Medical Student Education

Case-Based Collaborative Learning in Undergraduate Radiology Teaching—Are Essential Conditions for Group Discussions Met?

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Background: Delivering case-based collaborative learning (cCBL) at scale using technology that both presents the clinical problem authentically and seeks to foster quality group discussion is a challenge, especially argumentation which is critical for effective learning. The aim of this study was to investigate the presence of essential conditions to capitalize on a technology-enhanced cCBL scenario for teaching radiology and facilitating quality group discussion.

Methods: A questionnaire was administered to 114 fourth-year medical students who completed a technology-enhanced cCBL scenario for teaching neuroradiology. It consisted of individual online pre-class work and face-to-face in-class work, where group discussion followed individual work at a workstation. Items from the "Heedful Interrelating in Collaborative Educational Settings" scale and "positive emotional engagement" questionnaire assessed the quality of social-cognitive processes and emotional engagement during the group discussions. Structured interviews were used to explore the teachers' awareness of and engagement with the technology.

Results: The mean scores of most "heedfulness" items were below 3.5 (7-point scale), suggesting that participants did not enter the debriefing with a mindset conducive for argumentation. However, for the affective states "interest" and "enjoyment" the mean scores were above 5. Free text comments suggested participants enjoyed the superficial interactions, but did not necessarily engage in argumentation. Structured interviews revealed teachers were aware of the possibilities of the learning dashboard and used it as a common frame of reference, but did not really succeed to use it as a springboard for discussion.

Conclusion: A technology-enhanced cCBL scenario is useful for teaching radiology in undergraduate medical education, but the added value of acquiring in-depth knowledge will only be achieved when students are aware of the importance of an "heedful" mind-set.

Key Words: Radiology; Undergraduate; Case-based learning; Group discussion; Heedful; Mindset.

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INTRODUCTION

Case-based learning (CBL) is a long established pedagogical method in medical education. Although there is not really an international consensus as to its definition, the elements common to most definitions are that it requires the presentation of a clinical case followed by an "inquiry" on the part of the learner and provision of further information by a tutor who guides the discussion towards meeting the learning objectives (1). In CBL, the topics and learning objectives are defined by the teacher (1,2) and the method can be implemented on an individual, small group or large group bases.

Although discussion is regularly mentioned as part of CBL, it is usually unclear when, how, between which actors and to what extent these discussions take place. This lack of clarity about the role of discussion in CBL is problematic, because it is precisely group discussion that has been shown to help students in the long-term retention of the subject matter studied (3,4). Both fellow students and teachers can potentially play an important role in group discussions. Peers for instance may understand better than the teacher does what other students do not understand and explain things in more familiar terms. Teachers on the other hand can encourage students to think more deeply, offer some modeling of the types of questions students should be asking themselves, and seed the conversation with new ideas or alternatives (5,6). So CBL that employs group discussion involving both students and teachers, is what we should strive for in education.

Case-based collaborative learning (cCBL) is a variant of the CBL method that pays more focused attention to group discussions (7). In cCBL, cases with questions are presented and individually answered in class, followed by intra- and inter-group discussions. Individual tests to ensure the necessary prior knowledge are given before the class meeting. This combination of in-class active and interactive learning together with securing the required prior knowledge, makes cCBL an interesting teaching format for undergraduate education.

Whilst there is evidence to show that collaborative group discussion prompts disciplinary knowledge gains, not every discussion is effective for learning (8). There are types of conversation that are associated with positive learner outcomes, for example, argumentation is a specific type of dialog in which opinions are not only formulated but also justified in a rhetorical context of criticism, prompts long-term (delayed) knowledge gains (9,10). Argumentation also has the potential of deeply engaging students, making their thinking visible, and refuting misconceptions. This is thought to improve the organization of knowledge, enabling better recall and understanding (11).

However, argumentation in group discussions does not just happen by virtue of individuals expressing themselves, but requires a number of factors to be present. First, individuals need a disposition in which they enter the discussion with a certain attitude or mindset, in which the aim is to be curious and to grow in knowledge together through constructive interpersonal interactions (12,13). Second, individuals need to be interested and manage emotions such as anxiety in order to engage with any challenges related to the subject matter (14). Finally, the way a group discussion is moderated by a teacher and the way the moderator is supported by technology, will influence the quality of the interpersonal interactions.

Educational technology is often used as a means of both scaffolding a CBL task and facilitating group discussion, with developers designing software with various affordances for these purposes (15). The challenge for teachers and students is therefore to recognize and use these affordances individually and as a group to maximize collaborative learning when engaging in computer-supported CBL. CBL is also regularly used in undergraduate, postgraduate and continuing radiology education (16,17) with the technology providing a symbiotic relationship between the clinical sub-speciality and the educational process. Even with specifically designed technology-enhanced cCBL scenarios, the question remains whether the conditions are in place to harness their potential value for learning. Therefore, the aim of this study was to investigate the presence of essential conditions to capitalize on a cCBL scenario for learning radiology in undergraduate medical education.

MATERIALS AND METHODS

Context

A technology-enhanced cCBL scenario was developed and implemented for teaching neuroradiology in an undergraduate curriculum at a German medical school. With the active and interactive components of the cCBL scenario, the aim was to combine aspects of the cognitive and social constructivist models of teaching and learning. The social interaction was planned to take place mainly in medium-sized groups (about 16 students) after active individual work on a case at a workstation. Each group was supervised by a radiologist and supported by a learning dashboard, that presented the responses of the students to questions of the individual assignment on a large shared screen. This learning dashboard was intended to establish a common frame of reference for the group and to serve as a springboard for group discussions.

Subjects

In October 2022 a full cohort (n = 117) of fourth-year undergraduate medical students at the University of Muenster was enrolled in the third run of the technology-enhanced cCBL scenario for a mandatory neuro-radiology course. In order to ensure that students in the seven medium-sized groups of around 16 knew each other beforehand and did not waste unnecessary time on an induction process, the

composition was based as far as possible on study groups of six students formed in the first year to share more frequently in learning activities across the curriculum. Radiologists associated with the University of Muenster (n = 4 with main clinical employment at the University Hospital Muenster, n = 3 with external main employment), who also participated in one or two former runs of the scenario, each supervised a group during this third run.

Procedures

The technology-enhanced cCBL scenario encompassed the following elements:

- Preparatory e-learning module and individual knowledge test in advance of class: in the week before the in-class practical students had to prepare themselves with online teacher-defined study material (virtual patient program CASUS) that also tested the acquired knowledge with multiple choice, region of interest, mapping, and matrix questions (Fig 1a)
- Individual assignments with cases presented in-class: during a total 7 h practical, students had to answer free-text, multiple choice, long-menu, and marker questions for five patient cases in an assessment program (VQuest) with a viewer for CT and MRI-images (Fig 1b).
- Group discussions after individual work: in medium-sized groups (about 16 students) the former individual work-up of a case was discussed. Each group had their own PRISMA-learning dashboard (18) at their disposal and was supervised by one radiologist. The learning dashboard presented the responses of the involved individual students in a structured and anonymous way back to the group on a shared large screen (Fig 1c).

To promote a consistent implementation of the scenario during the in-class phase, all supervisors received a training session prior to their first run to ensure that they understood the purpose, components and implementation procedures of the educational intervention. In addition, in the week before each run, supervisors received a manual describing the schedule, group format, procedure and content of the five cases with the answers to the different types of questions. They were also given a short user manual for the two software programs used and a link to a test environment to familiarize them with their use.

Terms and Measures

The "*Heedful Interrelating in Collaborative Educational Settings*" *(HICES) scale* (19) was used to *assess the quality of the social-cognitive processes during the group discussions* after the individual elaboration of patient cases in the cCBL scenario. The HICES items were, with slight adapted wording, used for both the student self-report as for the teacher-ratings for a whole group they supervised.

Originally implemented within the organizational management literature, heedful interrelating is defined as interacting with sensitivity to the task at hand while at the same time paying attention to how one's actions affect overall group functioning (20). Based on this concept Daniel and Jordan developed the HICES scale, a six-item questionnaire to measure students' perceptions of the quality of the interactions during collaborative educational tasks (19). The reliability and validity of the HICES scale was confirmed by exploratory and confirmatory factor analysis. Because the undergraduate medical curriculum at the University of Muenster is set up in the German language and also the practical in question is conducted entirely in German, the original English-language items of the HICES have been translated into German for both students and teachers.

Appendix 1 shows the items of the HICES self-report instrument for students and of the teacher-rating instrument for a group.

The *questionnaire for "positive emotional engagement"* (21) was used to *assess the emotional engagement of the students during the group discussions* after the individual elaboration of patient cases in the cCBL scenario.

The items in this questionnaire for emotional engagement are restricted to the positive affective states "interest" and "enjoyment," because the negative affective state "anxiety" loaded in an exploratory factor analysis insufficiently on the latent variable "emotional engagement". The two-item questionnaire asking learners to indicate their levels of interest and enjoyment on a Likert scale showed a high validity and reliability for measuring learners' positive emotional engagement in a task-based interaction. Also the two items of this questionnaire were translated from English to German language.

Appendix 2 shows the items of the "positive emotional engagement" in the self-report instrument for students.

To explore whether teachers were aware of and actually utilized the features of the learning dashboard in the technology-enhanced cCBL scenario for the group discussions after students' individual elaboration of patient cases, *structured interviews with cued retrospective reporting* were used. As cue, screen records of the mouse and keyboard operations the teachers performed in the PRISMA learning dashboard, were used.

Verbal reporting techniques like concurrent reporting (during task performance) and retrospective reporting (after task performance) are regularly used in usability studies (22). In this study, these methods can give us the opportunity to shed more light on how teachers perceived the affordances of the PRISMA learning dashboard and to explore how teachers comprehended its function for the group discussions in a cCBL scenario for teaching neuroradiology. For real teaching practices, like the cCBL scenario under study, retrospective reporting is the only feasible investigation method because concurrent reporting would completely disrupt the natural processes taking place in the teaching scenarios.

The drawback of retrospective reporting, the forgetting of memories after task performance, can be mitigated with the

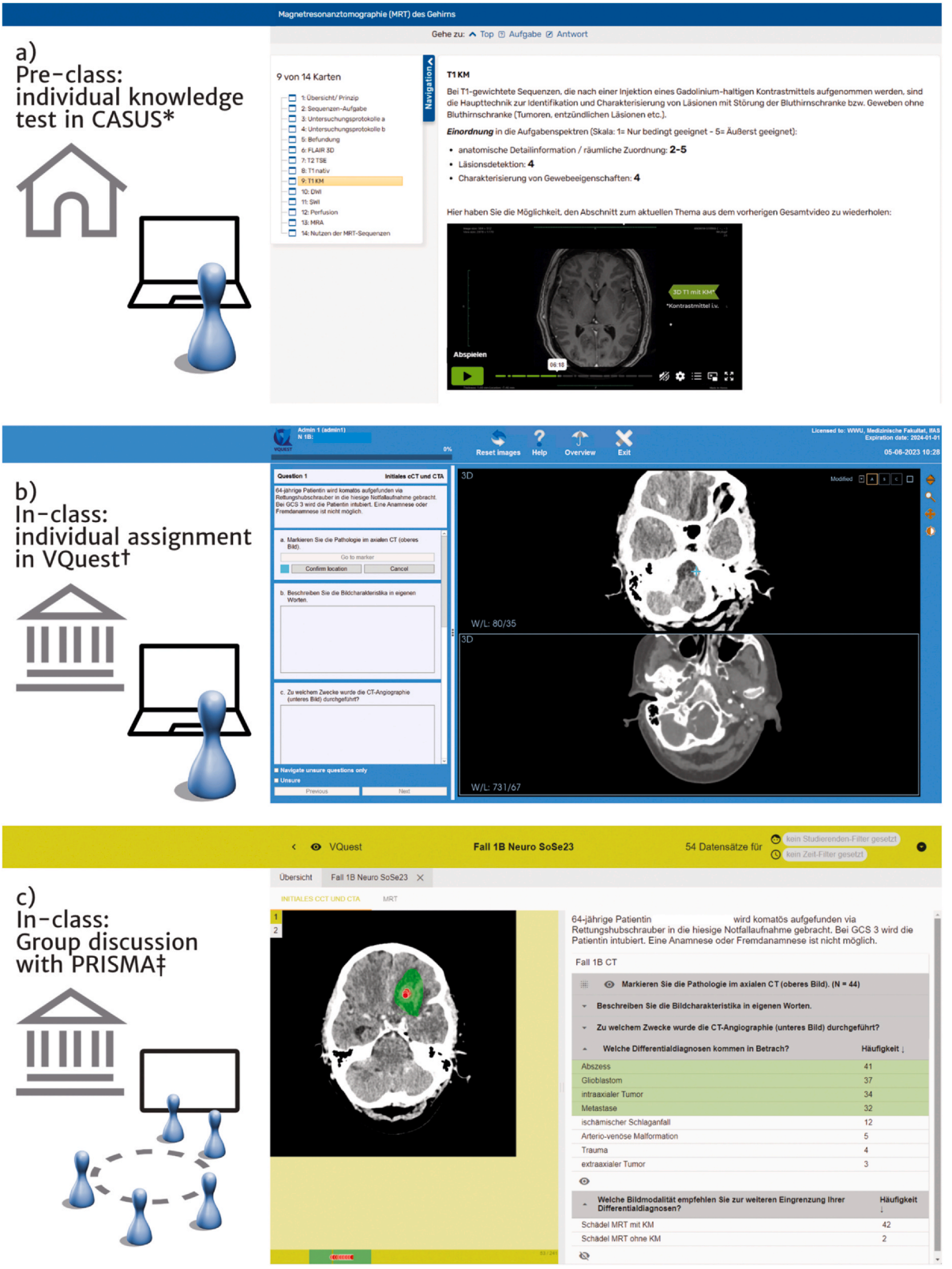

Figure 1. Workflow of the technology-intensive cCBL scenario for neuroradiology teaching. * CASUS: virtual patient software (https://www.instruct.eu/casus/virtual-patient-software). † Vquest: assessment software for volumetric and WSI images (https://vquest.nl/). ‡ PRISMA: learning dashboard software for radiology and virtual microscopy teaching (https://clovid.org/prisma-learning-dashboard).

TABLE 1. Demographic Information for Students and Teachers Participating in the cCBL Scenario

Students $N = 114$				
Gender	N		%	
Female	78		68	
Male	36		32	
Age	Mean	SD	Min	Max
	24,6	3,55	21	35
Teachers $N = 7$				
Gender	N		%	
Male	7		100	
Age	Mean	SD	Min	Max
	49	10	35	64

method of *cued* retrospective reporting, in which participants are instructed to report retrospectively on the basis of a record of observations (23). With a cue consisting of a combined record of eye movements and mouse–keyboard operations van Gog (van Gog, 2005) for instance, showed that cued retrospective reporting resulted in more information on actions taken ("action"), strategies used ("how") and self-monitoring ("metacognitive") information than did retrospective reporting alone. Because for our naturalistic research setting eye tracking is not a feasible option, we limited the cue to screen recording of the mouse and keyboard operations in the learning dashboard. The "why" information, not revealed by cued retrospective reporting, we addressed with probing questions of a structured interview.

Appendix 3 shows an outline of the questions posed during the structured interviews with the teachers.

Data Collection and Analysis

All participating students and teachers were asked to complete an online questionnaire (LimeSurvey) anonymously in German language, during the break after the small group discussion following the fourth case of the practical. Next to the six items on "heedful interrelating" (appendix 1), the students had to respond to the two items on "positive emotional engagement" (appendix 2) and were invited to comment on two open questions concerning the learning dashboard and the group discussions (Table 2c).

Further, the teachers ($N = 7$) were invited to take part in individual structured interviews within two days after the practical. As the teachers worked in different remote locations in Germany, the interviews took place online via video conferencing (Zoom) in German language. For the "cued retrospective reporting" part of the interview the screen of the interviewer was shared, showing a video-recording of the mouse and keyboard operations the teacher performed in the learning dashboard during the practicum from 1 to 2 days ago **(recorded with PostHog)**. The interviews themselves were video-recorded, transcribed literally and translated in English. The principal investigator (BdL), who read through the translated transcripts, made an English summary for each interview that was mailed to the teachers for approval. Finally, an overarching summary of all the input from the teachers, categorized under the themes addressed in the interview was written.

For the students' self-ratings and the teacher group-ratings the means, standard deviations and 95% confidence intervals were calculated per item.

RESULTS

Table 1 shows demographic data on gender and age for the students and teachers participating in the cCBL scenario. A total of 114 students, an average age of 24,6 years, and a percentage of 68% female provide a representative picture of a cohort of fourth-year medical students at the University of Muenster. All teachers were male and associate professor or professor resulting in an average age of 49 years.

Table 2a shows the students' scores on the six HICES statements in the self-report instrument that assessed the

TABLE 2A. Students Perceptions of the Quality of the Social-Cognitive Processes During the Group Discussions After the Individual Elaboration of Patient Cases

	$N = 114$		
Statements*	Mean	SD	95% CI
I helped to clarify the idea of another group member so that we would all understand her/his idea.	3.14	1.89	2.78-3.50
I rephrased what a group member had said so that I could check my understanding of his/her idea.	3.31	1.74	2.99-3.64
I asked a group member to elaborate on his/her idea so that I could make sure I understood what he/she was saying.	4.04	1.92	3.68-4.40
I carefully explained a concept to a group member who did not understand the concept.	3.41	1.80	3.06-3.75
I carefully contributed relevant examples in my group.	3.16	1.79	2.82-3.50
I tried to think about how I could connect my ideas to ideas offered by other group members.	4.09	1.67	3.78-4.41

* Items in the questionnaire were in German language and scores for the statements were expressed on a 7-point scale in which 1 = 'not at all true' and 7 = 'very true'.

TABLE 2B. Students' Perceptions of Their "emotional engagement" in the Group Discussions After the Individual Elaboration of Patient Cases

	N = 114		
Question*	Mean	SD	95% CI
How much have you been interested in the interaction?	5.85	1.31	5.60-6.09
How much have you enjoyed the interaction?	5.73	1.61	5.43-6.03

* Items in the questionnaire were in German language and scores for the statements were expressed on an 7-point scale in which 1 = 'not at all' and 7 = 'very much'.

TABLE 2C. The Topics Several Times (*n* > 5) Raised by Students in the Open-ended Questions of the Questionnaire

*What aspects of the Leaning Dashboard have you found valuable in supporting discussions?**
That it helped the teacher to convey the expert solution and to explain the right answers to the questions of a case.
That it provided an outline or structure for the summary of a case, with which you could verify if you understood the subject matter
That it could present the subject matter and student responses in such a concrete and detailed way that personal questions or questions focused on specific content could be asked more easily
That it anonymously presented your own knowledge together with that of your fellow students, allowing you to reflect on your own answers and also to check whether you were at the same level of knowledge as your peers.
That it also made the wrong answers visible and thus discussable.
*What aspects of the Leaning Dashboard did you find less useful in supporting discussions?**
That writing free-text in the individual assignment and later the joint reading of such texts in the learning dashboard was not appreciated. It was too in-depth and took too much time.
That discussions at the learning dashboard were made very difficult by the level of background noise generated by the different groups packed in one large room simultaneously conducting the group sessions with their teachers
That in the teaching program as a whole the content was too much for the time available or too demanding for the students' current level of knowledge

* Original responses were in German language and translated to English.

quality of the social-cognitive processes during the group discussions after the individual elaboration of patient cases in the cCBL scenario. The mean scores for four of the six 'heedfulness' items were below 3.5. For the items 'connecting their own ideas with those of others' and 'asking others to elaborate more on their ideas' the mean scores were a little bit higher than 3.5 (4.09 and 4.04, respectively).

Table 2b shows students' scores on the two questions in the self-report instrument that assessed their 'emotional engagement' in the group discussions after the individual elaboration of patient cases in the cCBL scenario. For both affective states 'interest' and 'enjoyment' the mean scores were above 5 (5.85 and 5.73, respectively).

Table 2c shows the topics that were raised by more than five students in response to the two open-ended questions in the questionnaire. For the question on the 'added value of the learning dashboard for the group discussions,' five topics emerged: publication of the correct answers, presentation of a summary, presentation of detailed information for focus, possibility for anonymous comparison with peers and attention for wrong answers.

For the question on 'less beneficial aspects of the learning dashboard for the group discussions' three topics emerged. Only one of them really concerned the learning dashboard: the presentation of all the free text answers could lead to a time-consuming review. Two topics were more about the whole course (too much and difficult content) or the physical learning environment (to noisy and crowded room).

Table 3a shows the teachers' ratings for the whole group they supervised on the six HICES statements for the quality of the social-cognitive processes during their group discussions after the individual elaboration of patient cases in the cCBL scenario. The mean scores for five of the six 'heedfulness' items were higher than 3.5. Only the mean score for the item 'Students asked other group members to elaborate on their ideas so that they could make sure they understood what was said' was exactly 3.5.

Table 3b shows the summary of the teachers' answers in the individual structured interview with cued retrospective reporting, categorized under the main themes that were addressed in the interviews.

DISCUSSION

As the type and quality of discussions in collaborative learning are crucial for its learning effect (10,11), we investigated three factors that might influence the social-cognitive processes during group discussions in a cCBL scenario for undergraduate radiology education. Social interaction in this technology-enhanced cCBL scenario was planned to take place in medium-sized groups (16 students) after active individual work on a case with 2D and volumetric radiological images at a workstation. Collaborative learning was supported by a content expert and a learning dashboard that

TABLE 3A. Teachers' Perception of the Quality of the Social-cognitive Processes During the Group Discussions After the Individual Elaboration of Patient Cases

	N = 7	
Statements*	Mean	SD
Students helped to clarify the ideas of other group members so that all would understand their ideas.	4.00	1.60
Students rephrased what other group members had said so that they could check their understanding of these ideas.	4.43	1.50
Students asked other group members to elaborate on their ideas so that they could make sure they understood what was said.	3.50	1.61
Students carefully explained concepts to other group members who did not understand the concept.	4.29	1.28
Students carefully contributed relevant examples in the group.	4.17	2.11
Students tried to think about how they could connect their ideas to ideas offered by other group members.	4.00	1.91

* Items in the questionnaire were in German language and scores for the statements were expressed on a 7-point scale in which 1 = 'not at all true' and 7 = 'very true'.

displayed students' responses to the previous individual task on a large shared screen.

First, students' mental attitudes towards learning were explored by asking both students and teachers to complete the 'Heedful Interrelating in Collaborative Educational Settings' (HICES) scale. Second, students' emotional involvement was explored by asking students to complete the 'positive emotional involvement' questionnaire and finally, teachers' perceptions of the affordances of a learning dashboard to support group discussions were explored using structured interviews and cued retrospective reporting.

Heedful Interrelating

For their own heedful interrelating, students reported a mean score above neutral (3.5 on a seven-point scale) for only two of the six HICES items: 'connecting their own ideas with those of others' and 'asking others to elaborate on their ideas' (4.09 +− 1.66 and 4.04 +− 1.91, respectively). These two items differ from the others in that they are focused on benefiting the individual rather than another person or the group. This is an indication that the regulation of learning processes mainly takes place at an individual level. Such a highly individualistic orientation hinders the promotion of knowledge, not only of other individuals and of the group as a whole, but probably also of one's own knowledge through a lack of self-explanation and feedback from others (24).

Teachers rated the heedful interrelating of students in their group above neutral on five HICES items. The only item that the teachers did not rate above neutral (exactly 3.5) was one that students themselves rated above neutral: 'asking others to elaborate on their ideas'. It seems that the activity the students thought they had brought in was not enough to make their thoughts visible to the teachers. This deprives both the teacher and the group of an important opportunity to deepen knowledge through argumentation and to discuss misconceptions (10).

Emotional Involvement

For their own emotional involvement, students reported for both 'interest' and 'enjoyment' in the interaction with mean scores well above neutral (5.85 +−1.30 and 5.73 +−1.60, respectively). However, this clearly positive assessment of their own affective involvement does not reflect the mediocre actual interaction reported by both students and teachers. Perhaps students are already satisfied with more superficial exchanges with their peers and are more interested in what the supervisor brings to the table as a content expert. This attitude is somewhat echoed in the students' free text responses to what they appreciated about the learning dashboard, where they regularly indicated that it helped the teacher to convey the expert solution and to explain the correct answers to the questions in a case. This was also reflected in the interviews with teachers, some of whom said that they had the impression that students mainly wanted to know the solution to a case. It may also be a factor that, although the question in the questionnaire on interactions refers exclusively to the discussion in the plenary, students include in their perception the interaction they have with their neighbors and the teachers while carrying out individual tasks at the workstations.

Perceived Affordances of PRISMA Learning Dashboard

In the structured interviews, teachers expressed how they understood and used the features of the PRISMA learning dashboard for group discussions. Many of the teachers said that they used the learning dashboard to prepare for the final discussions: to find out which topics needed to be discussed in the plenary group, based on the answers to the individual tasks. Some used this insight into the knowledge available already in the phase when students were still working on their individual tasks. This enabled them to identify common problems at an early stage and discuss them in smaller groups at the workstations. Teachers also said that the learning dashboard gave them a structure for debriefing. It enabled them to discuss details without losing sight of the big picture.

The current study has some limitations. The study was conducted with a single cohort from one medical school. Replication across multiple medical schools and cohorts would increase confidence in the results. It was also noted by

TABLE 3B. Summary of the Teachers' ($n = 5$) Answers* in the Individual Structured Interviews, Categorized Under the Themes Addressed

Learning Objective
All teachers expressed that the main learning objective of the cCBT scenario for neuroradiology was that students got an opportunity to learn about CT and MRT imaging and to think in a clinical way what information this kind of imaging conveys, as well as what it may contribute to diagnosis and therapy of neuropathological diseases. Next to making students aware of the general value of neuroradiological imaging for clinical practice, one teacher also mentioned the opportunity for students to get a taste of the diversity of possibilities of this underexposed discipline in the medical curriculum, like for instance, the therapeutic interventions to manage life-threatening neurological situations. Questions that teachers felt students should address in a clinical context from the start of an encounter, for choosing the best imaging method, till after the imaging process, to help in shaping a therapy were for instance: How are the different imaging techniques used for the diagnosis of neurological diseases? What method is applicable for what question? How do I have to look at radiologic images? How do different disease processes become visible in CT and MRT?
Group discussions
Most teachers did not observe a lot of discussion during the plenum, when students gathered as a group around the large shared screen showing the learning dashboard with all the responses they gave in the assignment they just finished. Some teachers had the impression that students mainly wanted to know the solution to the case: what are the right answers?, What kind of answers were given in the group? and whether they themselves had done well. Several teachers stated that most questions students had on the subject were already addressed before the plenum at the learning dashboard, during the elaboration of the cases at the workstations. At these workstations also some interpersonal interaction and discussion with neighboring students took place. The circulating teacher regularly facilitated such discussions in smaller groups of 2–3 students.
Role of learning dashboard
Most teachers said they used the learning dashboard to prepare for the plenum. A preview of all the student responses helped them to decide what to address in this concluding session. For instance, questions that showed a heterogeneous spectrum of answers could be used for discussions or questions with a lot of wrong answers to correct misconceptions. Some teachers even used the learning dashboard during the time students worked at the workstations on their individual assignments, in order to see where students got stuck and needed support. In addition, it provided the teachers an opportunity to check whether they themselves had seen all the important anomalies in the images and topics that had to be addressed in a specific case. During the plenum at the large shared screen, the learning dashboard was used by the majority of the teachers to organize their discussions. The presented structure of a case with the possibility to expand and collapse parts offered a thread from which detailed topics and images could be addressed without losing the planned path. Also the tabs, each presenting a different kind of CT and MRI sequence, enabled them to take a closer look at a specific sequence and to make comparisons, without losing the big picture of the patient case.
Ways to trigger a discussion
Expressed spontaneously:
• Asking students their approach in the interpretation of radiologic findings, for instance, first viewing the bony parts of skull and after that the soft tissues inside the skull. Then asking them to reflect on the pros and cons of each approach.
• Asking students to reflect on the consequences of pathologies found in the images for the patient functioning and their thoughts of what has to be done in the hospital.
• Asking students to reflect on the importance of the findings for other medical disciplines like neurosurgery and what must be communicated.
Expressed in cued retrospective reporting:
• Asking students to compare phenomena within images (for instance, both sides of a symmetrical structures, anatomical with pathological structures) or between images (for instance different sequences, follow-up image)
• Pointing to the text of an answer of a description question, revisit the corresponding image and asking students to elaborate a little further on it.
• Pointing to wrong answers to questions and asking students to explain the reasoning that led them to a particular answer
• Responding to murmurs in the group when looking at an image together and asking what the problem is.

* Original answer were formulated in German language and translated to English.

both students and teachers that the background noise generated by the many groups in a large room during the cCBL scenario was detrimental to the intelligibility of participants in a discussion. This was exacerbated by the masks that participants were required to wear due to covid measures.

CONCLUSIONS

The research in this study showed that the students' mindset in the group discussion of a technology-enhanced cCBL scenario was less conducive to argumentation and therefore less effective in realizing the potential for collaborative learning as

expected. Although students rated their own emotional involvement (interest and enjoyment) in the interaction positively, their behaviors and cognitions were not very heedful in the sense that they paid much attention to how their actions affected the overall functioning of the group.

One explanation for this less effective mindset for collaborative learning could be that the medical students involved may have a strong individualistic orientation to knowledge acquisition, which prevents the group from regulating its learning processes at the co-level and the socially shared level (25). Goal orientations set by the students will influence not only self-regulation but also group regulation for learning (26). In a mastery orientation, where the focus is on developing competence, students are more likely to interpret collaborative learning as an opportunity to improve their knowledge, which in turn will have a positive effect on all three learning regulations. However, a performance orientation, especially when appearing competent is paramount, can have a substantial negative effect on argumentation in group interaction. This is all the more true for a performance-avoidance orientation, where students want to avoid revealing deficits in their knowledge and appearing incompetent to others, and quick consensus seeking can be tempting. It is reasonable to assume that these two unfavorable orientations are not uncommon among highly competitive medical students (27).

In addition, this study showed that the PRISMA learning dashboard used in the technology-enhanced cCBL scenario acted as a common frame of reference for the group, but did not really act as a springboard for discussion. It is difficult to say whether this is due to an inappropriate mindset, a lack of need (much has already been discussed at the workstation), a failure to recognize the potential of the learning dashboard to stimulate discussion, or a combination of all these factors.

The implication we can draw from these findings is that it might be valuable for students and teachers to become familiar with the theory of distributed cognition (28), which suggests that knowledge is not anchored in the heads of individuals, but is distributed socially (team), materially (documents and tools) and temporally within a dynamic system (organization). Since in today's healthcare, the knowledge of a single health professional is often insufficient to cope with the complexity of their practice, and outcomes depend on how well the system as a whole works, the concept of extending the view of cognition outside the head of a single person is essential for health professions education (29).

It emphasizes the importance of using heedful interrelating in collaborative learning settings by helping students to understand that it supports not only the acquisition of sound knowledge but also of essential skills for healthcare practice, where they will need to work in multidisciplinary teams and also create new knowledge with these colleagues in practice.

CREDIT AUTHORSHIP CONTRIBUTION STATEMENT

Bas de Leng: conceptualization, methodology, investigation, project administration, writing—original, review and editing. Friedrich Pawelka: formal analysis, data curation, validation, review and editing. Rakesh Patel: validation, review and editing. Benedikt Sundermann: validation, review and editing Others: validation and resources.

DECLARATION OF COMPETING INTEREST

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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STATEMENTS AND DECLARATIONS

The authors have no conflicts of interest to declare that are relevant to the content of this article.

Approval for this study was obtained from the ethics committee of the Medical Chamber Westfalen-Lippe and the University Muenster, application code 2022–663-f-S. There were no conflicts of interest.

Written informed consent was obtained from all individual participants included in the study.

APPENDIX A

The Heedful Interrelating in Collaborative Educational Settings (HICES) Scale (Daniel, 2015).

In the self-report instrument for students:

The following statements refer to the four group discussions with the PRISMA learning dashboard you just participated in. Please rate all statements on a scale from 1 to 7, where "1" means "not at all true" and "7" means "very true".

1) I helped to clarify the idea of another group member so that we would all understand her/his idea.
2) I rephrased what a group member had said so that I could check my understanding of his/her idea.
3) I asked a group member to elaborate on his/her idea so that I could make sure I understood what he/she was saying.
4) I carefully explained a concept to a group member who did not understand the concept.
5) I carefully contributed relevant examples in my group.
6) I tried to think about how I could connect my ideas to ideas offered by other group members.

In the teacher-rating instrument for a group.

The following statements refer to the four group discussions with the PRISMA learning dashboard you just moderated. Please rate all statements on a scale from 1 to 7, where "1" means "not at all true" and "7" means "very true".

1) Students helped to clarify the ideas of other group members so that all would understand their ideas.
2) Students rephrased what other group members had said so that they could check their understanding of these ideas.
3) Students asked other group members to elaborate on their ideas so that they could make sure they understood what was said.
4) Students carefully explained concepts to other group members who did not understand the concept.
5) Students carefully contributed relevant examples in the group.
6) Students tried to think about how they could connect their ideas to ideas offered by other group members.

APPENDIX B

The **questionnaire for "positive emotional engagement"** (Dao, 2021).

In the self-report instrument for students:

The following two questions refer to the four group discussions with the PRISMA learning dashboard you just participated in. Please rate the level of interest and enjoyment on a scale from 1 to 7, where "1" means "not at all" and "7" means "very much".

(1) How much have you been interested in the interaction?

(2) How much have you enjoyed the interaction?

APPENDIX C

Structured interviews combined **with cued retrospective reporting**.

Outline of the questions posed during the structured interview.

Representativeness of Teaching Performance

Question: Did you implement your teaching in the small group during the current version of the radiology day in a similar way as you did on former occasions of the radiology day?

Learning Objective of the Tasks

Question: In your opinion, what is the learning objective for the students to elaborate and discuss the radiology cases?

a) The radiology cases are used as a means to look at and understand disease processes and mechanisms in the nervous system? E.g., localization of pathology can explain the dysfunction.

b) The cases are an application of radiological knowledge in the steps: perception, analysis and diagnosis.

Role of the Discussion

Question: With regard to this learning objective, where do you think discussions are instructive?

How to Stimulate and Guide Discussions

Question: How do you try to stimulate and guide discussion at such moments? What role does the Learning Dashboard play in this?

Cued Retrospective Reporting

Question: Now I will show you a video recording of the mouse and keyboard interactions you performed in the Learning Dashboard during a group discussion you facilitated.

Please think back and try to identify moments that you found most valuable for interaction and discussion in the group. Feel free to pause the video if you identify a moment you would like to comment on.

Improve Suggestions for Scenario or Tools

Question: Do you have any suggestions how we could improve the scenario or tools used?

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