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Original Research

GESDAV

Computer-supported collaborative learning at the clinical workplace: Students' perceptions and the effect of knowledge construction on learning outcome

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ABSTRACT

Objective: Individual online learning in medical education has shown positive learning outcome. However, from a social-constructivist perspective, students are participants of a collaborative learning process. Online collaborative learning in a clinical environment can be organised by computer-supported collaborative learning (CSCL). Although it is known that student's perceptions influences their knowledge construction in CSCL arrangements, it remains unclear whether students' knowledge construction in a CSCL environment can positively influence students' learning outcome, expressed by grades given by an expert. Therefore, the purposes of present study are (1) to explore medical students' subjective perceptions on a task in an asynchronous discussion forum of a CSCL environment. (2) To explore the effect of medical students knowledge construction on knowledge improvement. (3) To explore whether medical students' learning outcome was positively improved by active knowledge construction. **Methods:** Forty-four medical students were randomly assigned to either an experimental (n=21) or control group (n=23). Each individual student had to solve a self-selected clinical problem, written down in a pre-formatted critical appraisal paper. Students of the experimental group participated in a structured asynchronous on-line discussion on their papers. Students in the control group did not discuss their papers with peers. All students submitted their final paper for grading. Students in the experimental group were asked whether the paper was revised after discussion according to peer feedback. A questionnaire and a semi-structured interview was used to address students' perceptions on preparation, design, participation and knowledge improvement. Students' discussion postings were analysed on content. Postings were classified in revised or unrevised paper discussions, and compared. All papers were blinded by the researcher and independently rated by two experienced staff-members. Papers were classified in control group papers, and in pre and post (revised) papers from the experimental group. Grades were compared between pre and post papers, and between papers from the control group and post papers. Students' post papers were paired with the corresponding pre papers and compared by grade. **Results:** Questionnaire items showed positive students' perceptions on participation, design, and knowledge improvement. Interview items reported both positive and negative perceptions by students. Content-analysis of postings showed a significantly higher level of knowledge construction in the revised paper discussions. However, no grade differences were found between the pre and post papers, as well as between the control group papers and the post papers from the experimental group. Six post papers were revised by students after discussion and paired with corresponding pre papers, showing no significant differences between pairs. **Conclusion:** Medical students show positive subjective perceptions on a structured asynchronous on-line discussion of their papers. Medical students revising their written task after discussion, show significantly higher active knowledge construction during an asynchronous CSCL discussion. Active knowledge construction of medical students during an asynchronous CSCL discussion is not necessarily paralleled by a significantly higher expert grading.

KEY WORDS: Clinical clerkship, cooperative behavior, distance education

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INTRODUCTION

In medical education, individual online learning has a positive effect on learning outcome, for instance by online modular courses [1,2], and by online solving clinical case problems [3-6]. However, from a social-constructivist perspective, students' are not to be considered as individual learners, but as participants of a collaborative learning process during which knowledge is actively constructed, and situated in realistic settings [7-9]. Knowledge construction, as a component of the social-constructivist perspective, is considered as a process in which a student integrates new knowledge with their existing knowledge. Learning collaboratively, instead of individually, is regarded as essential to the learning process, fostering students' active knowledge construction by stimulating critical thinking, deeper-level learning and shared understanding in a social manner. Collaborative knowledge construction shows more active, reflective, and socially engaged learners [8,10-12]. Collaborative learning in a clinical environment, where medical students' are spread across clinical attachments, can be organized online, by computer-supported collaborative learning (CSCL). CSCL not only involves students' in a collaborative learning process, but the principles of CSCL, such as deep-level learning, problem solving and critical thinking are also consistent with the social-constructivist perspective of learning [13,14]. Collaboration among students' can be enhanced via participation on an asynchronous discussion forum. This allows students' to participate at a time and on the location they prefer [15] and provides them the necessary time to submit a well-considered reply [16]. Students' participating on the forum in a CSCL environment contributes to their knowledge construction process by externalizing and verbalizing their thoughts by writing down their opinions. Moreover, they share these thoughts in a structured way with their peers by explaining, discussing and reflecting these opinions [8,12,14]. These activities contribute to students' knowledge construction, and influences the learning process of students positively [8,9,12,15]. In medical education, research reports on CSCL by an asynchronous discussion forum in a clinical workplace are few. One study on CSCL by a structured discussion forum provided evidence for a positive learning outcome on knowledge improvement by pediatric interns after solving a theoretical, clinical case [9]. In a recent explorative study on CSCL using an asynchronous discussion forum for formative peer review [17], we found a high level of knowledge construction activities during students' learning process. Furthermore, we demonstrated those medical students' scored positive perceptions on knowledge improvement and on high level of participation during discussion. These subjective perceptions seemed to be related to a high level of knowledge construction by students' during the discussion. Previous studies described that students' perceptions of their learning environment tend to guide their attitudes, behavior and modes of knowledge construction in that environment [14]. Students' positive perceptions can mediate the meaningfulness and the effectiveness of classroom learning arrangements both traditional and CSCL ones [11,14,18-20]. However, it remains unclear whether in clinical education medical students' knowledge construction during discussion in a CSCL environment can positively influence students' learning outcome. Therefore, the first aim of the present study was to explore medical students' subjective perceptions on a task in an asynchronous discussion forum of a CSCL environment. Next, the second aim was to explore the effect of medical students' knowledge construction on knowledge improvement. Finally, the third aim was to explore whether medical students' learning outcome was positively improved by active knowledge construction.

METHODS

Participants and Task

This study was conducted with students' during the final (third) year of the Master in Medicine education at the Faculty of Health, Medicine and Life Sciences at the Maastricht University, the Netherlands, from January until June 2009. Participating students' followed an 18 weeks elective in various clinical disciplines in nine different hospitals, eight of which were localized in the Netherlands and one in Austria. During this elective, each student had to perform a number of specific tasks, individually. One of which was the thorough investigation of a self-selected clinical problem encountered during the elective. To address this clinical problem, each individual student had to write a pre-formatted paper, a so-called critical appraisal of a topic (CAT). In this task students' investigate the research literature regarding etiology, diagnosis and prognosis of the disease, therapy and follow-up [21,22].

Study Design

Forty-four students' participated in this study. They all received informed consent before the start of the study and were free to withdraw their cooperation at any time. In a controlled study design, the participants were randomly assigned to either a control group (n = 23; 17 female and 6 male students', mean age: 24 years) or an experimental group (n = 21; 16 female and 5 male students', mean age: 25 years). Randomization of participants was conducted by the principal investigator by first allocating the students' name to a number. Every individual number was put in a separate envelope. An independent faculty member drew an envelope to allocate in an alternating way the containing students' number to either the experimental or control group. In both groups, students had to execute the CAT task. The intervention in the experimental group was that, after completion of the CAT task, students' participated in an asynchronous structured discussion forum of the open source CSCL environment DOKEOS (http://www.dokeos.com) to discuss their pre CAT paper. After this discussion, the students' of the experimental group were allowed (but not compelled) to revise their CAT paper, as inspired by the feedback received from their peers. All students' uploaded their final paper (post CAT paper) on the CSCL environment, and specifically indicated whether or not their paper was revised after discussion. Students' in the control group did not participate in an asynchronous discussion forum, and submitted their CAT papers by E-mail to the principal investigator of this study [Figure 1].

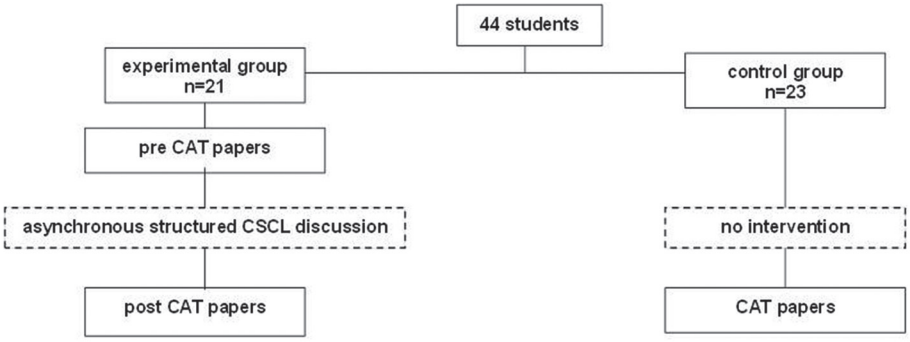

Figure 1: Flow chart of present study design

In the experimental group, seven subgroups with three students' each were created. Each individual student uploaded his pre CAT paper to "drop-box" in the CSCL environment. Within each subgroup, the students' critically commented their peers' CAT papers on three prescribed topics of critical appraisal, i.e.: (1) the process of the literature search regarding the clinical problem, as presented in the paper; (2) the design and the execution of the cited research used to address the clinical problem and, (3) the quality, respectively the amount of evidence in the cited research used to address the clinical problem. Each prescribed topic consisted of six subtopics each. Students' postings were visible for the subgroup members and the principal investigator only.

To prepare students' in the experimental group on their task, each student received an instruction manual via E-mail. The manual contained information about the design and use of the CSCL environment. According to the characteristics of a CSCL task, where students' have to regulate, control and evaluate their learning process [23], the arrangements of the discussion on an individual CAT paper including the start, the sequence, and the sufficiency of the discussion was left to the group members. A 2 week period was allowed for the discussion of one individual paper.

Measurement Instruments and Statistical Analysis

To address the first research aim, students' perceptions on the use of the CSCL arrangement were evaluated by using a questionnaire concentrating upon the items "preparation," "participation," "design," and "knowledge improvement." It was considered to be important to get insight in these four items, for proper preparation by an instruction session and a manual facilitated the use of the CSCL environment and task and to execute the tasks properly [9,24-27]. The extent of students' participation was considered to support students' active contribution on the knowledge construction process [8,24]. The design of the structured task and forum were measured, for positive perceptions on the design are found to contribute to achieve meaningfulness, the effectiveness of CSCL arrangements, and knowledge construction [9,11,14,17-20]. Knowledge improvement was measured in order to find similarities between students' subjective perceptions and objective learning outcome by grades. To achieve further insight on students' questionnaire scores, it was decided to conduct a semi-structured interview as well. Students' were asked to score each questionnaire item on a five-point Likert scale (1 = absolutely disagree; 5 = absolutely agree). Descriptive statistics (mean ± standard deviation [SD]) were calculated on each of the four perception items.

The individual interviews lasted for 30 till 45 min each, and were recorded with an electronic recording device. All 21 interviews were qualitatively analyzed by a structured analysis method [28]. First, the text of 10 interviews was assessed, and irrelevant information was removed. The remaining text was fragmented and labeled to one of the four items of students' perceptions. Validation of labeling was conducted by analyzing the remaining interviews following the analysis method as described above.

To address the second research aim, students' level of knowledge construction during discussion was operationalized by content-analysis of students' activity during discussion, defined by the postings that student sent each other during the discussion on the forum. Content-analysis of these postings was performed according to the validated rainbow system [29]. Accordingly, seven categories of communicative interaction can be distinguished, which are then grouped into three collaborative problem solving activities, i.e. outside activity, non-task-focused activity or task-focused activity. Within the group of task-focused activity, the categories five, six and seven are considered to reflect the highest levels of knowledge construction, respectively [Table 1].

All blinded postings were analyzed by the principal investigator. Individual postings were considered as a unit of analysis, and labeled to one of the seven categories of communicative interaction. When an analysis unit contained multiple categories of communicative interaction, a posting was split into different units of analysis [25,30].

Furthermore, to address students' knowledge improvement labeled units were classified as belonging to revised or unrevised CAT papers. For every category of communicative interaction, the number of analysis units was statistically compared between revised and unrevised papers using a Mann-Whitney U-test for independent samples.

Table 1: Rainbow system for content analysis; activity, category, and category definitions

Content analysis system (Baker *et al.* 2007)		
Collaborative problem solving activity	**Category of communicative interaction**	**Definition**
Outside	Outside	Any interaction that is not concerned with interacting in order to carry out the defined task, e.g., talk about last night's party
Non-task-focussed	Social relation	Interaction concerned with managing the students' social relations with respect to the task, e.g., greeting, leave-taking, politeness
	Interaction management	Interaction concerned with managing the interaction itself, e.g., coordination (who will speak and who will not), establishing contact, topic shifting
Task-focussed	Task management	Management of the progression of the task itself, e.g., planning what is to be discussed, establishing whether problem is solved or not
	Opinions	Interaction concerned with expressing opinions about the topic of discussion, e.g., beliefs, acceptances
	Argumentation	Expression of (counter) arguments directly related to a thesis, or theses themselves, e.g., requests for justification
	Broaden and deepen	Interaction concerned with (counter) arguments linked to (counter) arguments, argumentative relations and the meaning of arguments themselves, e.g., elaborations of arguments, definition

To address the third research aim, students' learning outcome was operationalized by students' paper grades. Pre and post CAT papers from the experimental group and CAT papers from the control group were blinded by the principal investigator first. Then all papers were sent to two experts for independent grading. This grading was conducted according to a CAT scoring list, commonly used in the medical curriculum of the Maastricht University. In more detail, this scoring list consists of 18 subtopics addressing the three prescribed topics of critical appraisal, described earlier in the study design section. Grading was conducted on a scale of 1-10 (where 10 are the highest score). Descriptive statistics (mean ± SD) were calculated on the overall CAT paper grades, as well as on the three critical appraisal topics. In order to determine the rating consistency of paper grades, an inter-rater kappa reliability analysis was performed on the overall mean paper grades given by the two experts. Furthermore, the mean overall and topic grades were statistically compared between the pre and post CAT papers of the experimental group, and between the post CAT papers of the experimental group and the CAT papers from the control group, using an independent-samples *t*-test. Finally, the mean overall grades of revised post CAT papers were compared with the corresponding pre CAT papers, using a paired-samples *t*-test.

RESULTS

Twenty-three CAT papers were submitted by students from the control group. In the experimental group, 21 papers (pre CAT) were uploaded before discussion, and 21 papers (post CAT) were uploaded after the discussion. From these post CAT papers, 6 papers were revised, and 15 were not revised.

Students' Perceptions

Questionnaire results

Nineteen (91%) students' from the experimental group expressed their perceptions by returning the questionnaire. The questionnaire results are presented in Figure 2.

Students' reported positive perception scores on the questionnaire items "participation" (mean ± SD: 3.7 ± 0.6), "design" (mean ± SD: 3.6 ± 0.5), and "knowledge improvement" (mean ± SD: 0.5 ± 3.5) on the item "preparation" students' score rather low (mean ± SD: 2.8 ± 0.5).

Interview results

All students' of the experimental group (n = 21) participated in the interviews, which concentrated upon the items "preparation," "participation," "design," and "knowledge improvement."

Regarding "preparation," student's felt that exact instructions were missing on how to start a discussion and at what moment the discussion was sufficient. The instruction manual did not provide sufficient structure or guidelines that were clear enough for students' to start and finish their discussions. Further structuring the task by scripting on how to start and finish the task could be a solution here.

For "participation" it appeared that students' who participated actively, contributed positively on peers' CAT papers by critical reading and providing critical feedback. Furthermore, these active students' felt motivated to reflect more critically on their own CAT paper before and after discussion. Some remarks these students' made were: "First, I thought this collaborative task was senseless. However afterwards I think this collaborative task adds value to the individual task." "I critically read the paper of my peers and provided them with feedback. My peers read my paper critically and send useful feedback to me. I think it was a good collaboration." Students' who did not participate actively thought their papers were of a good quality already and considered participation in an electronic discussion on CAT papers as time-consuming and extra work load to their elective. These students' mentioned low participation in the discussion group, by not providing and receiving any feedback on the posted CAT papers. These students' provided statements such as: "Lack of time is the reason that my activity of sending postings to other students during discussion was less. The elective is busy already, I had to study at the evening, and had to conduct several other tasks. This resulted in few possibilities to discuss the CAT paper on the internet". Another student replied: "I consider a CAT paper of a 6th year medical student that good, that further improvement is not necessary, and in that way I believe this task was useless to our kind of students."

A group of students' are willing to provide peers with feedback on their papers, and critically consider and revise their own paper as well. Another group of students' consider their paper of high quality already, and/or experience high time pressure during their elective, and, therefore, these students' do not contribute by sending feedback on their peers' papers. A willingness to participate in the discussion seems to depend on the perceived quality of students' CAT papers, and perceived time pressure as well.

Regarding "design," students' thought that the lay-out of the CSCL environment was clear, and that the tools were user-friendly. The structured forum was considered appropriate to the specific CAT task, and convenient to have a quick overview of all students' contributions. The opportunity to have access to the CSCL environment anytime and anywhere during the elective was appreciated by these students'. Students' answered: "The learning environment was that clear, probably is no manual needed," and "the learning environment was well-arranged and I think there are no changes needed." However, students' mentioned difficulties with the learning environment such as hard to log-in, to up and download articles and CAT papers, and to find the "drop-box" for storing articles and papers as well. Apparently, when students' have to overcome technical difficulties in a CSCL environment this negatively influences their motivation to participate to the discussion.

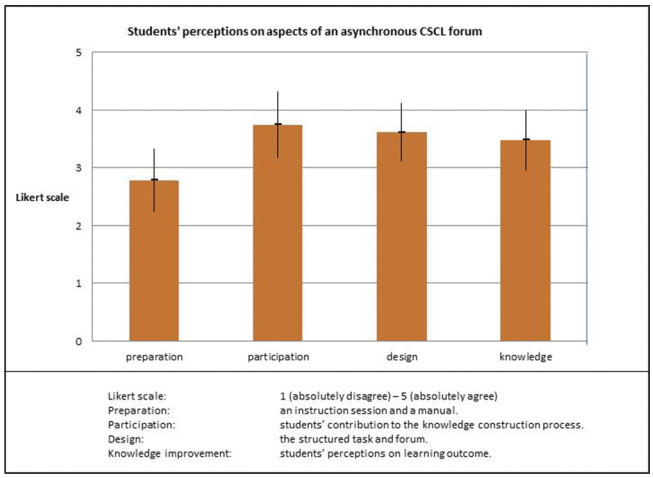

Figure 2: Mean ± standard deviation questionnaire scores of students' perceptions of aspects of an asynchronous computer-supported collaborative learning forum

Finally, "knowledge improvement" was reported in scientific reasoning, specifically in topic 1: "The process of literature search regarding the clinical problem," and in topic 3: "The quality, respectively the amount of evidence in the cited research used to address the clinical problem."

A student stated: "I've learned to formulate a research question better, and improved the process of my literature search."

Students' Knowledge Construction

Overall, 171 postings were recorded during the asynchronous forum discussions. After content-analysis, 391 units of analysis could be identified, which were differentiated to the discussions of either revised or unrevised papers. For the distribution of analysis units were skewed, the units are presented by frequency and median (95% confidence interval [CI]) values [Table 2]. Overall, a significantly higher activity during discussion (sending postings) was found in the group of revised than unrevised papers ($P = 0.03$). This difference could be exclusively linked to a higher task-focused activity in the group of revised papers ($P = 0.01$). In more detail, significantly more analysis units were found on levels of knowledge construction in the group of revised papers, i.e. Category 5: "Opinions" ($P = 0.005$), Category 6: "Argumentation" ($P = 0.02$), and Category 7: "Broaden and deepen" ($P = 0.003$).

Overall CAT Paper Grades

Overall and topic paper grades (mean ± SD) of the control and the experimental group are presented in Table 3. The kappa of the inter-rater reliability of the overall mean paper grades for the two independent experts was 0.719 ($P < 0.001$), 95% CI (0.517-0.921). Since this value can be considered to be sufficiently high, the grades as presented in Table 4 represent the average of the two independent expert ratings. Comparison of pre CAT paper grades ($n = 21$) and post CAT paper grades ($n = 21$), as well as comparison of the post CAT papers of the experimental group ($n = 21$) and the control group CAT papers ($n = 23$) revealed no significant differences on the mean overall grade and topic grades.

Table 2: Students' activity during discussions according to the rainbow system, classified by revised and unrevised papers

Discussion activity	Revised paper discussions (n=6)		Unrevised paper discussions (n=15)		Mann-Whitney U-test
	Total units	Units/discussion	Total units	Units/discussion	*P* value
	Frequency	Median (95% CI)	Frequency	Median (95% CI)	
Outside (Category 1)	3	0.5 (0-1)	15	0.0 (0-2)	0.5
Category 2: Social relation	38	5.0 (1-18)	66	4.0 (2-6)	0.6
Category 3: Interaction management	15	1.0 (0-7)	37	1.0 (1-3)	0.6
Non-task-focussed (Category 2 and 3)	53	6.0 (1-25)	103	5.0 (3-9)	1.0
Category 4: Task management	13	1.0 (0-10)	8	0.0 (0-0)	0.09
Category 5: Opinions	75	12.5 (2-22)	33	2.0 (1-3)	0.005
Category 6: Argumentation	51	7.0 (1-21)	22	1.0 (0-2)	0.02
Category 7: Broaden and deepen	14	1.5 (0-8)	1	0.0 (0-0)	0.003
Task-focussed (Category 4-7)	153	22.0 (4-50)	64	3.0 (2-7)	0.01
Discussion (Category 1-7)	209	28.0 (10-74)	182	11.0 (6-16)	0.03

Table 3: Mean±SD values of CAT paper grades in the control and experimental group

Topics	Control group (mean±SD)	Experimental group (mean±SD)	
	CAT papers (*n*=23)	Pre CAT papers (*n*=21)	Post CAT papers (*n*=21)
Mean overall grade	6.6±1.1*	6.7±0.9*	6.8±0.8*
Topic 1: Literature search regarding the clinical problem	6.6±1.1*	6.8±1.1*	6.8±1.2*
Topic 2: Design and execution of cited research	6.9±1.0*	6.8±1.0*	7.0±0.8*
Topic 3: Quality of evidence in cited research	6.4±1.2*	6.5±1.0*	6.5±0.9*

*Calculated on grades of six subtopics. Control group CAT papers: Original CAT papers, sent in for expert feedback without any intervention. Experimental group pre CAT papers: Original students' CAT papers before intervention. Experimental group post CAT papers: Students' CAT papers after intervention, sent in for expert feedback with or without revision. Mean overall grade: (Mean±SD) value of topic grades. CAT: Critical appraisal of a topic, SD: Standard deviation

Table 4: Mean±SD of individual paired CAT paper grades in the experimental group

CAT paper	Mean±SD		Paired-samples *t*-test
	Pre CAT paper grade	Post CAT paper grade	*P* value
Overall CAT papers	(6.7±0.6)	(6.9±0.8)	0.1[$]
CAT paper 1	(7.6±0.6)	(7.5±0.6)	0.3*
CAT paper 2	(7.2±0.9)	(6.5±0.6)	0.09*
CAT paper 3	(7.1±0.5)	(7.2±1.1)	0.8*
CAT paper 4	(6.8±0.6)	(6.9±0.6)	0.4*
CAT paper 5	(6.7±1.3)	(6.6±1.4)	0.3*
CAT paper 6	(5.0±1.4)	(6.6±1.4)	0.09*

[$]Calculated on grades of six papers. *Calculated on grades of six subtopics. CAT: Critical appraisal of a topic, SD: Standard deviation

Pre and Post CAT Paper Grades

Six students' decided to revise their paper after peer discussion. These six revised post CAT papers were paired with the corresponding six pre CAT papers. Each individual pair of these pre CAT and post CAT papers was evaluated on the overall grade (mean ± SD), as presented in Table 4. The revised post CAT papers one, three, four and five were graded quite equally, while a grade increase was found for paper 6 (+1.6), and a decrease for paper 2 (−0.7). Grade comparison of each individual pair of CAT papers showed no significant differences. An overview of the 21 pre and 6 (revised) post CAT paper grades are visualized in Figure 3. The left panel shows the individual scores of 21 pre CAT papers. The right panel shows the scores of six post CAT papers that were revised after students' discussion. The lines connect the paper grades of the pre and (revised) post CAT papers. Although arguable, papers that were graded below six were considered as low quality papers. Overall, five (24%) pre CAT papers were considered as low quality papers. After discussion, only one of these CAT papers (CAT paper 6) was improved that much, that this paper reaches the range of the high quality post CAT papers.

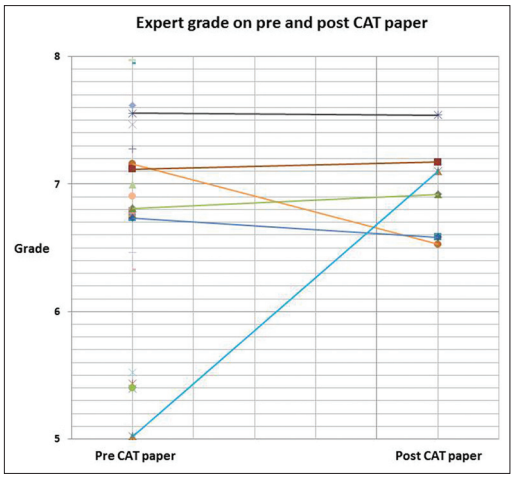

Figure 3: Overview of pre and post paper grades

DISCUSSION

In the present study on the value of asynchronous CSCL discussion on a clinical problem from the workplace environment, it is demonstrated that students' report positive perceptions on "participation," "design," and "knowledge improvement" of the CSCL environment. Discussions with active knowledge construction lead to the revision of CAT papers. However, revision seems not to depend on the quality of these papers. It has been demonstrated earlier that the success of a CSCL environment depends on, among other factors, the intensity of the online activity of students' [10,23,31].

The results of present study confirm the former research outcome that high discussion participation is associated with high task-focused activity and higher levels of knowledge construction [9,24,25]. The consequence of this observation is that students' should be maximally stimulated in discussion to reach a high level of knowledge construction. The results of the questionnaire and the interview items: "Task preparation," "participation," "design of the CSCL environment," and "knowledge improvement" could shed more light on how students' can be engaged to actively discuss their papers.

The task preparation in present study is perceived as a weak factor by students'. Although this authentic task with a structured discussion forum was designed as self-directed, by following the characteristics of a CSCL task [23], students' mention that exact instructions to start and to end the discussion are missing. Secondly, the participation in the forum discussion is perceived positive by students'. They feel stimulated to provide critical feedback on their peers' contributions, as well as to critically reflect on their own paper. In contrast, other students' mention a low participation grade in the discussion group, and doubt that they can profit from a thorough discussion of their own or others paper. Therefore, low participation in collaborative discussions is a serious cause for concern in a CSCL task. As such it should be clear for students' that the productivity of the individual and group achievement highly depends on the willingness to participate in relevant discussions [32]. Thirdly,

also the design of the CSCL environment is positively perceived by students' during clinical workplace learning. This perception concerns the accessibility of the forum and the high flexibility in time and place of the asynchronous learning tool. In workplace learning, for instance in a medical elective, this is an essential feature, for learning in such an environment is unpredictable and time demanding [33-35].

Providing that the design is adequately adapted to their needs, the experience of an appropriate design can stimulate students' to participate. However, in contrast a number of students' who decide not to revise their paper mention negative, merely practical aspects of the design of the learning environment, such as log-in difficulties, problematic up and downloads of an article or paper, and difficulties in navigation. Problems in the design of CSCL have therefore to be avoided, for this has been associated with low quality of interaction and learning outcome [36].

Finally, students' report a knowledge improvement on scientific reasoning; specifically on topic 1 "literature search" and on topic 3 "quality and amount of evidence." To our surprise, this positive perception is not visible by grading. When we take into account that the subjective perception of their knowledge improvement can be caused by an improved insight into one or two subtopics only, it is well possible that such a subtopic revision hardly affects the overall mean grading of the particular paper. Indeed, the overall grading is based upon the average rating of six subtopics in each of the three prescribed discussion topics.

Therefore the statistical chance to significantly improve the mean overall grades of the post papers was rather slight.

One of the limitations of this study is the relatively small experimental group of 21 students'. To prevent confounding of unmotivated students' in case of an obligatory participation, students' were asked to voluntarily participate in this study, which reduced the amount of participating students'. Another limitation is a low activity during discussion as seen with students' with unrevised papers. Although it can be expected that a voluntarily participation would maximally motivate students' to participate, there still remain active and less active students' in discussion. This could be of influence on knowledge construction, on knowledge improvement and on learning outcome. Another limitation was that it was not quite clear to students' when to start and when to end the discussion. This could be of influence on students' activity during discussion as well. Anyhow, all participating students' initiated activity during discussion on their CAT papers with their peers in a self-directed way. More guidance in preparation on the discussion task on how to start and when to end their discussion could be provided by a script [23].

The outcome of present research strongly suggests that in future research more attention should be given to stimulate students' collaborative activity on the discussion forum in order to improve knowledge construction. And moreover, to further elaborate on the ideas of Cook *et al.* [34,35] in future research, more attention should be paid to the question of "how and when" e-learning should be applied in medical education, to support students with different affective factors such as motivation, attitude and emotional state on knowledge construction and collaboration in CSCL [37,38]. This resonates well with research on collaborative learning in general [39], where clear guidelines have been identified for scaffolding collaborative learning. We need to find similar conditions or scaffolds for CSCL, and future research should be directed at identifying these. Furthermore, students' knowledge construction during discussion should be analyzed in more detail to consider students' learning improvement, instead of using paper grades as outcome measure.

CONCLUSION

Our first conclusion is those medical students' show positive subjective perceptions on their participation in the discussion forum, on the design of the CSCL environment, and on their knowledge improvement after discussion on an asynchronous forum. Second, medical students' are revising their written task after discussion, show significantly higher active knowledge construction during an asynchronous CSCL discussion. And finally, active knowledge construction of medical students' during an asynchronous CSCL discussion is not necessarily paralleled by a significantly higher expert grading.

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