.53 (0.33)	9.58 (0.29)	8.16 (0.72)	8.12 (0.72)	8.37 (0.66)	6.18 (0.95)	8.37 (0.66)	8.25 (0.62)	8.37 (0.66)	8.23 (0.62)	5.60 (0.87)	6.21 (0.80)
Amount of messages		0.24 (0.07)	0.23 (0.07)	0.33 (0.16)	0.19 (0.07)	0.23 (0.07)	0.18 (0.73)	0.19 (0.08)	0.17 (0.07)	0.15 (0.07)	0.14 (0.07)	0.13 (0.07)
Gender (girl)			1.48 (0.70)	1.51 (0.70)	1.34 (0.67)	1.10 (0.66)	1.33 (0.67)	1.54 (0.62)	1.32 (0.66)	1.21 (0.60)	1.03 (0.58)	
Girl * Amount of messages				−0.11 (0.18)								
Attitude towards TBL					0.25 (0.05)	0.23 (0.06)	0.25 (0.05)	0.25 (0.05)	0.24 (0.05)	0.25 (0.05)	0.20 (0.05)	0.20 (0.05)
LS (deep)						3.54 (0.91)					3.80 (0.81)	4.09 (0.79)
LS (strategic)						2.38 (0.90)					2.96 (0.82)	3.28 (0.80)
Mean LKC							0.24 (0.73)	0.62 (0.79)				
Highest LKC									0.19 (0.28)	0.71 (0.36)	0.87 (0.40)	0.83 (0.40)
Random												
Level 2												
$\sigma^2_{\mu 0}$	0.51 (0.40)	0.37 (0.32)	0.51 (0.41)	0.52 (0.41)	0.27 (0.28)	0.47 (0.39)	0.26 (0.3)	0.27 (0.27)	0.25 (0.27)	0.39 (0.32)	0.70 (0.48)	0.64 (0.46)
Level 1												
$\sigma^2_{\varepsilon 0}$	8.60 (0.78)	8.21 (0.75)	8.28 (0.80)	8.26 (0.80)	7.60 (0.74)	6.59 (0.70)	7.61 (0.74)	5.64 (0.83)	7.60 (0.74)	5.75 (0.67)	4.79 (0.60)	4.88 (0.61)
$\sigma_{\varepsilon 0 \varepsilon LKC}$								2.07 (1.33)		−1.58 (1.15)	−2.90 (1.49)	−2.79 (1.51)
$\sigma^2_{\varepsilon LKC}$								18.24 (7.46)		4.91 (1.87)	6.63 (2.56)	6.54 (2.57)
Deviance	1245	1233	1117	1116	1076	895	1076	1072	1075	1063	879	882
χ^2		12.777	115.843	0.372	40.905	180.649	0.107	3.398	0.426	12.337	183.792	−3.087
df		1	1	1	1	2	1	2	1	2	2	1
p		0.000	0.000	0.542	0.000	0.000	0.744	0.183	0.514	0.002	0.000	0.079
Reference model		Model 0	Model 1	Model 2a	Model 2a	Model 3	Model 3	Model 5a	Model 3	Model 5c	Model 5d	Model 5e

Note: Values in parentheses are standard errors.

In model 2b the interaction effect between 'gender' and 'the total amount of messages a student posted' was tested. This analysis pointed out that there is no significant interaction and that there is no improvement as compared with model 2a. Neither the interaction effect ($\chi^2 = 0.39$, $df = 1$, $p = 0.533$) nor the difference in the deviance of model 2a and 2b ($\chi^2 = 0.37$, $df = 1$, $p = 0.542$) is statistically significant. Taking this result into account, the next model was based on model 2a instead of model 2b.

The next student characteristic was added to the model: '*student attitude towards task-based learning*' (model 3). There appears to be a significant effect of this variable on final exam scores ($\chi^2 = 26.43$, $df = 1$, $p = 0.000$), implying that the more students appreciate task-based learning, the higher the scores they obtain on the final test. This model is a significant improvement of model 2a ($\chi^2 = 40.91$, $df = 1$, $p = 0.000$).

The inclusion of '*learning styles*' was based on the administration of the short version of the ASSIST (Entwistle *et al.* 2000). On the basis of this instrument, we could distinguish between students with a '*deep approach*', a '*strategic approach*,' and a '*surface approach'*. Two dummies were created with the deep and strategic approach contrasted against the reference group with a surface study approach (model 4). Adding these dummies, the model appears to be a significant improvement over model 3 ($\chi^2 = 180.65$, $df = 2$, $p = 0.000$). Moreover, the analysis reveals significant effects for students with a deep ($\chi^2 = 14.98$, $df = 1$, $p = 0.000$) and strategic approach ($\chi^2 = 7.03$, $df = 1$, $p = 0.008$). The results imply that students with a deep or a strategic approach accomplish significantly higher final exam scores than students with a surface approach. However, as can be derived from table 1, the initial significant effect of the variable '*gender*' disappears after adding the variable '*learning styles*'.

To study whether the level of knowledge construction obtained by individual students played a decisive role, the next analysis focused on adding '*the mean level of knowledge construction*' students reached for their postings over the four discussion themes (model 5a). For the fixed part, we observe no significant effects ($\chi^2 = 0.11$, $df = 1$, $p = 0.742$), which seem to imply that the mean level of knowledge construction does not really matter. What appears to be more important, however, is the number of messages students contribute to the discussion. However, by allowing the coefficient of the mean level of knowledge construction to vary randomly across groups and across students within groups (model 5b), we notice a significant complex variance at student level. More specifically, the quadratic variance function indicates that the variance between students in their final test scores decreases when a student's mean level of knowledge construction increases. However, this broader model is not significantly better than the previous model ($\chi^2 = 0.11$, $df = 1$, $p = 0.744$).

Second, if we include '*the highest level of knowledge construction a student reached for a posting*' in the model (model 5c), no significant effect is observed ($\chi^2 = 0.43$, $df = 1$, $p = 0.512$). Allowing the main effect of this variable to vary at random at student and group level (model 5d) did lead to a significant fixed effect, implying that students with higher levels of knowledge construction also attain significantly higher final test scores. Moreover, significant complex variance at student level is obtained, revealing that the variance between students in their final test scores decreases when the students' highest level of knowledge construction ever reached increases. In other words, the higher the level of knowledge construction ever reached by an individual student, the more predictable their score on the final exam. This new model is a better fit to the data than model 5c ($\chi^2 = 12.34$, $df = 2$, $p = 0.002$).

By adding student learning style, as in model 4, we notice again an improvement of the model. The difference in deviance of both models is statistically significant ($\chi^2 = 183.79$, $df = 2$, $p = 0.000$). As can be seen in this model (model 5e) the impact of gender is no longer significant. Therefore this explanatory variable was excluded from the model, which leads us to the final and most appropriate model (model 6). Model 6 reflects that the posting of a high number of messages has a significant positive impact on final exam scores. Moreover, the highest level of knowledge construction in the messages contributed to the discussion has an additional impact; as well as the learning style of the student and his or her attitude towards task-based learning. Students with a 'deep' or a 'strategic' approach and a high appreciation for task-based learning will also attain higher scores on the final exam. No significant group-level explanatory variables were found, implying that the characteristics of the group to which students are assigned do not have a significant impact on the final exam scores. Moreover, also the group level random part indicates that no significant part of the variance final exam scores is explained by group-level factors.

To facilitate the interpretation of the estimates and obtain a better understanding of the statistical power of the obtained effects, effect sizes were calculated for both final models and included in table 2.

Table 2. Effect sizes for the explanatory variables predicting students' final exam scores.

Parameter	Model 6	ES
Fixed		
Intercept	6.21 (0.80)	
Amount of messages	0.13 (0.07)	0.13
Attitude towards TBL	0.20 (0.05)	0.27
LS (deep)	4.09 (0.79)	1.35
LS (strategic)	3.28 (0.80)	1.08
Highest LKC	0.83 (0.40)	0.20

Note: Values in parentheses are standard errors.

Conclusion: As to the hypotheses with regard to the impact on final exam scores, we can conclude that student characteristics have a much more important impact on final exam scores than group characteristics. Learning style has the most significant impact on exam scores. Furthermore the attitude towards task-based learning, the number of messages they contributed to the discussion and the level of knowledge construction in these contributions significantly affect final exam scores. The intensity of group discussions, however, has no significant impact on individual exam scores. This implies that we can reject the hypothesis on the level of group characteristics: students who participate in a discussion group with intensive discussion activity do not obtain significantly higher or lower final exam scores than students in less intensive discussions. The hypotheses about the impact of student characteristics, however, are all confirmed by the research results. Individual active participation in the discussion groups has a significantly positive impact on final exam scores: the more messages students contribute to the different discussion themes, the higher their final exam scores. In addition, the level of knowledge construction matters as well: students achieving higher levels of knowledge construction attain significantly higher final scores. Finally, the hypothesis with regard to student learning styles is confirmed also, implying that students with a strategic or deep learning style obtain significantly higher final exam scores than students with a surface learning style.

6.3 *Hypotheses with regard to the level of knowledge construction*

To test the hypotheses regarding to the impact on the level of knowledge construction similar two-step procedures were followed. Two tests of the hypotheses were performed, building on two different operationalizations of the dependent variables: (a) the students' *mean level* of knowledge construction per discussion theme and (b) the *highest level* of knowledge construction per theme.

6.3.1 Mean level of knowledge construction per discussion theme. As can be inferred from model 0 in table 3, the overall variability in the mean level of knowledge construction per discussion theme can be attributed mostly (79.41%) to theme-level factors (differences between the four discussion themes), for 18.49% to group-level factors (differences between the groups), and only for 2.10% to differences between students within the groups. This is an important finding implying that differences between groups and between students are much smaller than differences in students' levels of knowledge construction between different assignments. As a consequence, it is necessary to consider characteristics of the theme assignments in our analysis.

To understand the changes in the level of knowledge construction from discussion theme 1 to theme 4, the variable '*measurement occasions*' was added to the fixed part of the model (model 1). No significant changes in levels of knowledge construction are observed for the second theme ($\chi^2 = 0.003$, $df = 1$, $p = 0.956$). However, for the third ($\chi^2 = 12.34$, $df = 1$, $p = 0.000$) and fourth theme ($\chi^2 = 4.70$, $df = 1$, $p = 0.030$), a significant decrease in students' mean levels of knowledge construction is observed. In the best fitting model (Model 2), we see that the number of messages ($\chi^2 = 16.19$, $df = 1$, $p = 0.000$) and students' attitude towards the discussion groups have a significant positive effect on students' mean level of knowledge construction per discussion theme. Students who 'rather like' working in discussion groups ($\chi^2 = 4.33$, $df = 1$, $p = 0.037$) and students who 'really like' it ($\chi^2 = 3.94$, $df = 1$, $p = 0.047$) attain higher mean levels of knowledge construction. Learning styles do not seem to be a significant predictor. Only the group characteristic 'group interaction intensity' had a significant impact on the dependent variable. Compared with groups with low discussion activity, there was a significant effect for groups with high discussion intensity ($\chi^2 = 4.17$, $df = 1$, $p = 0.041$) but not for groups with average discussion activity ($\chi^2 = 0.61$, $df = 1$, $p = 0.433$). Figure 4 illustrates the differences between groups characterized by low, average and high interaction patterns.

We already referred to the importance of the theme assignment characteristics when we observed significant differences between students' mean level of knowledge

Table 3. Summary of the model estimates for the three-level analyses of mean level of knowledge construction per theme.

	Model		
Parameter	0	1	2
Fixed			
Intercept	1.73 (0.08)	1.82 (0.09)	1.53 (0.16)
Theme 2		0.01 (0.07)	−0.03 (0.08)
Theme 3		−0.25 (0.07)	−0.24 (0.08)
Theme 4		−0.15 (0.07)	−0.22 (0.08)
Amount of messages			0.04 (0.01)
Attitude towards DG (rather high)			0.19 (0.09)
Attitude towards DG (high)			0.19 (0.09)
Intensity of interaction (average)			0.12 (0.15)
Intensity of interaction (high)			0.36 (0.18)
Attitude towards TBL			
Random			
Level 3			
σ^2_{v0}	0.04 (0.02)	0.05 (0.03)	0.03 (0.01)
Level 2			
$\sigma^2_{\mu0}$	0.01 (0.01)	0.01 (0.01)	−0.01 (0.01)
Level 1			
$\sigma^2_{\varepsilon0}$	0.19 (0.02)	0.17 (0.02)	0.16 (0.02)
Deviance	354	336	243

Note: Values in parentheses are standard errors.

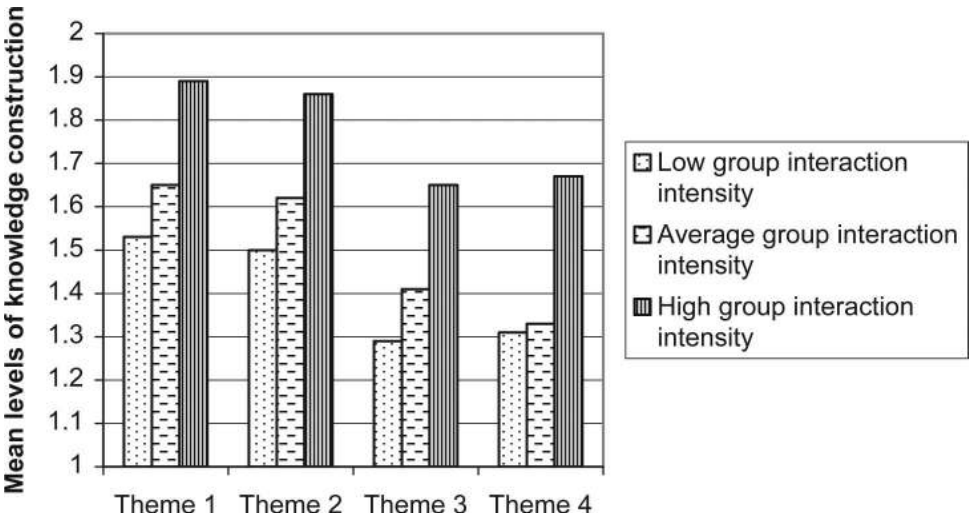

Figure 4. Differences in mean levels of knowledge construction according to the group interaction intensity.

construction per theme. We test whether the differences in the level of knowledge construction between discussion themes will still be observed after adding a variable that estimates the complexity of the theme assignment. After including the variable '*task complexity*' in the model (model 2), we no longer observe significant differences between the themes. Based on this finding we can state that the increasing degree of complexity of the theme assignments was at the base of the surprising results about the significant decrease in levels of knowledge construction in the last two discussion themes. It makes us aware of the fact that characteristics of the assignment are of essential importance to foster knowledge construction. This will have crucial implications for designing CSCL environments.

In summary, we can conclude that student, group, and task characteristics influence the mean level of knowledge construction. At the student level, the individual number of postings, a positive attitude towards task-based learning and a high appreciation for group discussions results in higher mean levels of knowledge construction. At the group level, groups with a high level of activity have a positive impact. Finally, the complexity of the theme assignments affects the mean level of knowledge construction. The significant decrease in level of knowledge construction reported earlier disappears when correcting for task complexity. To facilitate the interpretation of the estimates and determine the statistical power of the obtained effects, the effect sizes of the significant explanatory variables were calculated and presented in table 4.

6.3.2 Highest level of knowledge construction per theme. With regard to students' highest level of knowledge construction per theme as the dependent variable, table 5 reveals that the highest proportion of the variance is accounted for by theme level factors (77% and 81.2%).

Table 4. Effect sizes for the explanatory variables predicting students' mean level of knowledge construction per theme.

Parameter	Model 2	ES
Fixed		
Intercept	1.53 (0.15)	
Amount of messages	0.04 (0.01)	0.25
Theme 2	−0.03 (0.08)	−0.06
Theme 3	−0.24 (0.08)	−0.49
Theme 4	−0.22 (0.08)	−0.45
Intensity of interaction (average)	0.12 (0.15)	0.24
Intensity of interaction (high)	0.36 (0.18)	0.73
Attitude towards DG (rather high)	0.19 (0.09)	0.39
Attitude towards DG (high)	0.19 (0.10)	0.39
Attitude towards TBL		

Note: Values in parentheses are standard errors.

Table 5. Summary of the model estimates for the three-level analyses of students' highest level of knowledge construction per theme.

	Model	
Parameter	0	1
Fixed		
Intercept	2.62 (0.12)	2.69 (0.12)
Amount of messages		0.13 (0.02)
Theme 2		−0.05 (0.12)
Theme 3		−0.17 (0.12)
Theme 4		−0.08 (0.12)
Random		
Level 3		
σ^2_{v0}	0.09 (0.06)	0.05 (0.03)
Level 2		
$\sigma^2_{\mu0}$	0.08 (0.04)	0.01 (0.03)
Level 1		
$\sigma^2_{\varepsilon0}$	0.57 (0.06)	0.50 (0.05)
Deviance	682	620

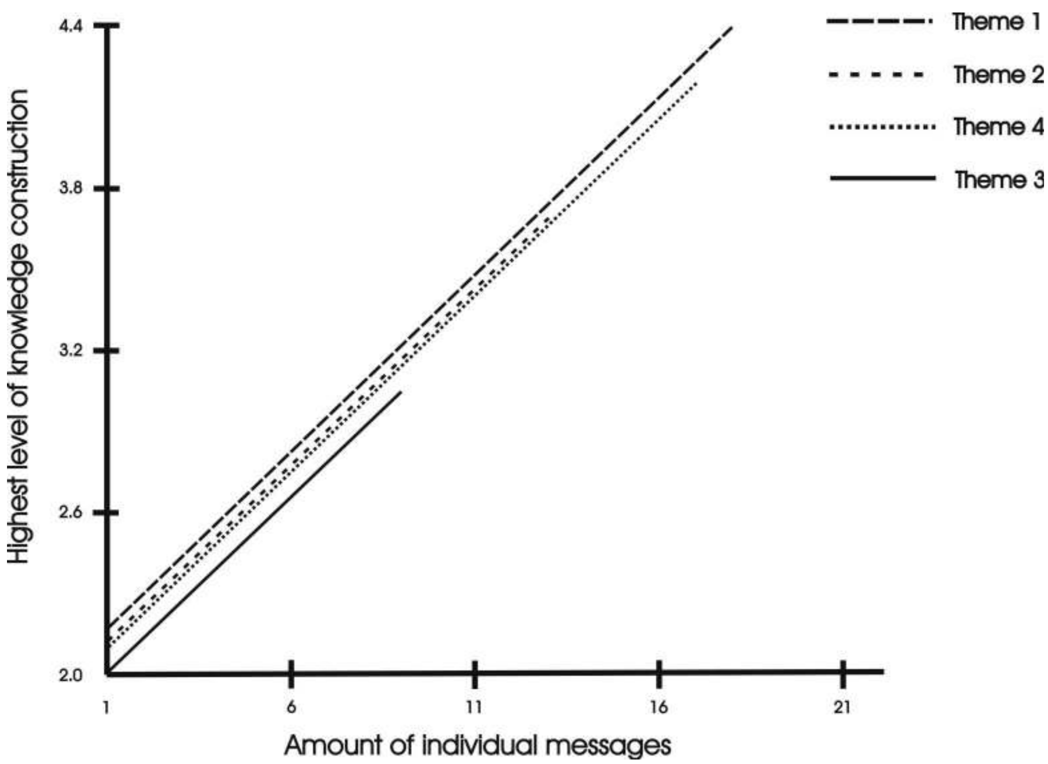

Figure 5. Achieved level of knowledge construction according to student's amount of messages per discussion theme.

Table 6. Effect sizes for the explanatory variables predicting students' highest level of knowledge construction per theme.

Parameter	Model 1	ES
Fixed		
Intercept	2.70 (0.12)	
Amount of messages	0.13 (0.02)	0.47
Theme 2	−0.05 (0.12)	−0.06
Theme 3	−0.17 (0.12)	−0.19
Theme 4	−0.08 (0.12)	−0.09

Note: Values in parentheses are standard errors.

When including the variable '*theme*' in the model, no overall significant changes in levels of knowledge construction are observed. Further, only one additional significant explanatory variable could be detected: the total amount of messages posted by individual students (Model 1: $\chi^2 = 67.04$, $df = 1$, $p = 0.000$). Figure 5 illustrates this increase in levels of knowledge construction as it is related to the amount of individual contributions. In line with the observation that the third discussion theme is the most complex one, figure 5 shows that students contributed the lowest number of messages to this discussion theme and consequently attained lower levels of knowledge construction.

From this alternative analysis about the impact on the dependent variable '*level of knowledge construction*', we conclude that the only significant variable is the total amount of messages posted by individual student. All other students, group and task characteristics do not significantly influence the highest level of knowledge construction. Effect sizes are reported in table 6.

7. Discussion and conclusion

7.1 *Hypotheses with regard to the final exam scores*

With regard to the hypotheses on students' final exam scores, the present study focused on the impact of both student and group characteristics. First, we can conclude that the impact of student-level variables on student final exam scores is apparently of more significance than characteristics of the discussion group. The following factors significantly influence the final exam scores: (a) the attitude towards task-based learning, (b) the number of messages submitted to a discussion, (c) the level of knowledge construction and (d) the learning style of students. Consequently, we can conclude that all hypotheses in relation to the impact of student characteristics can be accepted. Active participation in the discussion groups has a significantly positive impact on their exam scores. Apart from the number of contributions, the level of knowledge construction reflected in the contributions also matters: students reflecting higher levels of knowledge construction attain significantly higher exam scores. Learning style has the most important impact on final exam scores. It appears that students with a strategic or deep learning style perform significantly better on the final exam than students with a surface approach.

As to the influence of group level characteristics, the results do not reveal a significant impact. The hypothesis about the potential impact of group characteristics has to be rejected. Students participating in a highly active discussion group do not obtain significantly higher or lower final exam scores. This result entails that what especially matters is the individual contributions of students and not the fact whether they are part of a group with high or low interaction intensity.

These findings are important because they suggest that stimulating students to be active and to contribute on a frequent basis leads to better performance. It also appears that student attitudes are to be considered, e.g. their attitude towards the kind of (online) learning environment is of importance. The question arises, how to influence these variables? As Westrom (2001) states, most students can be good learners, but only if they want to learn. Compared with other researchers (Jones 1998, Quinn 1997), he stresses that learning should be an enjoyable activity. Instead of using a rewards system, he suggests fostering *engagement* in the learning activities. Westrom (2001) suggests combining peer pressure and teacher supervision to keep students on task. But in an online environment, the pressure of fellow students and teachers is not so prominent. Student autonomy is high and self-discipline has to be developed to keep students focused. There are a number of recognized strategies consistent with constructivist approaches to learning and instruction to foster engagement in an online learning environment: achievable goals, authentic learning, and tasks set at the appropriate complexity level.

7.2 *Hypotheses with regard to the level of knowledge construction*

With regard to the hypotheses focusing on the levels of knowledge construction, the study analysed the impact of student, group, and task characteristics. The results indicate that a large part of the overall variability in levels of knowledge construction can be attributed to differences between the theme assignments.

As to the impact of student characteristics, the amount of individual contributions is a significant predictor of both the mean and highest level of knowledge construction. The mean level of knowledge construction is also significantly influenced by the attitude towards task-based learning and the attitude towards the group discussions. Accordingly, it can be concluded that the first two hypotheses about the impact of student characteristics are confirmed. More intensive and active individual participation in the discussion groups is positively related to students' achieved level of knowledge construction, as well as adopting a positive attitude towards the learning environment and towards participating in group discussions. The third hypothesis, however, has to be rejected. No significant differences in levels of knowledge construction were found for students with different learning styles. Students with a deep or strategic learning style did not obtain a significantly higher level of knowledge construction compared with students with a surface approach.

Regarding the impact of group characteristics, students in groups with a lively discussion perform at a qualitatively higher level, which is in line with earlier research findings (Schellens and Valcke, 2005). Again this result points to the importance of stimulating students to discuss.

As to the impact of task characteristics, significant differences between the consecutive themes were found. However, these were not in line with the expected results. It was hypothesized that students would reach higher levels of knowledge construction as they deal with the consecutive theme assignments. The results showed a significant decrease in levels of knowledge construction, especially for the third theme. Further analysis, however, illustrated that this significant decrease in level of knowledge construction disappeared when correcting for task complexity. This finding points at the importance of the task design and task solution support. In this respect we refer to studies that also emphasize the relevance of task instruction (De Wever *et al.* 2002, Lockhorst *et al.* 2002, Strijbos *et al.* 2004). The studies demonstrated the beneficial impact of a pre-imposed task structure, fostering role taking during task solution and encouraging student motivation. Previous research of Schellens and Valcke (2005) also revealed that the attainment of high levels of knowledge construction was positively related to the provision of task structure. The latter study showed how a clear task structure fosters task-oriented communication. On the other hand, the study also showed that a too rigid task structure could inhibit specific types of cognitive processing. In the present study, task complexity appeared to be an important task characteristic. When the tasks were too complex the levels of knowledge construction were significantly lower. On the other hand, when the tasks are too straightforward, we might expect that students experience no challenge and the number and quality of the contributions would drop. This presents a dilemma for instructional designers. It appears that *challenge* is an important concept in this context. The learning challenge should be balanced to keep it within a 'zone' that matches the learner's ability (Quinn 1997). Czikszentmihalyi (1990) refers in this respect to the 'flow state', expanding on the challenge concept. The challenge level needs to be matched to the available knowledge and skills of students.

7.3 *Limitations and recommendations*

The present study can also be criticized due to a number of limitations. First, the research sample consisted of first-year educational science students. It can be questioned whether the findings can be generalized to students in other knowledge domains and to other educational levels. Second, with the exception of the student variable '*learning styles*', the effect sizes of the explanatory variables on both the final exam scores and the levels of knowledge construction were rather small to moderate. Subsequent research with larger samples is necessary to explore whether larger effects can be determined. Third, the question can be raised why the relationship between the different outcome variables (e.g. students' final exam score and levels of knowledge construction) was not investigated by exploring causal paths. A combination of both multilevel and structural equation modelling techniques should be considered in future studies. Fourth, the fact that only one content analysis scheme was used, might be considered as a weakness. However, as part of a dissertation research work, an alternative analysis scheme based on Veerman and Veldhuis-Diermanse (2001) was applied to validate the results. The results of these analyses mirror the present findings (Schellens 2004).

Future research should focus on larger sample sizes and a wider range of higher education students to get a better understanding of the impact of group, students and task characteristics on students' levels of knowledge construction and cognitive processing. In this respect, Lockhorst and colleagues (2002) highlight that subsequent research is especially needed with regard to task variables. They state that in the field of CSCL much attention is paid to the cognitive learning processes and outcomes, while too little attention is paid to the influence of task instruction variables.

According to De Laat (2002) a community of practice can be described by the density of the participation within the discussion, the central participants, the activity of the members, and the quality of the discourse. In this research, students' activity (number of messages students submitted to the discussion) and the quality of the discourse (level of knowledge construction in the contributions) was included. However, to gain more complete insight in the community of practice, it might also be interesting to consider the perspectives of 'density' and 'central actors'. In this respect, Preece (2001) also stresses the importance of 'interactivity' and 'reciprocity'. Thread depth, for example, is recommended as a measure of interactivity, whereas measures of reciprocity should take into account the ratio of giving and taking from a community, for example, the number of questions an individual asks compared with the number of responses to others (Preece 2001).

Notwithstanding the limitations of the present study and the fact that further research is needed, the strengths of the present study are clear. The study was set-up in an ecologically valid context and centred on the complex interaction of a large number of variables. The full complexity of collaborative learning in online discussion groups, taking into account student, group, and task variables, was considered.

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