Self-explanation to support knowledge development for clinical reasoning: Perspectives from third year medical clerks

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Abstract

Background:
Self-explanation (SE) used as a learning strategy with clinical cases, can benefit medical clerks' diagnostic performance. However, its specific contributions to students' knowledge development remain unexplored. We qualitatively investigated the students' perception of the impact of SE on knowledge development relevant to clinical reasoning.

Methods:
Eleven medical clerks orally self-explained and listened to examples of SE while solving clinical cases. One week later, we interviewed them after they diagnosed new cases, asking if SE contributed to their knowledge development, and if yes, the nature of that contribution. Verbatim transcripts were analyzed first inductively in an iterative approach, then deductively using Schmidt’s theory of expertise.

Results:
Students commented that SE allowed reactivation and elaboration of knowledge. SE forced them to explicitly describe underlying pathophysiological mechanisms. SE allowed them to identify specific gaps in their medical knowledge. One week later when solving new clinical cases, students reported being able to recognize more easily relevant illness scripts and to better argument their diagnosis.

Conclusions:
According to students, using SE while solving cases valuably supported knowledge elaboration and enrichment of illness scripts. Our participants emphasized that verbalisation when self-explaining and listening to a resident’ SE might have further contributed to this support.
Keywords: Self-Explanation; Clinical Reasoning; instructional technique; Medical expertise; Monitoring; Qualitative Study

Introduction

Developing clinical reasoning (CR) skills in medical students is among the primary objectives for many medical curricula. CR is a multi-faceted competency (Young et al., 2018) in which specific knowledge, and an individual’s comprehension of that knowledge, play a key role (Schmidt and Rikers, 2007). Schmidt and Rikers (2007) offer one conceptualization of how knowledge is transformed through four stages in the development of medical expertise: Stage 1 is the individual’s creation of elaborate causal networks in which biomedical knowledge and pathophysiology explain causes and consequences of diseases; Stage 2 is knowledge encapsulation; Stage 3 is the emergence of illness scripts; Stage 4 is the enrichment of formal knowledge by clinical exposure.

While the theoretical conceptualization of CR development has been studied (Norman, 2005), educators are faced with the challenge of implementing teaching methods that simultaneously engage learners in constructing and progressively organize their knowledge and allow them to develop their CR expertise (Schmidt and Rikers, 2007). In a narrative review of the variety of approaches used to teach CR, Schmidt and Mamede (2015) note that, despite the importance of this topic, research into specific ways of teaching it is still scarce. There is some empirical evidence that knowledge-oriented approaches to teaching CR contribute to students’ improvement of CR skills (Schmidt and Mamede, 2015). One learning strategy aiming at helping students construct knowledge and that has been found to support their diagnostic performance is self-explanation (SE) (Chamberland et al., 2011; Chamberland et al., 2013; Chamberland, Mamede, St-Onge, Setrakian, Schmidt, 2015; Chamberland, Mamede, St-Onge, Setrakian, Bergeron et al., 2015).

SE is an educational activity where each student explains to him/herself – either aloud or via internal monologue – the selected teaching material. SE engages the student in an active learning process and allows him/her to interact with the teaching material, whilst simultaneously assessing his/her progressive understanding (Chi and Bassok, 1989; Chi, 2000; Dunlosky et al., 2013). This learning strategy helps the individual learner elaborate, organize, and integrate his/her knowledge (Chi, 2000). SE thus supports the development of deep, interconnected, and coherent knowledge (Richey and Nokes-Malach, 2015). Throughout the SE process, the student’s awareness of knowledge gaps (i.e., the monitoring of the individual’s own knowledge) can further support his/her ongoing revision of knowledge (Chi, 2000; Richey and Nokes-Malach, 2015). SE’s effectiveness as a learning strategy has been demonstrated in several domains (Chi and Bassok, 1989; Chi et al., 1994; Chi, 2000), most recently in medicine when used to support the improvement of students’ diagnostic reasoning (Chamberland et al., 2011; Larsen et al., 2013; Chamberland, Mamede, St-Onge, Setrakian, Schmidt, 2015; Chamberland, Mamede, St-Onge, Setrakian, Bergeron et al., 2015).

Chamberland and collaborators have investigated the effectiveness of SE in medical learners. They observed that students who used SE with training cases made better and more accurate diagnoses one week later, on evaluation cases, than those in the control group, particularly on unfamiliar cases (Chamberland et al., 2011). Subsequently, they observed that students expressed significantly more SE segments related to biomedical knowledge with unfamiliar cases than with familiar cases (Chamberland et al., 2013). These authors propose that the positive effect of SE on diagnostic performance could be related to a reactivation of biomedical knowledge and to greater cognitive engagement. By supporting connections between biomedical and clinical knowledge, SE could help create more coherent representations of knowledge, facilitating both the long-term retention and the transfer of knowledge (Chi, 2000; Chamberland et al., 2011, 2013; Larsen, Butler and Roediger Iii, 2013). Additionally, when third-year students used SE in combination with the review of an audio recording of an SE exercise completed by a junior
resident about the same case, the students’ diagnostic performance further improved (Chamberland, Mamede, St-Onge, Setrakian, Bergeron et al., 2015). This increase in students’ diagnostic performance could be explained by the fact that, when self-explaining, residents make their reasoning more explicit, thereby making links between pieces of information more accessible to the students for learning purposes. By comparing their reasoning to that of the residents and by building on residents’ self-explanation statements, medical students could enhance their own knowledge base.

The effectiveness of SE improving medical students’ diagnostic performance has been documented for third-year medical students (Chamberland et al., 2011; Chamberland, Mamede, St-Onge, Setrakian, Bergeron et al., 2015), however, we have yet to explore how this instructional technique impacts on students’ knowledge development relevant to clinical reasoning. In the present study, we explored third-year medical students’ perception of the impact of self-explanation on knowledge development for clinical reasoning.

Methods

We conducted a two-phase qualitative description study (Sandelowski, 2000), with the phases being conducted one week apart. In Phase 1, each participant was individually (i) introduced to the SE technique, (ii) asked to individually solve four clinical cases using SE and (iii) asked to review their diagnoses after listening to an example of SE given by a resident. This intervention phase was then followed up, one week later, with Phase 2. In the second phase of the research, each participant was asked to diagnose new clinical cases and then to participate in a semi-structured one-on-one interview. This study was approved by our institutional review board.

Context and Participants

This study was conducted at a Canadian medical school with a curriculum characterized by 2.5 years of problem-based learning followed by an 18-month clerkship. At the time of the study, participants were third-year medical students, were 7 months into the clerkship, and were engaged in a 4-week internal medicine rotation in which an individual SE learning activity, including two-sessions of 2 hours over two consecutive weeks, was included. We invited all clerks (n=11) on rotation in one university medical center during this period to take part in this study. All agreed to participate and gave their written consent.

Phase 1: The SE Intervention

During the first week — Phase 1 — of the activity, each student met with a research assistant separately. The research assistant introduced briefly SE to the participant, offering the definition of SE (orally and with written resources given to the learner), and explaining how to self-explain to solve a case (i.e., to identify signs and symptoms in the case; to explain them with one’s own knowledge; to produce diagnostic hypotheses throughout the cases). The technique was further illustrated to the participant with an audio example of SE on a clinical case not used in the study (i.e., acute monoarthritis) but of a similar format. This six-minute example illustrates how a learner makes links between pieces of information in the case, and between biomedical and clinical knowledge. The example also demonstrates knowledge monitoring via questioning and identifying uncertainties.

The participant was then asked to use SE to solve four clinical cases, one after the other, related to jaundice. Jaundice was selected for the case because it is a relatively complex problem to which third-year students have limited exposure during their first years of training. Each case contained information about the patient's history, physical examination, and laboratory tests. The participant was instructed to self-explain orally the content of each case based on his/her prior knowledge and, when needed, to go back to underlying pathophysiological mechanisms.
The participant was allotted 8 minutes for each case. At the end of each case, the participant was asked to write down his main diagnosis, two supporting arguments, and two alternative diagnoses.

The participant then listened to an 8-minute audio recording of a junior resident self-explaining the same case and who had received the same instructions as the student (Chamberland, Mamede, St-Onge, Setrakian, Bergeron et al., 2015). At three specific moments while the participant was listening to the resident’s audio recording, the recording was paused and the participant was prompted to explain or compare their reasoning to the resident’s. The participant was asked to either reconsider or confirm his/her prior diagnoses and arguments, and to again writing down the main diagnosis, two supporting arguments, and two alternative diagnoses.

**Phase 2: Assessment of the Intervention**

One week later, the principal investigator (HC) met each participant individually. The principal investigator was not known to the participants. During this meeting, the participant had one hour to solve seven new clinical cases: four similar cases of jaundice (same final diagnosis but with a different clinical scenario), and three other clinical cases (i.e., heart failure, pulmonary embolism, and kidney failure). After solving the seven cases, the student participated to a 30-minute semi-structured interview with the principal investigator (HC). The semi-structured interview guide asked participants to describe: if SE contributed to their knowledge construction (and if yes, how); and if SE contributed to their clinical reasoning related to the clinical topic of jaundice.

**Data Analysis**

The interviews were conducted, recorded, transcribed, and analyzed in French (the first language of the participants and the interviewer). All members of the research team are fluent in French. Data analysis was first conducted inductively by the primary author (HC), with the goal of identifying regularly occurring topics in the data. The research team observed that some topics aligned with Schmidt’s theory of expertise (Schmidt and Rikers, 2007). HC revised the coding structure to explicitly show this alignment and collapsing codes into themes when relevant. The coding was verified by a content expert (MC). Throughout the process, the team members (CSTO, LV, MC, HC) met several times to analyze and discuss data excerpts.

**Results/Analysis**

We identified two main clusters of themes about learner’s experiences with SE as an approach for developing their diagnostic reasoning: 1) the kinds of cognitive work required by the SE approach, and 2) how SE impacted knowledge. The data extracts illustrating these themes have been translated from French to English and confirmed by back translation.

**Cognitive Work Required by the SE Approach**

Participants described five elements related to the cognitive work they engage in when self-explaining the clinical cases: 1) knowledge reactivation, 2) knowledge elaboration and organization, 3) increase awareness about gaps and ambiguities in knowledge, 4) recall of pathophysiological mechanisms, and 5) deliberate, systematic analysis of the elements of the clinical case.

**Knowledge Reactivation**

Participants described calling up prior knowledge to understand specific elements of the clinical case. We labeled this process *knowledge reactivation*. Participants stated that this reactivation was triggered and/or enhanced by having to explain the clinical cases to themselves:
"The exact metabolism of bilirubin, you know, I have little bit forgotten... but it came back to me during the session... it did bring back some prior knowledge, without the need to do anything else, it came to me spontaneously as I was trying to explain it to myself." (Participant 06)

Knowledge Elaboration and Knowledge Organization
Participants engaged in a process of making connections between different pieces of information, a process we labeled as knowledge elaboration. Participants reported that, during SE, they made these links between the symptoms and the pathophysiological mechanisms of jaundice, as well as between the symptoms, the data from the physical examination, the laboratory work-ups, the diagnoses of other diseases presenting with jaundice, and even between elements of the different clinical cases solved.

"I associated the symptoms with my findings on the physical exam, depending on the different etiologies that I had in mind... then, well, with the work-ups... and then, I tried to figure out which pathology would best explain everything...” (Participant 06)

Participants also engaged in a process of dividing the information into subsets, and of constructing relationships between each of the subsets, in an order that was easy for them to understand. During SE of the different cases, for example, the participants subdivided the causes of jaundice into broad categories according to the pathophysiological mechanisms involved (e.g., conjugated and unconjugated hyperbilirubinemia). With each mechanism, they associated a diagnosis, in terms of symptoms, clinical signs, and paraclinical data. We defined these processes as knowledge organization.

"When I first started, I wrote on my paper ‘conjugated hyperbilirubinemia could mean...’ and ‘unconjugated could mean...’. Then, as I read through the case, if I saw a clue that made me think, ‘That doesn’t work with conjugated anymore,’ I’d make a little check mark next to ‘conjugated’ or ‘unconjugated.’ (Participant 05)

Increase Awareness about Gaps and Ambiguities in Knowledge
All the participants described specific moments when, as they were attempting to self-explain, they became more aware of the status of their knowledge. Participants identified gaps, uncertainties or ambiguities and sometimes even erroneous understandings.

"I find that it helps us see where we struggle the most whereas if I have not asked myself questions, I may have never realized that I had those gaps." (Participant 05)

According to the participants, listening to the resident example contributed to their monitoring effort.

"[Listening to the resident’s example] enables me to learn and correct my mistakes, and to reassess my understanding which did not match the resident’s explanation." (Participant 07)

Participants also perceived that being required to verbalize their self-explanations supported monitoring of their knowledge.

"Hearing yourself talk really does help. It, sort of, crystallizes what you are thinking. You listen to yourself talking and you think ‘OK, does what I’m saying make sense?’" (Participant 03)

Recall of Pathophysiological Mechanisms
Participants reported that, during the SE activity, they tended to explain the symptoms, physical signs, and results of laboratory tests presented in the clinical case to themselves based on the pathophysiological mechanisms of jaundice. This helped them better understand the elements of the clinical case. This process, which we labeled recall of the pathophysiological mechanisms, seems to have been enhanced by SE.
"It's just that you don't necessarily always think about the pathophysiological mechanisms. But when you're self-explaining, you kind of have no choice but to go there." (Participant 07)

The need to go back to underlying mechanisms seemed dependent on prior knowledge. If the participant had a solid understanding of the relevant biomedical knowledge, resorting to the pathophysiological mechanism became less necessary.

"I only do that if there are symptoms I don't understand or something I can't explain. That's when I'll try to explain the underlying mechanisms to myself." (Participant 08)

Deliberate, Systematic Analysis of the Elements of the Problem
Participants described how SE required them to engage in a detailed, careful, and systematic analysis of the clinical cases. The participants reported focusing on each element of the clinical case. They explained having to engage deeply in questioning and exploring a variety of paths to solve the clinical cases. We called this process deliberate, systematic analysis of the elements of the problem.

"I think the strategy helps me to be more systematic in searching information, be more reflective, asking questions, and going a step further for a better understanding of things." (Participant 01)

How SE Impacted Knowledge
Participants cited three different ways that SE contributed to the development of their knowledge about jaundice: 1) Interconnected knowledge, 2) Enrichment of illness scripts, 3) Knowledge retention and recall.

Interconnected Knowledge
The participants expressed surprise when realizing that, a week later in the second meeting, while diagnosing the new clinical cases of jaundice, they were able to make links between the physical signs and the mechanisms of jaundice, or between the physical signs and a clinical syndrome, without the need for additional and detailed explanations of each sign or symptom. We have defined this as interconnected knowledge.

"I saw 'spider angioma,' 'portal hypertension,' and 'splenomegaly,' so I immediately wrote 'looks like cirrhosis' next to them, whereas last week, I really got stuck on 'spider angioma,' then 'splenomegaly,' then..." (Participant 10)

Enrichment of Illness Scripts
The participants reported that, while solving the clinical cases on jaundice during the second meeting, their mental representations of the different diseases related to jaundice seemed more detailed, complete and clear. They were able to anticipate and look for key elements that pointed them in the direction of one diagnosis rather than another. We labeled this enrichment of illness scripts. Furthermore, they expressed that they had more differential diagnoses in mind for the jaundice.

"The first time, I really had to reason and interpret each sign. I had to think about things more, but now I'm quicker at recognizing patterns and linking between symptoms... I have spontaneously more diagnoses in my differential." (Participant 06)

Listening to an example of SE by a junior resident seems to have contributed to the construction of illness scripts related to jaundice. In fact, according to the participants, the resident's SE sometimes contained additional knowledge that students used as an external resource. Listening to the resident's SE sometimes seems to have helped the participants to consider diagnoses they wouldn't initially have raised in their own SE. Participants reported having integrated parts of the junior resident's knowledge expressed while self-explaining with their prior knowledge, which helped them to build a good mental representation of jaundice-related diseases.

"Of course, self-explaining really helped me to think about the diagnoses, then the resident brought up the
possibility of others, which I had to then try to understand and explain to myself. Explaining things to myself solidified what I already knew. It was more listening to the example that prompted me to consider other diagnoses.” (Participant 08)

Knowledge Retention and Recall

While solving the new clinical cases on jaundice one week later, participants reported recognizing the different clinical presentations of the disease. They compared the new clinical cases of jaundice with those seen during the first meeting and identified similarities and differences. They clearly remembered the links they had previously made, allowing them to solve the new clinical cases with greater confidence and certainty. Some students attributed the improved knowledge retention to the personal and active thinking work that SE required them to do. Some students were even amazed that they were able to solve the clinical cases without having to review the material. We defined this reinforced knowledge as knowledge retention and recall.

"I guess it's the technique, but I was able to make the links faster. I guess I found things were much clearer. I don't know if it's because it's recent or if the self-explanation really made a difference, but I had more knowledge, and it came to me faster. I found it was much clearer." (Participant 02)

Discussion

The aim of our study was to document third-year medical students’ perceptions of the impact of SE on knowledge development relevant to clinical reasoning as per Schmidt and Rikers (2007) conceptualizations of medical expertise. The participants were almost unanimous in viewing SE as a strategy that requires active cognitive engagement on their part. Self-explaining forced them to reactivate prior knowledge, to generate elaborations from the elements in the case and to recall pathophysiological mechanisms in order to make sense of the clinical data. The SE exercise led students to adopt a deliberate and systematic approach to analysing the clinical problem and to trying to understand each element in order to reach a diagnosis. Students seemed to elaborate their knowledge by linking underlying mechanisms with clinical knowledge and by making links and adding ideas between clinical elements of the problem. In this perspective, SE might be a simple and practical instructional technique that engages students in a form of deliberate practice on clinical cases. SE might be a useful technique that could help students at the clerkship level improve their diagnostic justification ability which was found insufficient even at the end of their training (Williams et al., 2014).

When students described the cognitive engagement required by SE, they emphasized becoming aware of the limits or gaps in their knowledge. According to the participants, self-explaining the elements of a problem required them to make explicit relevant knowledge and to apply it and this resulted in unrevealing ambiguities or gaps. Although knowledge monitoring is viewed as an integral part of SE (Chi, 2000; Richey and Nokes-Malach, 2015), we were surprised by the importance participants accorded to it. In a previous study (Chamberland et al., 2013) involving participants of the same institution, at the same level of training, and using the same clinical cases, students’ SE verbatim were analyzed and statements types were characterized and categorized. The number of monitoring statements, in which participants expressed that they did or did not understand, were confused or had questions about the text, represented only about 3% of all SE statements (Chamberland et al., 2013). Therefore, it appears that even though monitoring statements are not commonly articulated in the SE exercises, these statements seem to represent significant moments for individual students where students become aware of gaps and ambiguities of their knowledge. which they assess their own specific knowledge.

Students primarily described the impact of SE as an increase of links or connections between pieces of information and as mental representations of diseases being richer in elements, clearer, and more coherent and
easily retrievable one week later when facing new cases. From these descriptions, we may infer that the level of knowledge development of these third-year medical students corresponds to the active construction and refinement of illness scripts where linking biomedical knowledge to clinical knowledge plays a critical role in the coherence of scripts (Woods, 2007). In the present study, some elements of the SE technique might have further influenced the cognitive work of students on illness scripts. First, SE instructions were open-ended prompts (Wylie and Chi, 2014) and did not steer the students exclusively toward pathophysiological explanations. Hence, they were free to self-explain any element of the problem during the session. Second, while using SE to deepen their understanding, students were also required to solve the case and think about likely alternative diagnoses. Therefore, it is possible that the diagnostic task itself may have encouraged the students’ elaboration on their illness scripts. Third, listening to an example of SE by a junior resident, a more experienced learner with a more elaborate and rich clinical knowledge and more encapsulated or implicit biomedical knowledge, may also have influenced the students’ work on the illness scripts. Hence, students reported that residents offered via their own SE statements, mainly additional information on diseases representations as well as diagnostic alternatives.

Two elements of the technique of self-explanation used by students in this study deserve additional discussion: the instruction of verbalization, and the learning material used. In this study, the students were instructed to verbalize their SE while solving the clinical cases. While there is some evidence that overt SE might be more effective for learning than covert or silent SE (de Bruin, Rikers and Schmidt, 2007), this requirement may represent a challenge when implementing SE in educational practice. Therefore, students’ perceptions of the value of verbalization is relevant. Our participants easily engaged in SE and did not complain about having to verbalize. Furthermore, some students reported that verbalization played a positive role, particularly in terms of making them aware of the state of their knowledge. Thinking through and hearing their own self-explanation helped them identify gaps and ambiguities in their knowledge.

Regarding the learning material used, students reported that having to work through a variety of cases on the same clinical topic seemed to have help them gradually enrich their specific knowledge related to the topic of jaundice. The variety of cases allowed them to compare and contrast the clinical presentations of the different cases, thus forming a rich and coherent mental representation of diseases presenting with jaundice. This is in line with the importance of exposing students to a variety of examples of different representations of the same clinical situation (Eva, 2005).

This study has limitations. The exploration we did of the impact of SE on learning is based on students’ perception of their learning and not on direct assessment of change in knowledge. Also, since the development of knowledge is directly related to the level of the learners, the results of this study might not apply to other levels of students. In the purpose of exploring how SE influence knowledge building, we reproduced the setting of SE that yielded the better impact on learning in medical students (Chamberland, Mamede, St-Onge, Setrakian, Bergeron et al., 2015) and added residents’ SE examples to the learning activity. While students tended to discuss distinctly the role of their own SE vs residents’ SE examples, this additional intervention could have been confounding.

Conclusion

In terms of helping students build a body of relevant and organized knowledge for clinical reasoning, SE may be a simple and practical instructional method. Third-year medical students perceive self-explanation as a technique that gets them actively engaged with the learning material and verbalization may positively contribute to it. Knowledge elaboration seems to support interconnection of their knowledge as well as enrichment and increase coherence of their illness scripts. Students report that using SE while solving cases makes them aware of gaps and
ambiguities in their knowledge. More research is needed into how and when along the educational continuum SE is best suited to supporting learning.

**Take Home Messages**

- Self-explanation is a promising learning activity that supports knowledge construction and the development of interconnected knowledge
- Self-explaining appears to increase students’ awareness of ambiguities and gaps in their knowledge
- When used by third-year medical students for solving clinical cases, self-explanation seems to enrich and increase the coherence of their illness scripts
- Requiring students to verbalize while self-explaining appears to further support their engagement in learning

**Notes On Contributors**

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Appendices

None.

Declarations

The author has declared that there are no conflicts of interest.

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Ethics Statement

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