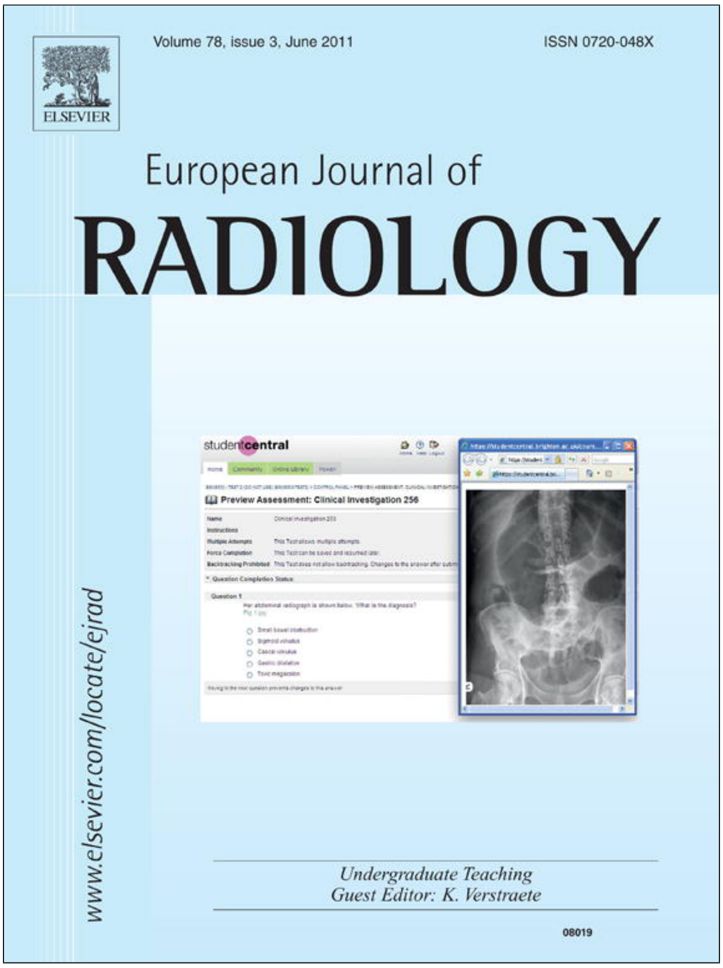
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The quality and impact of computer supported collaborative learning (CSCL) in radiology case-based learning

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ABSTRACT

Objective: The aim of this research was to explore (1) clinical years students' perceptions about radiology case-based learning within a computer supported collaborative learning (CSCL) setting, (2) an analysis of the collaborative learning process, and (3) the learning impact of collaborative work on the radiology cases.

Methods: The first part of this study focuses on a more detailed analysis of a survey study about CSCL based case-based learning, set up in the context of a broader radiology curriculum innovation. The second part centers on a qualitative and quantitative analysis of 52 online collaborative learning discussions from 5th year and nearly graduating medical students. The collaborative work was based on 26 radiology cases regarding musculoskeletal radiology.

Results: The analysis of perceptions about collaborative learning on radiology cases reflects a rather neutral attitude that also does not differ significantly in students of different grade levels. Less advanced students are more positive about CSCL as compared to last year students. Outcome evaluation shows a significantly higher level of accuracy in identification of radiology key structures and in radiology diagnosis as well as in linking the radiological signs with available clinical information in nearly graduated students. No significant differences between different grade levels were found in accuracy of using medical terminology.

Conclusion: Students appreciate computer supported collaborative learning settings when tackling radiology case-based learning. Scripted computer supported collaborative learning groups proved to be useful for both 5th and 7th year students in view of developing components of their radiology diagnostic approaches.

1. Introduction

A lot of changes have been introduced in the undergraduate medical curricula around the world have undergone a lot of changes during the last decades [1,2]. The core, shared by most of these curriculum innovations stresses the development of self-directed, student centered learning, aimed at Evidence-Based Practices [3]. The latter introduces an emphasis on e.g., problem based learning. This has also largely affected radiology teaching and learning practices. The relevance as well as potential advantages and disadvantages of problem based learning in radiology have been discussed [4]. It also introduced an emphasis on learning environments that build multimedia in radiology teaching [5,6], the adoption of interactive E-learning [7–9] and computer radiology case-based learning [10–13]. In the context of the present article, we focus in particular on a less studied aspect of radiology curriculum innovations: case-based learning, set up in computer supported collaborative learning (CSCL) settings. This approach is assumed to be effective in terms of attaining learning goals and to enhance student satisfaction [14,15]. Though a large number of studies reported positive empirical evidence about CSCL [16], recent studies also point at critical issues that have to be considered in setting up more advanced CSCL research. First, some authors addressed the non-conclusive results of a number of studies [17,18]. Researchers pointed to low or uneven levels of participation [19,20], low average levels of cognitive processing [21,22], the detrimental impact of weak prior knowledge [23], and struggles with the structure in the discussions [24]. These issues underscore the statement that online collaboration does not automatically lead to improved learning performance [25]. This has resulted in a new generation of CSCL research and practices that stress the need to add structure to the collaborative tasks. Authors have advanced the concept of **scripting** to refer to a variety of ways to structure collaborative tasks [26].

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Table 1
Descriptive and inferential statistics in relation to the case-based learning subscale of the Evaluation Radiology Teaching Concept Scale (ERTeCS).

Statement[a]	Year 5 (N = 161) Mean (SD[b])	Year 7 (N = 72) Mean (SD[b])	t-Value	df	p	Effect size[c]
A sufficient number of cases is offered to develop problem solutions	3.86 (0.71)	3.50 (0.60)	3.77	231	<0.001	0.55
Working in small groups on a particular radiology case is interesting because you learn from each other by discussing the problems together	3.30 (1.05)	3.47 (0.62)	−1.60	213	Not significant	
Working in small groups on a particular radiology case is relevant, because the problem can be solved more quickly	3.21 (0.98)	3.04 (0.62)	1.56	201	Not significant	
Working in small groups on a particular radiology case is interesting, because we can work together via the university's electronic learning platform	3.13 (1.07)	2.68 (0.73)	3.74	192	<0.001	0.49

[a] Statements were scored from "totally disagree" (1) to "totally agree" (5).
[b] SD = standard deviation.
[c] Effect size based on Cohen's *d*: small effect (>0.20); medium effect (>0.50); large effect (>0.80).

In the literature, a distinction is made between **content-oriented** and **communication-oriented scripts** [27].

A content-oriented script helps learners to select, organize and integrate the knowledge base that is at the base of the collaborative task (such as knowledge about infections to solve a discussion task about tropic diseases). A typical content-oriented script e.g., invites participants to label their discussion contributions on the basis of medical procedures, or a diagnostic protocol. Other scripts present a clear cut structure to tackle problems or cases. Lastly, scripting can build on carefully prepared cues, hints, guidance by a staff member. A communication-oriented script fosters the engagement of group members in the collaborative process by helping them to adopt different or specific perspectives, to consider in a conscious way the input of peers, etc. Typical examples of communication scripts build on adopting the role of a moderator, summarizer, theoretician, etc. [28]. Both scripting types are expected to invoke (1) an active cognitive processing of the declarative and/or procedural knowledge; (2) the meta-cognitive regulation of the cognitive processes during the collaborative process, since adding structure helps to trigger meaningful discourse; and/or (3) the level of interaction in the online discussion. In the context of the present study, content-oriented scripts have been adopted to foster the CSCL work.

Case-based learning, within a scripted CSCL setting, is relatively new at Ghent University (in use since 2008–2009). This introduced the need to evaluate this instructional approach; whether it resulted in student satisfaction and helped to develop and improve radiologic problem-solving abilities of medical students. This evaluation was set up in the context of a broader evaluation of a large scale curriculum reform at Ghent University when an integrated contextual medical curriculum was introduced in 1999. The mean features of this curriculum can be labeled as: patient centered, student centered, community oriented, problem and evidence-based learning and teaching [29].

In this study we center on student perceptions about the CSCL approach toward **radiology case-based learning**, building on data from a large scale survey study. Further we focus on **the *process evaluation* and *outcome evaluation* of the collaborative work** in terms of the impact on components of diagnostic approaches in student contributions.

2. Research objectives

This study consists 2 sub-studies.

Part 1: Survey study.

The key research question guiding this sub-study is: How do the clinical year students **experience the CSCL approach towards case-based learning**?

Part 2: Qualitative and quantitative study.

In view of the second sub-study, the following research questions were put forward. The first question builds on a *process evaluation* of the groups discussion: To what extent do we observe differences in the components of diagnostic approaches in the discussions between **nearly graduated students and fifth year students** in? The second question looks at the *outcome evaluation*: To what extent do we observe significant differences in the **case solutions of fifth year students versus nearly graduating students, in terms of accuracy of visual pattern recognition, cognitive patterns and verbal justification**.

3. Research design

3.1. Part 1: Survey

3.1.1. Participants

Students, enrolled for the medical doctors training in 2008 (year 2–7) at Ghent University, were asked to complete a questionnaire about their perceptions in relation to the innovative undergraduate radiology curriculum components. The design, content and structure of the Evaluation Radiology Teaching Concept Scale (ERTeCS) was extensively discussed in a previous article [30]. The ERTeCS was filled out anonymously, and after obtaining informed consent. The questionnaire was accompanied by a letter giving background information about the objectives of the study. Participation was voluntary and students were informed that neither participation nor non-participation would affect their grades. Ethical approval was granted by the Human Investigation Ethical Committee of the Ghent University Hospital. In the context of the present article, we focused on the ERTeCS -section centering on case-based learning in radiology. We build on the data gathered from 5th (early clinical year students) and 7th (last year students) year students.

3.1.2. Research instrument

3.1.2.1. The Evaluation Radiology Teaching Concept Scale (ERTeCS). Since we focus in the present study on radiology case-based learning, only the data in relation to the specific subscale of the ERTeCS are used in this research report. This subscale consists of four items: tree statements center on the computer supported collaborative learning approach, one item centers on the cases to be solve during the discussions (Table 1).

3.1.3. Statistical analyses

The data were analyzed using SPSS (version 15, Statistical Package for the Social Sciences, SPSS; Chicago, IL, USA). The quantitative analysis focused on a screening of the descriptive statistics, after checking for accuracy of data entry, missing values and outliers. An independent samples *t*-test was applied to compare group means for 5th and 7th year students regarding their perceptions about radiology case-based learning.

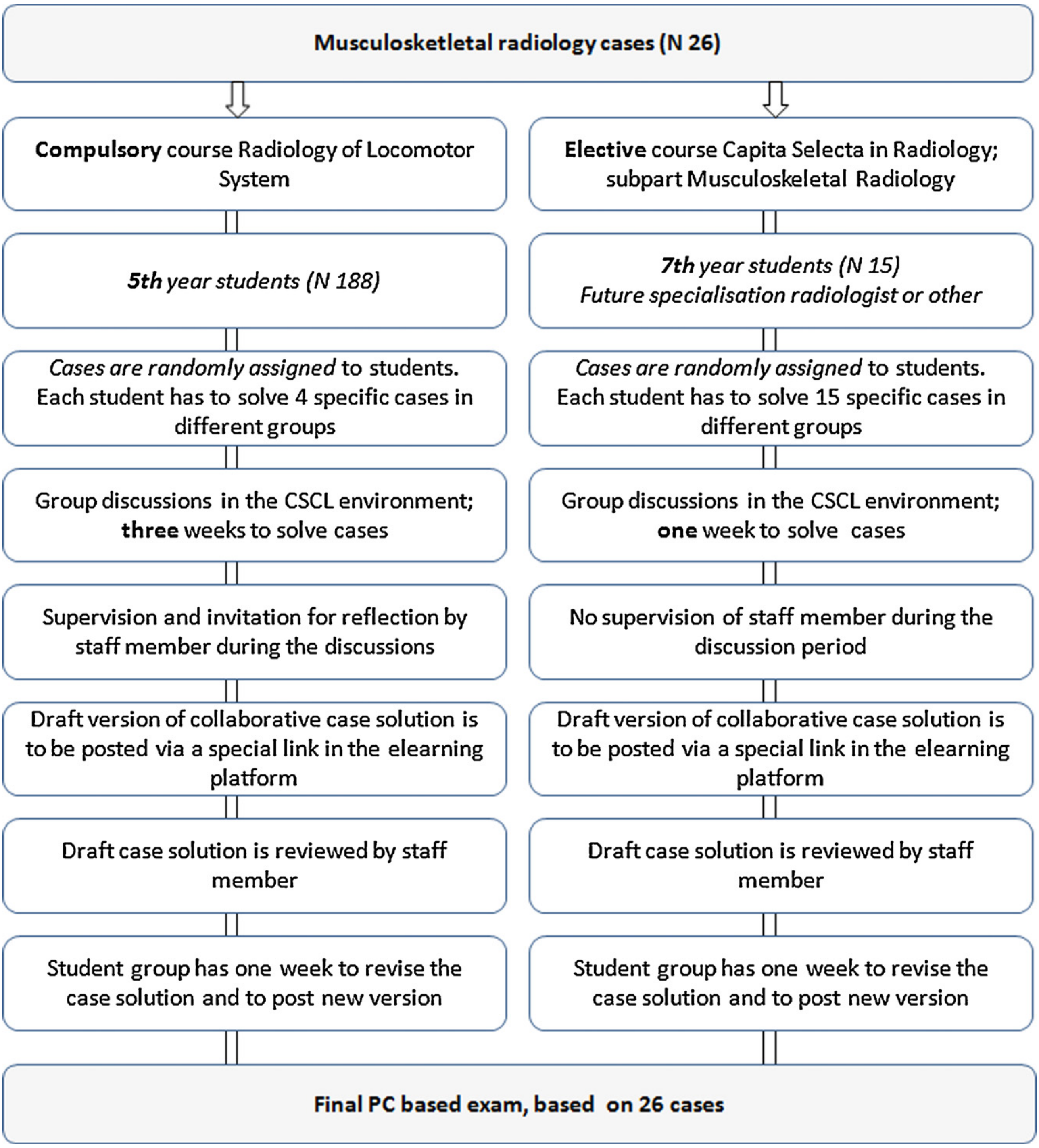

Fig. 1. Participants and procedure of qualitative study.

3.2. Part 2: Qualitative and quantitative study

3.2.1. Participants and procedure

Data gathered during the CSCL sessions from classes 2008 were used for this study. This qualitative and qualitative study builds on an innovative approach to tackle radiology cases in a computer supported collaborative learning environment (threaded discussion groups). As stated earlier, scripting was provided by presenting the students a structured case solving task. In addition, prestructured guidance was developed. To standardize the teacher interventions, the guidance centered on (1) invoking reflection on what they discussed at that moment (for example: "the irregular delineation of the vertebral endplates on thoracic level: What disease causes?") or centered on the steps in developing a case (for example: "enter a "general diagnosis" for this case"). Fig. 1 is an outline of this CSCL approach to case-based learning.

Solving cases online is an integral part of the radiology core curriculum "Radiology of Locomotor system" for all 5th year students. For nearly graduated students, an elective course "Capita Selecta in radiology for future medical specialists" is available in the radiology curriculum. This elective course comprises a specific part about musculoskeletal radiology who want to specialize in the field of radiology, rheumatology, orthopedic surgery, traumatology and/or physical therapy. In the context of the present study, the focus was on their CSCL activities about the online cases related to musculoskeletal radiology.

The cases, to be solved via group discussions, were carefully designed following evidence-based principles of case-based learning [31] and according to the learning objectives for the courses of musculoskeletal radiology. Each case consisted of one or more radiology images (X-ray (radiographic examinations), MRI (Magnetic Resonance Imaging), or CT (Computed Tomography images) downloaded from a PACS system), and a related brief patient history (see Fig. 2). Cases covered a variety of difficulty levels, depending on the nature of the pathology and the medical imaging. The students were asked – in all 26 cases – (1) to identify the radiological key structures, (2) to list a series of deferential diagnoses and (3) to formulate a final diagnosis. In 19 cases, groups were asked to (4) to identify and mark anatomic structures, and in 13 cases they had (5) to make a link with other available clinical data or pathology. In 6 cases, they had (6) additionally top chose the appropriate imaging technique to further solve the specific clinical problem.

The case had to be solved by group of students separately; groups did not have access to each other CSCL workspace. The cases were assigned randomly to students. Each 5th year student had to solve 4 out 26 cases and each 7th year student had to solve 15 out 26 cases. As such each student was involved in different groups to solve the assigned cases. The radiology cases were digitally available in the CSCL environment and only accessible after a personal login to their discussion group.

Fig. 3 shows a print screen of such discussion. Teacher could continuously track student participation in the discussion; who did what, when and how many times in relation to each case. Automatic log files helped to obtain objective measures in view of these variables.

In the CSCL setting, when consensus was attained in relation to a case, each group of students posted their final case solution via a special link in the electronic learning environment (drop box), in view of teacher feedback. The teacher reviewed 26 cases delivered form different group of students. The teacher based his feedback on a prestructured answer format that focused on the accuracy and the rationale presented to ground case related decisions. After the review process, the case solution with feedback was returned to the group of students in view of updating their case solution.

Within a specific amount of time, students were expected to resubmit their final version of the case solution. After a review by the teacher, this case solution was published online and available now for all students (see Fig. 4). The latter review process was necessary since these case solutions were the base of the domain knowledge to be studied in view of a final exam. For this exam the students had to study all 26 cases (also the case solutions developed by the other groups of students).

3.2.2. *Qualitative/quantitative analysis of the group discussions*

Two approaches were adopted. First, *a process evaluation* was carried out based on the nature of the discussion contributions and secondly, *an outcome evaluation* was set up by analyzing the content of the reviewed group case solutions.

For this study, an independent evaluator did evaluate each individual group discussion of 5th ($N = 26$) and 7th ($N = 26$) year students, and the reviewed case solutions. This analysis was directed by an analysis scheme that reflects the key concepts of diagnostic thinking approaches as established in previous studies [32,33].

As a part of *process evaluation* **general characteristics of the CSCL discussions** were noted such as:

1. Number of meaningful contributions.
2. Number of times that students did consult a case.
3. Number of times that a teacher did intervene in a discussion.

The next part of the *process evaluation* of CSCL discussions was based on the identification **of specific components that normally should be covered during a diagnostic thinking approach**. These included:

1. Number of radiologic key structures that were missed during a group discussion.
2. Number of anatomic structures being missed during a group discussion.
3. Number of diagnoses missed during the discussion.
4. Number of differential diagnoses presented during the discussion.
5. Number of appropriate radiology imaging techniques missed during the discussion.
6. Number of adequate medical terms used during the discussion.
7. Number of lay terms used during the discussion.

The outcome evaluation based on the reviewed versions of each case solution. **The accuracy and correctness of the diagnostic thinking pattern** was evaluated on a scale of 1–4 with 1 = completely correct; 2 = correct but with missed key findings; 3 = correct but with not relevant findings; 4 = completely incorrect. The following components of diagnostic thinking patterns were considered:

– Approach of visual pattern recognition

1. Accuracy of identification of radiological key structures.
2. Accuracy of recognition of radio anatomical structures.

– Approach in cognitive patterns

3. Accuracy of radiological diagnosis.
4. Accuracy of linking the radiological signs with available clinical information.
5. Accuracy of choosing appropriate radiological imaging techniques for solving the specific clinical problem.

– Approach during verbal justifications

6. Accuracy of using medical terminology

Finally, also **the final radiology exam scores** of 5th and 7th year students were taken in consideration *as part of the outcome evaluation*. These final exams were PC-based and consisted of questions that solely built on the cases being dealt with during the CSCL activities. The mean exam scores for 5th and 7th students were used for further analysis.

3.2.3. *Statistical analyses*

The quantitative analysis of the process and outcome measures was done with SPSS (version 15, Statistical Package for the Social Sciences, SPSS; Chicago, IL, USA). The analyses build on descriptive statistics, after checking for accuracy of data entry and missing values. Data about the quality of the groups discussions were analyzed with a Mann–Whitney U test (nonparametric equivalent of an independent samples t-test) to compare groups means of 5th and 7th year students. The differences in mean final exam scores were analyzed using an independent samples t-test. A significance level of $p < 0.05$ was put forward as a benchmark for the statistical analysis results.

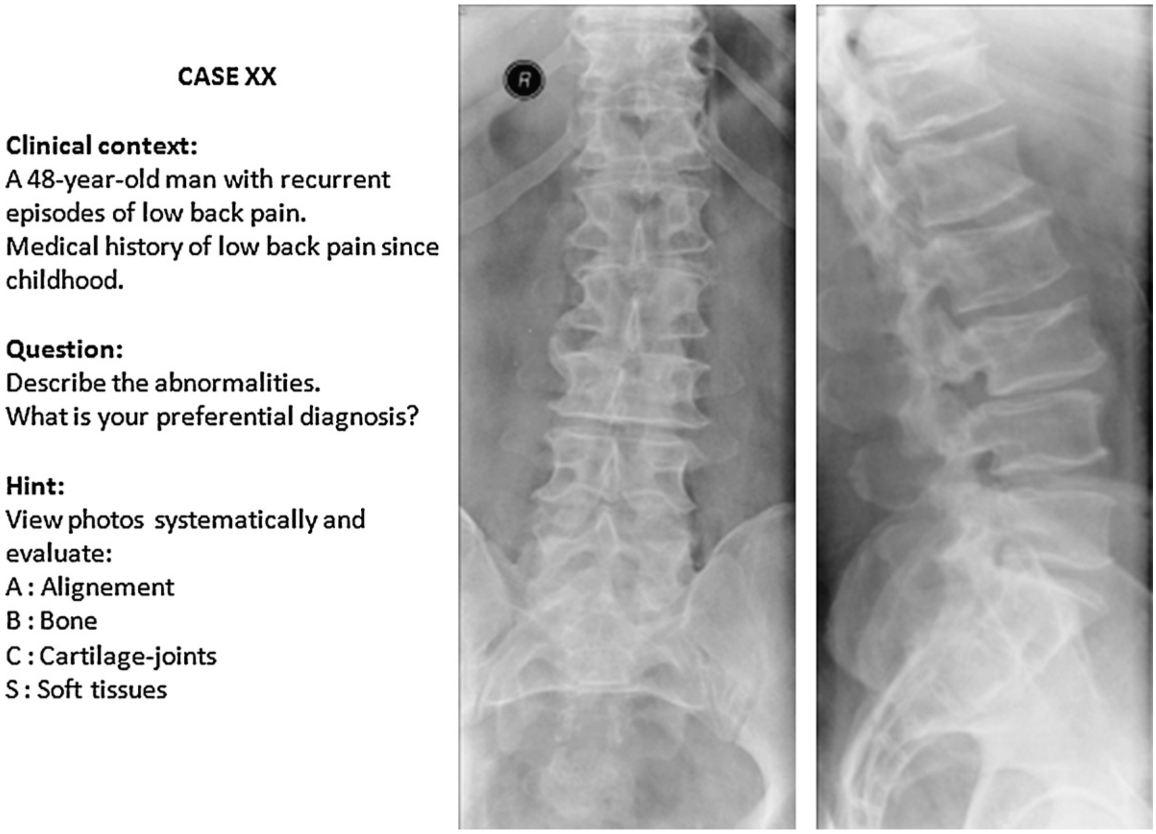

Fig. 2. Example of a radiology case.

4. Results

4.1. Part 1: Results from the survey study

The number of 5th year students filling in the ERTeCS questionnaire was 161/188 (85.6%), the 7th year students 72/84 (85.7%). Table 1 summarizes student perceptions in relation to the radiology CSCL and case-based learning statements. As can be derived from the table, significant differences can be observed in relation to two topics. Students enrolled in 5th year of training seem to be more satisfied with the number of radiology cases to be solved in the CSCL setting (mean 3.86) while nearly graduated students are still positive, but slightly less satisfied about this issue (mean 3.50, $p < 0.001$, Cohen's d 0.55, medium effect size effect). The analysis of perceptions **about the potential of the CSCL approach to learn from each other when solving radiology cases**, reflects a rather

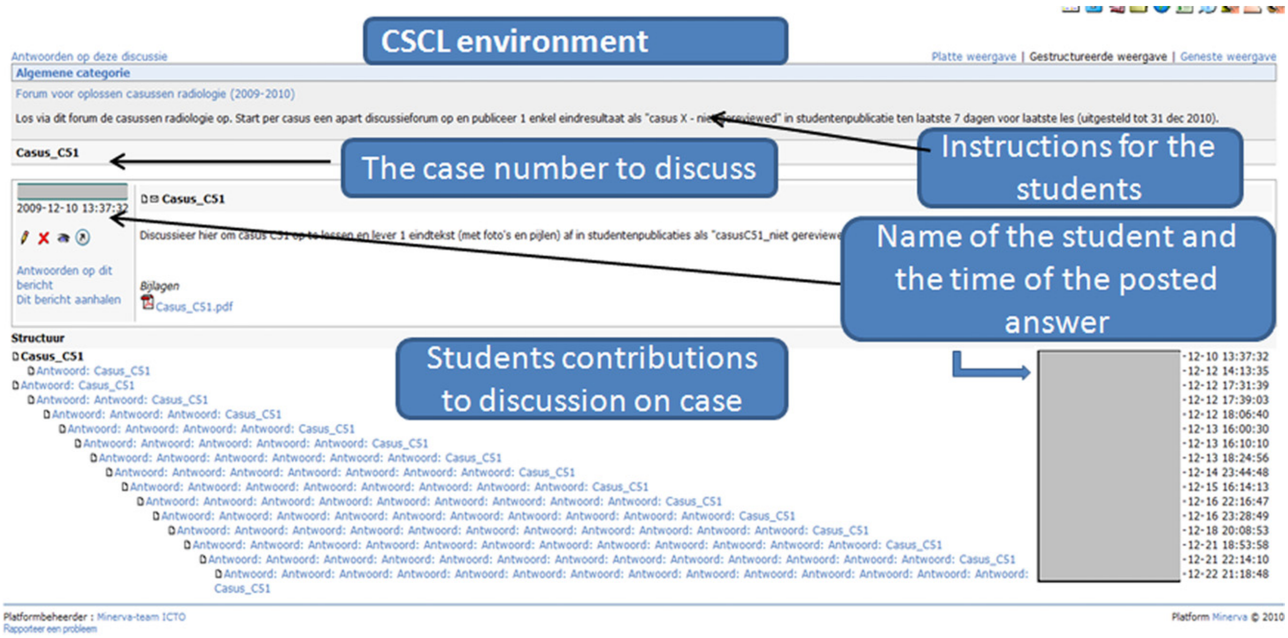

Fig. 3. A print screen of a group discussion.

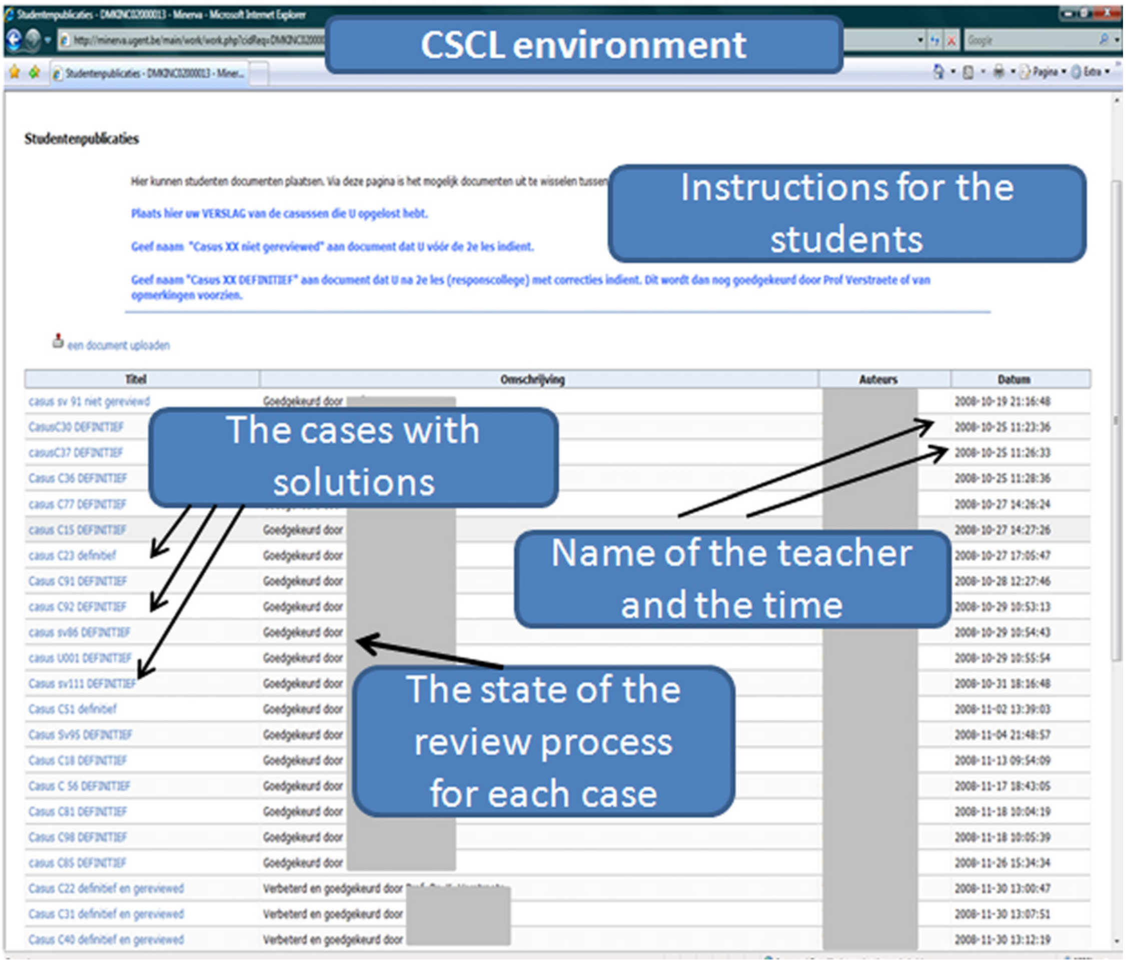

Fig. 4. The case solutions are published online and available for all students.

neutral to positive attitude (mean > 3); **with no significant differences** between students of different years. Also, student seem to adopt a neutral to slightly positive perception about **the potential of the CSCL setting to solve cases more quickly**; again no significant differences were observed between the two student samples. The statement about the actual **use of the CSCL setting to develop case solution** resulted in significant differences in student perceptions. The 5th year students are significantly more positive about online groups discussions (mean 3.13) as compared to 7th year students (mean 2.68, $p < 0.001$, Cohen's d 0.49, medium effect size effect).

4.2. Part 2: Results from qualitative/quantitative study

Table 2 reflects the general characteristics of the group discussions. We repeat that the time available to solve the cases differed for 5th year and 7th year students. Interventions of a teacher were not provided for the 7th year students. The latter builds on the selected nature of this advanced group of last year students, with a future interest in radiology, rheumatology, orthopedic surgery, traumatology and/or physical therapy. These students are expected to solves the cases more quickly, since they can build on their radiology clerkship experience during the 6th year of their curriculum, and the prior knowledge acquired throughout the medical curriculum. This is reflected in the lower average number of meaningful contributions to solve cases (mean 4.7). In contrast, 5th year students are still developing both the radiology knowledge and skills base and attend courses about radiological anatomy, imaging techniques, and radioprotection. They have yet no clinical experiences with radiology. This results in the expectation that these students need more time to solve the cases. The average number of meaningful contributions is as a result higher and also the overall number of times students did work in the CSCL setting (N 144, SD 47).

Though not based on the systematic analysis of the data gathered while analyzing the CSCL discussions, anecdotal evidence shows some particular differences in the way students from the 5th and 7th year interact. **The structure of** 5th year students' **discussions** has more repetitive character with checking on each other the correctness of the proposed item to solve the case. Contrary to the structure of discussion of the last year students which is more constructive. Students make their decision mostly during the first discussion session and continue to work on additional relevant issues.

Another important point during the CSCL sessions is the need of teacher to intervene during the discussions of 5th year students. The average number of teacher interventions across 26 discussion was 2.54. The reasons why these **teacher interventions** are necessary were mostly related to (1) a wrong direction in identifying a radiological structure or a diagnosis, (2) to stimulate the group to identify other relevant items related to their diagnosis or a validation of issues being raised.

Table 3 summarizes the differences in components of the diagnostic approaches adopted by the two different student samples during the CSCL sessions. Significant differences are visible for the number of radiological key structures being missed (mean 0.81 vs 0.10, respectively, $p < 0.05$) as a part of the **visual pattern recog-**

Table 2
General characteristics of the CSCL discussions.

Year	Total number cases to solve	Number cases to solve for each student	Time to solve the cases	Number of meaningful contributions across 26 discussions (mean; [SD[a]])	Number of times that students did consult a case across 26 discussions (mean; [SD[a]])	Number of times that teacher did intervene during the discussion across 26 discussions (mean; [SD[a]])
5th year students	26 cases	4 cases	3 weeks	9.23 [3.76]	144 [47]	2.54 [0.99]
7th year students	26 cases	15 cases	One week	4.77 [1.68]	32 [11]	NA

[a] SD = standard deviation.

nition components and significant differences in the number of diagnoses missed during the CSCL sessions (mean 1.1 vs 0.1, respectively, $p < 0.05$) as part of the **cognitive pattern components**. No significant differences were observed in the number of anatomical structures, appropriate radiology imaging techniques, and the number of differential diagnoses being missed. Significant differences can again be observed in the **verbal justifications**. Junior students adopt significantly more lay terms during their discussions (mean 1.7 vs 0.5, respectively, for year 5 and 7; $p < 0.05$). Nevertheless, both student groups seem to master and apply almost an equal number of adequate medical terms (mean 6.2 vs 5.6, respectively, for year 5 and 7).

Table 4 summarizes the analysis results of the outcome evaluation data. Significant differences are observed between 5th and 7th year students in their **visual pattern recognition**, though this difference is only due to the significant differences in the accuracy in identifying the key radiological structures. 7th year students outperform 5th year students (mean 1.25 vs 1.65, respectively, for year 7 and 5, $p < 0.05$). No significant differences are observed in terms of accuracy of recognition of anatomical structures. Significant differences are observed in the final case solutions of 5th and 7th year students in terms of the **cognitive patterns**. Both the accuracy of the radiological diagnosis (mean 1.5 vs 1.92, respectively, for year 7 and 5, $p < 0.5$) and the accuracy to link radiological signs to clinical information is significantly better developed in 7th year students (mean 1.46 vs 2.08, respectively, for year 7 and 5, $p < 0.05$). There are no significant differences in the accuracy to choose an appropriate radiological imaging technique. The latter finding is positive since the knowledge and skills to recognize anatomical structures and to choose appropriate radiological imaging techniques are central learning objectives within the radiology curriculum from year 2 up to the last year of medical training. The significant differences in both visual pattern recognition and cognitive patterns point at the clear impact of the curriculum shift after the 5th year. Seventh year students have attained a higher "level of experience" with radiology. The latter was already substantiated in a previous study [34] focusing on the added-value of radiology clerkships. In addition, the significant differences also point at the value of integrating the radiology curriculum within the context of the broader medical curriculum [35] and the interdisciplinary nature of the clinical setting [14]. The latter is beneficial in development diagnostic thinking abilities. Consistent with the findings reported in Table 3, no significant differences are found reported in the actual use of **verbal justifications**, as reflected in the final group case solution (accurate use of medical terminology).

Finally, no significant differences between year 5 and 7 were found in final exam scores. The mean final exam score was 14.03 [SD = 3.4] for year 5 and 14.41 [SD = 2.0] for year 7 student, $p = 0.51$. This implies that all students got comparable opportunities to develop their knowledge and skills and to prepare for the final exam. This is an important finding since the final test comprises both the application of radiological diagnosis and imaging interpretation skills, in addition to applying a factual and conceptual knowledge base in relation to the cases to be solved.

5. Discussion

At Ghent University, "Web-based radiology cases" has been implemented as a part of the large innovative project in radiology teaching since 2008–2009 and were introduced in year 5 and 7 in the context of a computer supported collaborative learning setting. The present study presents a first evaluation of this innovative instructional concept in terms of students experiences, and in terms of a qualitative and qualitative analysis of the collaborative process and outcomes.

Previous research already emphasized the potential of developing an interactive and multimedia learning environment, focusing on radiology case-based learning [11]. The findings of the present study confirm that a scripted CSCL approach is favorable for both early clinical year students and students at the end of their medical education career. It is known that collaborative learning enhances students satisfaction [14,15,36]. The students in the present research reported a neutral to positive attitude towards collaborative learning, thus conforming partly the social constructive benefits from working in small groups [4]. Students report to learn from each other, learn to collaborate and tend to solve clinical radiological problems more quickly.

The fact that 7th year students were somewhat less in favor of the CSCL setting can be related to the very different nature in the study profile of 7th year students. They already have a clear and

Table 3
The components of the diagnostic approaches during the CSCL activities (process evaluation).

The components of the diagnostic approaches	N cases	Year 5 Mean [SD*]	Year 7 Mean [SD*]	Z
Visual pattern recognition				
Number of radiological key structures that were missed during a group discussion	26	0.81 [1.1]	0.19 [0.4]	−2.66*
Number of anatomical structures being missed during a group discussion	19	0.53 [1.2]	0.05 [0.2]	−1.49
Cognitive patterns				
Number of diagnoses missed during the discussion	26	1.1 [1.1]	0.1 [0.4]	−3.88*
Number of differential diagnoses presented during the discussion	26	1.1 [1.3]	0.9 [1.2]	−0.47
Number of appropriate radiology imaging techniques missed during the discussion	6	0.2 [0.4]	0.0 [0.0]	−1.00
Verbal justifications				
Number of adequate medical terms used during the discussion	26	6.2 [3.0]	5.6 [2.3]	−0.62
Number of lay terms used during the discussion	26	1.7 [1.8]	0.5 [0.8]	−2.38*

* $p < 0.05$

Table 4
Accuracy and correctness of discussion contributions related to the radiology diagnostic thinking patterns (outcome evaluation).

Diagnostic thinking approach[a]	N cases	Year 5 Mean [SD[a]]	Year 7 Mean [SD[a]]	Z
Visual pattern recognition		1.65 [0.8]	1.25 [0.4]	−2.26*
Accuracy of identification of radiological key structures	26	1.69 [0.9]	1.27 [0.5]	−2.04*
Accuracy of recognition of anatomical structures	19	1.53 [0.6]	1.26 [0.4]	−1.40
Cognitive patterns		1.95 [0.8]	1.51 [0.6]	−1.95*
Accuracy of radiological diagnosis	26	1.92 [0.8]	1.50 [0.6]	−2.10*
Accuracy of linking the radiological signs to available clinical information	13	2.08 [0.9]	1.46 [0.9]	−2.14*
Accuracy of choosing appropriate radiological imaging techniques	6	2.17 [1.2]	1.33 [0.5]	−1.40
Verbal justifications				
Accuracy of using medical terminology	26	1.38[0.6]	1.15 [0.5]	−1.87

[a] Items are scored: 1 = completely correct; 2 = correct but with missed key findings; 3 = correct but with not relevant findings; 4 = completely incorrect.
* $p < 0.05$.

personal orientation in view of a future specialization (radiology, rheumatology, orthopedic surgery, traumatology and/or physical therapy). Students in these high-stake performing settings are known to less be less oriented towards collaborative learning settings. These students have a strong personal commitment to solve the radiology cases [11].

The process and outcome analysis results of the CSCL discussions showed significant differences in the mastery of 5th and 7th year students. This illustrates that case-based “problem-solving is content specific” [37]. The results also suggest that the design of the cases was relevant, and did cover the adequate learning objectives of the curriculum [38].

In the introduction, we emphasized the importance of content scripting in the context of CSCL. The current research findings help us to refine this approach in the context of solving radiology cases. We first review the main findings. From our research, it is clear that the last year students have already attained a systematic approach in their radiology problem solving. Fifth year students still need to improve this kind of abilities: to recognize the key radiology structures, to define a diagnosis and to relate radiological signs to available clinical information. But clinical radiology in the Ghent University curriculum is only being from the 4th curriculum year. As a result, 5th year students hardly have attained radiological clinical experience. Though we can conclude that the CSCL case-based learning approach has fostered their knowledge and skills, we think that a more thorough – clinical thinking – scripting approach could be adopted. This script could be more explicitly imprinted on the case solution approach. In the literature, we can build on available experiences [39]. For instance, Miller and Andrew [40] proposed a structured radiologic problem-solving system, based on six steps: problem sensing, problem hypothesizing, problem searching and definition, problem identification, resolution, verification. Available evidence suggests that following this solution pattern approach helps to come to more thorough decision [32]. This type of script could be imposed at an early stage. Research indicates that – after an initial phase of rigid application of these scripts in diagnostic thinking, the degree of flexibility in thinking and the level of knowledge structuring in memory largely increases [33]. It is expected that a more explicit scripting approach will stimulate the development of integrated radiology thinking approaches.

We observed – in 5th year students – the need for teacher interventions to direct the case solution process. Again, we can link this to the scripting approach discussed above. These scripts could also serve as guides for the teacher to give hints, cues, recommendations, and invoke reflection in the students during the group discussions. We expected that teacher interventions would maximize the results of the group decision in terms of diagnostic interpretation of the patient case as a whole. The latter is important to prevent students to proceed on a symptom-by-symptom basis [33]. Research shows that students perceive experts' interventions during collaborative sessions as useful and important [15]. Moreover, studies also point at the modeling and motivating impact that result from the active engagement of teaching staff when managing CSCL settings, and revising draft group solutions [36].

From previous research about expertise in medical imaging diagnosis, it is known that in parallel to expertise, also the ability to verbalize the thinking process clearly improves [41]. We found no differences in accuracy of usage of medical terms between 5th and 7th year students, but significant differences were found in the usage of lay terms during the CSCL discussions. This points at the critical position of these and related courses in the curriculum to develop reporting skills that force students to actively apply their medical vocabulary. It is suggested that CSCL settings might be beneficial in this context.

In the setting of CSCL, the robust electronic learning platform is vital to support this way of teaching: to ensure the possibility of online discussions and data communication and storage as well as an access to the system. Availability of personal computers or pc's at school that can be used by students during the learning is also important element of this system.

5.1. Limitations

A number of limitations have to be mentioned in relation to the present study. First, the study was based on a local implementation of an instructional system at Ghent university. Secondly, though we compared 5th and 7th year students, it was not our intention to judge the differential impact of CSCL case-based learning in both student samples. The approach of the present study was not experimental in nature, but rather evaluative and explorative. It helped nevertheless to point at a positive shift in competences in 7th year students. Additionally, we have to acknowledge that “problem-solving is content-specific” [37]. The present study only focused on cases about musculoskeletal radiology, which is only a part of the broader radiology curriculum. Future research could center on radiological cases at the thoracic level (radiology of heart, lungs) or abdominal level (radiology of digestive tract or radiology of the uro-genital system). Next, tough we emphasized the need to adopt a content scripting approach, future research should be more explicit about the nature and structure of the scripting, the way teachers intervene and how learners adopt these scripts. It is important to note that a CSCL approach towards case-based learning is labor intensive in terms of faculty time. Future studies could explore peer tutoring approaches that have been proven to be successful in other domains [42]. Lastly, our study design focused on the nature and quality of group discussions and products. This neglects within-group differences. Also, since then difficulty level of the cases was clearly different, again differences within and between groups could have occurred that are now neglected in the present analysis approach. Future research could center on multi-level analysis techniques that respect the nested nature of students in groups, studying different cases.

5.2. Direction for future research

Future studies could also focus on a discourse analysis to study the particular patterns in the CSCL interactions. This would be helpful to analyze in what way students build on each others' contributions, share information and how they attain a consensus on a case solution.

6. Conclusions

To conclude, the result of the present research indicate that students appreciate CSCL case-based learning. Scripted computer supported collaborative learning groups proved to be useful for both 5th and 7th year students in view of developing components of their diagnostic approaches.

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Glossary

Computer supported collaborative learning (CSCL): (1) as the field that investigates "processes of intersubjective meaning-making and how technological affordances mediate or support such processes" (p. 332) (Suthers DD. Technology affordances for intersubjective meaning-making: a research agenda for CSCL. Int J Comput Supported Collaborative Learn 2006;1:315–37); (2) aims at supporting groups of learners in acquiring content knowledge in a specific domain by means of computers. The context of the collaborative learning situation affects how groups achieve the goal of content knowledge acquisition. Such learning context can include, e.g. the other group member, the design of the learning material, or characteristics of communication media (Engelmann T, Dehler J, Bodemer D, Buder J. Knowledge awareness in CSCL: a psychological perspective. Comput Hum Behav 2009;25(4):949–60).

Script: cognitive sciences concept that aims at explaining how humans understand real-world events and why this understanding in most cases occurs almost effortlessly (Gardner H. The mind's new science: a history of cognitive revolution. New York: Basic Books Inc. 1987. p. 165–9). In the context of CSCL, scripts help to structure collaborative learning activities. *Content-oriented script* helps learners to select, organize and integrate the knowledge base that is at the base of the collaborative task (such as knowledge about infections to solve a discussion task about tropic diseases). *Communication-oriented script* fosters the engagement of group members in the collaborative process by helping them to adopt different or specific perspectives, to consider in a conscious way the input of peers, etc. (Schellens T, Van keer H, De Wever B, Valcke M. Scripting by assigning roles: does it improve knowledge construction in asynchronous discussion groups? Int J Comput Supported Collaborative Learn 2007;2:225–46).

Scripts-based clinical reasoning: a script activation is automatic and almost unconscious, activated scripts are used in a conscious and strategic way to confirm or refute corresponding hypotheses, and activated scripts serve to guide information selection, memorisation and interpretation (Charlin BD, Tardif J, Boshuizen HPA. Scripts and medical diagnostic knowledge: theory and applications for clinical reasoning instruction and research. Acad Med 2000;75(2):182–90).