SELF-EXPLANATION FOSTERS CLINICAL REASONING AMONG MEDICAL STUDENTS

Martine Chamberland

Cover by Marie-Paule Garant-Chamberland (mpchamber@cgocable.ca)
Printed by Impression JG Sherbrooke

ISBN 978-2-9814843-0-7

Self-explanation fosters clinical reasoning among medical students

Uitleggen aan jezelf helpt medische studenten klinisch te redeneren

Thesis

to obtain the degree of Doctor from the
Erasmus University Rotterdam
by command of the
rector magnificus

Prof.dr.H.A.P. Pols

and in accordance with the decision of the Doctorate Board
The public defence shall be held on

13th of November 2014 at 15:30 hrs
by

Martine Chamberland
Sherbrooke, Québec, Canada

ERASMUS UNIVERSITEIT ROTTERDAM

Doctoral Committee

Promotor(s): Prof.dr. H.G. Schmidt

Other members: Prof.dr. A.P.N. Themmen
Prof.dr. H.T. van der Molen
Dr. W.W.van den Broek

Copromotor(s) : Dr. S. Mamede

CONTENTS

Chapter 1	Introduction: problem statement, conceptual frameworks and research questions	9
Chapter 2	The influence of medical students' self-explanations on diagnostic performance	35
Chapter 3	Students' self-explanations while solving unfamiliar cases: the role of biomedical knowledge	53
Chapter 4	Is there an added value of observing peers or experts' examples of self-explanation on medical students' diagnostic performance?	75
Chapter 5	Self-explanation in learning clinical reasoning: the added value of residents'examples and prompts	99
Chapter 6	Summary of main findings, implications for medical education and directions for further research	127
Appendices		153
Acknowledgments		189
Curriculum Vitae		193
Author's publications		195

Chapter 1

Introduction: problem statement, conceptual frameworks and research questions

This thesis explores the use of self-explanation by medical students as a tool supporting the learning of clinical reasoning in the clerkship. Self-explanation (SE) is a learning technique in which students explain to themselves pieces of a learning material for the purpose of improving their understanding. SE has been successfully used in several domains. However, to our knowledge, this thesis is the first attempt to investigate the use of SE to foster medical students' learning of clinical reasoning.

Clinical reasoning is at the heart of medicine. Making sound clinical judgments is considered one of the most valuable attributes of physicians, and developing students' clinical reasoning abilities appears as a central goal in medical curricula. Clinical reasoning can be broadly defined as the "intellectual activity done by the physician which synthesizes information obtained from the clinical situation, integrates it with previous knowledge and experience, and uses it for making diagnostic and management decisions".[1] Since Elstein's seminal book on medical problem solving in 1978, tremendous research efforts have been devoted to explore this complex skill. This research has successfully explored and identified multiple facets of clinical reasoning[2-7], but researchers agree on the centrality of knowledge in clinical reasoning. Experts' knowledge base is extensive and multidimensional; includes several types of knowledge, biomedical, clinical and experiential; and has an organizational structure that makes it usable in daily problem solving.[5,8-10] The most prevalent theory of medical expertise suggests that the development of expertise is associated with a progressive expansion and restructurating of knowledge base through different stages of representations of diseases that gradually allows the clinician to solve problems more and more efficiently.[5] Besides medical knowledge, other components of clinical reasoning have received much attention. Studies on reasoning processes have described how the clinician, facing a patient presenting a specific clinical problem, automatically and/or deliberately, activates the relevant knowledge and diseases representations, generates hypothetical solutions, evaluates them and matches the clinical data with expected findings. The dual process theory of reasoning, which combines analytic and non-analytic reasoning, has been applied to medicine to explain the dynamic processes involved in medical problem solving.[3] More recently, another piece of the puzzle has been explored: the role of context, broadly defined which incorporates attributes of the particular patient, the particular doctor and the particular context of care which may explain why and how expert clinical reasoning is in fact a unique problem solving event within each clinical encounter.[11-14] Although we are aware of these different components of clinical reasoning and also that clinical reasoning is only a part of clinical practice that involves also, for instance, the integration of clinical skills and communication skills, this thesis will focus on knowledge development and organization for clinical reasoning.

Despite these significant advances in our understanding of how medical experts solve problems, a major challenge for future research is to determine how medical students can effectively develop this ability.[15] Practical educational implications of research on medical expertise were not explicitly considered until the last decade.[2-4,10,16-20] Since then however, knowledge derived from this research has led to many suggestions on how to support the development of students' clinical reasoning. For instance, teaching approaches should emphasize acquiring domain-specific knowledge over general problem-solving strategies and should also support the integration of biomedical with clinical knowledge.[3-5,10] Exposure to patients' problems appears to be critical in the transformation of the medical knowledge structures. Students should, therefore be exposed early to a variety of cases or clinical examples that provide an accurate representation of the range of ways diseases occur. Students should also be provided with many opportunities to practice and to engage in problem solving, to reflect and elaborate on patients' problems.[4,5,20] The clinical clerkship, which is the first moment of medical training that offers intense exposure to clinical problems, represents then a critical moment in the journey of students' clinical reasoning development, and designing specific learning activities for this period of training appears relevant and promising. Even though these general recommendations provide guidance, specific instructional approaches or educational methods of proven effectiveness still remain scarce.[20]

Research in disciplines outside medical education such as cognitive psychology and educational psychology can provide theoretical frameworks and evidence-based learning strategies that could be combined with suggestions from research on medical expertise to design practical instructional approaches. Self-explanation and example-based learning are such instructional strategies of proven effectiveness in other domains that could be transposed or applied to learning clinical reasoning in clerkship. Since these two instructional strategies are known to support knowledge development and revision of mental representations, it is reasonable to think that, when transposed to clinical problem solving, these methods could help students develop their clinical reasoning.

The next sections will discuss in more details the conceptual frameworks used in this thesis: the theory of medical expertise, self-explanation and example-based learning. Then the research questions will be presented.

Conceptual frameworks

Theory of expertise in medicine: development of clinical reasoning

Experts in their respective domains have developed an extensive and highly organized knowledge base, which is 'chunked' into complex schemata that can be easily activated and retrieved to think effectively and to solve problems in these domains.[21,22] This general characteristic of expertise applies to medicine as well. Medical knowledge represents the foundation of expert clinical reasoning, and this is a consensual statement among the research community. Medical knowledge organisation has been the focus of many studies and debates.[2,4] Different types of structures have been proposed to describe the architecture of expert knowledge. In this structure paradigm of research, the theory of medical expertise proposed by *Schmidt et al*. explains the development of expertise in medical students in the course of their training.[5,23,24] According to this most influential theory, medical students go through transitory stages, each stage characterized by a different way in which knowledge is structured, kept in memory and used to solve clinical problems. The first stage is characterised by elaborate causal networks that explain causes and consequences of diseases in terms of underlying pathophysiological processes. With repeated application of knowledge, this knowledge organisation shifts to the second stage where these elaborate networks rich in biomedical knowledge becomes compiled into a limited number of summarizing concepts, clinical syndromes or diagnostic labels. This latter mechanism, called "knowledge encapsulation", is defined as the "subsuming or "packaging" of lower-level, detailed concepts and their inter-relations, under a smaller number of higher-level concepts with the same explanatory power".[5] Repeated practice and particularly exposure to clinical problems, lead to the emergence of illness scripts, which characterize the third stage of development. Illness scripts are cognitive structures containing limited knowledge about causal mechanisms, because of previous encapsulation, but a large amount of clinically relevant information about a particular disease.[5,8,23] This clinical information comprises enabling conditions (predisposing factors and boundary conditions, such as age and sex, that make the disease more or less likely), the faults (brief description of the malfunction) and the consequences of the disease, such as symptoms, signs, abnormal laboratory tests as the disease occurs in real patients. Illness scripts may be general and represent for instance, disease categories or more specific and then contain information of a prototypical presentation of a disease. In the context of solving a clinical problem, the clinician activates relevant illness scripts and searches for the most appropriate one by matching the elements of the script and the information of the particular patient. In this process of the script selection and verification, the characteristics of the patient are included and encoded as a practical example of the disease, a process called 'script instantiation'. Repetition of these processes again through clinical exposure leads to the fourth stage of the development in which clinician's formal knowledge is now enriched by experiential knowledge in the form of numerous instantiated scripts, which provide concrete examples of particular patients available for future problem solving.

By relying on rich illness scripts and on numerous and varied examples of patients previously seen, expert doctors can quickly and efficiently generate the most likely diagnoses for most routine problems.[5,8] In fact, in many situations and mostly for routine cases, scripts activation occurs automatically through pattern-recognition. Scripts verification to confirm or rule out diagnostic hypotheses then proceeds in a more deliberate or analytical way.[8] Even though illness scripts are the structures used mostly by experts in daily problem solving, knowledge structures of previous stages remain accessible to clinicians and may be activated when they face complex or unusual cases. Encapsulated biomedical knowledge also provides coherence of the illness script by allowing expectations on acceptable and physiologically plausible values of its attributes and by explaining the relationships between them.[5,8] Moreover, the role of biomedical knowledge in novice diagnosticians' learning of clinical reasoning has been acknowledged. Biomedical knowledge learned concurrently with clinical knowledge leads not only to better and longer knowledge retention, but also to improved performance in subsequent diagnostic tasks.[10,25-27] It has been proposed that these results reflect the development of more coherent mental representation of diseases in learners' memory.

So, in the course of their medical training, especially through clinical exposure, students are expected to expand and reorganize their knowledge and to build up a large set of illness scripts, which gradually increase their ability to correctly diagnose patients. The clerkship appears to be a critical moment for learning clinical reasoning for medical students. At this moment of their training, they have already acquired a significant amount of formal knowledge, which enable them to approach and understand clinical problems. Clinical exposure during the clerkship gives them their first significant exposure to patients' problems as they occur in practice and, therefore, the opportunity to elaborate, construct and refine their illness scripts by using and integrating this experiential knowledge.[16] However, for students to learn from their clinical experience, they have to be actively engaged in the problem solving process and knowledge construction. Designing educational methods that promote this effortful and deliberate learning from clinical examples during the clerkship seems to be relevant, and this thesis explores whether and how self-explanation can be used with that purpose.

The role of self-explanation in fostering learning

What is self-explanation?

Self-explanation is a learning technique first described by Chi[28] "that engages students in active learning and insures that the learner attend to the material in a meaningful way while monitoring their evolving understanding".[29] It involves having students generate for themselves explanations about pieces of information in a to-be-learned text or a to-be-solved problem.[28,30,31] The focus for the student is on trying to understand the material, to make sense of it personally.

The following paragraph illustrates an example of self-explanation that may help clarify the concept. Chi and colleagues asked 8th-grade students to generate self-explanations while reading a text on the human circulatory system. A student reading the fragment "The septum divides the heart lengthwise into two sides. The right side pumps blood to the lungs, and the left side pumps blood to the other parts of the body" produced the following remarks: So the *septum is like a wall* that divides the heart into two parts…it kind of like *separates* it so *that the blood doesn't get mixed up*…".[32] In this example, the words in italic are the statements generated by the student while self-explaining.

Self-explanation differs from explaining to others. In the latter case, the explanation tends to be more formal and with an implicit demand for coherence. Explanation directed to others may take into account the listener's knowledge and requires some monitoring of his/her comprehension. Moreover, most of the time, the explainer will focus on knowledge he or she understands most. In contrast, self-explanation, as the term implies, is self- generated and self-directed. Self-explanation statements are often fragmented and incomplete and tend to focus on what the learner does not understand. Self-explanation involves a special effort to deepen learner's personal comprehension by trying to resolve misunderstandings.[29,30]

Is there evidence of self-explanation effectiveness to foster learning?

Since the seminal study of Chi & Bassock,[28] which showed self-explanation to be effective in teaching problem solving in physics in college students, the positive effect of the technique has been replicated in studies in other domains such as biology,[32] electricity and magnetism[30] and chess.[33] However, to our knowledge, this technique has not been investigated in diagnostic problem solving and in medicine. Self-explanation has also been used across a range of tasks and learning materials and for a variety of learners. The self-explanation effect has also been demonstrated on a wide range of assessment criterion from measures of memory, comprehension, problem solving and on near and far transfer tasks.[31] It has been observed that the benefit of self-explanation increases when the problem at hand is complex, and its effect seems more apparent on far transfer tasks.[30,34] Given its broad applicability and the robustness of its effect, self-explanation can be described as a domain general constructive activity and be qualified as an evidence-based learning technique at least in experimental contexts.[30,31,35] However, despite the positive and promising results of this research, studies on the efficacy of self-explanation in representative educational contexts still remain limited.[34,36,37] Moreover, the durability of the effect needs to be explored, as the majority of the studies assessed the immediate impact of self-explanation, i.e., within minutes after completing the learning task; only a limited number of studies looked at the effect after one or two weeks.[31,32,34,38]

What are the mechanisms underlying the self-explanation effect?

Self-explanation is based on an assumption of learning "which is that new knowledge (declarative or procedural in nature) cannot be readily and perfectly assimilated by the student from direct instruction, either in the form of listening to a teachers' explanation or in the form of reading from a textbook. Instead the acquisition of new knowledge requires the students to be actively involved in the construction of their own knowledge".[30] But how people construct knowledge? In order to better understand how self-explanation supports knowledge building, we will briefly describe some relevant research-supported principles from the science of learning and the science of instruction.[22,39]

The memory systems are the central components of the human information-processing model, which describes the architecture of human cognition. This model comprised the sensory memory where the external stimuli enter, the working memory where the knowledge construction occurs, and the long-term memory that stores the cumulative individual knowledge for future retrieval and use. Long-term memory has unlimited information storage capacity. However, working memory capacity for processing information is highly constrained and "can hold no more than five to nine information elements and actively process no more than two to four elements simultaneously, which makes it act as a sort of bottleneck in the system".[39] How experts overcome the limits of working memory and solve complex situations? Their knowledge is organized in such a way that when facing problems, they do not activate isolated pieces of information but chunked complex integrated information or mental models that can be handled within the limited number of working memory units.[40] As previously discussed in the section on medical expertise, illness scripts represent a particular type of mental representations that is activated by clinicians during clinical reasoning and that allows effective problem solving and overcoming the limits of the working memory.

Schemas construction takes place in the working memory when a student engages in making sense of the presented material. In doing so, he or she activates generative processes, namely selection, organisation and integration, which lead to knowledge building.[39] During learning, students can construct schemas by chunking elements together while solving problem, by integrating new information to existing schemas retrieved from the long-term memory but also by using available knowledge representations from other people or resources.[22] Learning medical knowledge for clinical reasoning involves building appropriate mental representations of diseases or illness scripts.

Self-explanation is a practical constructive activity that is assumed to foster these generative processes.[30] What happens precisely during self-explanation? When students are asked to self-explain out loud, for example, while reading a text, they produce a variety of types of statements or self-explanation utterances which can be categorized as low or high quality statements according to their impact on learning.[29,30] Low quality statements comprise re-reading and paraphrases whereas inferences and monitoring statements represent high quality self-explanation utterances. Paraphrases are statements in which students only reiterate the text in their own words without adding new information. In contrast, inferences entail that students elaborate on, draw a conclusion or add information beyond what is said explicitly in the text. These types of statements may either fill information gaps, link elements of the text or integrate new information with prior knowledge. Inferences that referred to underlying domain principles (i.e., principle-based SE) were particularly associated with successful learning.[41] Monitoring statements reflect otherwise comments where participants state that they do or do not understand, are confused, or raise questions about elements of the learning resource. In fact, while trying to actively make sense of the text or the problem, learners become more aware of what they know or understand well, but are also confronted with uncertainties, forgotten information or with the limits of their prior knowledge or mental representation. Then, monitoring presumably helps students focus learning on their specific needs. Inferences and monitoring statements are qualified as high quality statements since they reflect deep analyses of the material and support knowledge construction. Finally, as self-explanation remarks reflect the student's ongoing understanding of the learning material, these comments are not necessarily complete, but often partial or even erroneous. However, if the learner, detecting these misunderstandings, then tries to resolve them, even these incorrect or erroneous statements may indeed promote learning.[30]

In sum, research on SE suggest that as a result of knowledge elaboration, organisation, integration and monitoring, self-explanation supports knowledge restructuring, allowing the learner to revise and build a more coherent and integrated knowledge representation that facilitates transfer of learning. Even though principle-based self-explanations appear particularly effective to support learning, little is known about which knowledge structures activated by SE are most useful in improving mental models.

How self-explanation can be supported in students?

Learning appears to correlate with the amount of SE. When students are explicitely asked to self-explain with prompts (prompted SE), they perform better than when they self-explain spontaneously (unprompted SE). However, the more high quality statements, in particular inferences and principle-based SE, students' self-explanation contains, the better they gain from the activity.[30] Also, even though students may engage to some extent in 'covert' SE when reading a text or studying a material in silence, verbalization of self-explanation out loud ('overt SE') seems necessary to produce the full self-explanation effect.[33]

Studies have shown that the degree to which learners spontaneously self-explain while studying examples or reading a text varies considerably among them.[29] A wide range of training procedures has been used indicating clearly that learners can easily be trained to self-explain.[29,42] However, it has the disadvantage of requiring extra time before the procedure. Nevertheless, the benefits of self-explanation are observed even though students are provided with minimal instructions and most often little or no practice with SE before going through the learning or experimental task.[31]

The application of prompts during the learning task is another intervention that fosters students' self-explanation. Prompts are specific instructions or requests that require learners to process the example or the content in a specific way.[43] Content-free prompts, which do not include any mention of the specific to-be-learned content, can be used with different materials and do not require any direct interaction with the teacher.[31] For example, Chi et al. used the following content-free prompt in their original study in physics problem solving:

Explain what it (the sentence) means to you. That is, what new information does each line provide for you, how does it relate to what you already read, does it give you a new insight into your understanding of how it works, or does it raise a question in your mind. Tell us what ever is going through your mind-even if it seems unimportant.[32]

Even though studies on prompts are still limited, there is evidence that their use with SE enhances the effect of self-explanation.[32,34,43,44] Effective prompts presumably support the specific cognitive processes of the activity. 'Gap filling prompts' and 'mental-model revision prompts' are two types of effective prompts studied with self- explanation.[37] For instance, a 'gap filling prompt' may require students to generate the principal justification and to focus on the underlying concepts (fostering generation of principle-based SE). Examples of this type of prompt would be: *What principle is being applied in this step? This choice is correct because…* On the other hand, 'mental-model revision prompts' help students highlight discrepancies between their prior knowledge representation and the one provided in the learning material. Examples of this type of prompt would be: *How does it relate to what you already know? Does it help you gain more insight on how to solve the problem?*

Prompts are usually directly integrated in the learning environment and hence involve additional preparation of the learning material. However, recent studies have shown promising results towards the development of generic self-explanation training focusing on principle-based SE that students could then used on their own in new learning contents.[45,46]

Self-explanation in learning from examples

Self-explanation has been used with a variety of learning materials that include texts, problems and worked-out examples, which are examples providing the solution steps of the problem. Similarly, learning from examples is effective only if learners explain the rationale underlying the presented solution to themselves, that is, when they self-explain. Indeed, self-explanation and example-based learning represent two complementary instructional methods often used together to support knowledge construction.

Example-based learning (EBL) refers to the process of learning by studying examples or observing models performing a skill. EBL has been studied from two different perspectives, namely using cognitive and social cognitive theoretical frameworks. The cognitive research perspective has mainly focused on the use of ideal, didactically designed examples for learning highly structured tasks. The social cognitive research perspective has mainly studied naturally occurring modeling examples which provide students with opportunities to learn by directly observing others while performing the to-be-learned task; these natural examples are not always ideal and may sometimes include irrelevant details or even errors. Despite these differences between the two theoretical frameworks, both perspectives agree on the final learning outcome of EBL: observing or working with examples helps learners construct appropriate knowledge representation of the skill, which in turn guides performance of that skill in the future.[47]

What is the theoretical basis for EBL?

From the cognitive perspective, it has been suggested that the guidance provided by the example decreases the learners' cognitive workload since they can concentrate on the steps of the solution and progressively develop cognitive schemata or mental representations. The cognitive load theory describes the different components of the learner's workload, which is again related to the limited capacity of the working memory.[22,39,48] According to this theory, three additive types of demand or load coexist and dispute the limited space of learners' cognitive system: the effective load, the intrinsic load and the extraneous load. The effective load represents the generative processing that leads to meaningful learning. The intrinsic load describes the essential processing inherent to the complexity of the task. The extraneous load comprises the ineffective processing that distracts the learner. In any given learning situation when the sum of the loads exceeds the capacity, learners become overloaded and this will lead to ineffective learning. According to this theory, learning can be supported by instructional strategies that increase effective load and foster generative processes, manage intrinsic load or decrease extraneous load. In example-based learning, having learners carefully study worked examples that provide them with the steps of the solution, reduces extraneous load. Learners do not have to search by themselves for all steps of the procedure and can then focus on making links between pieces of information and constructing knowledge. Novices seem to benefit more from worked examples since they don't have already available in their long-term memory appropriate mental representations that they can retrieve and use to solve the problem. Interestingly, the cognitive load theory also reinforces self-explanation as a specific way of engaging students in generative processes and optimizing the effective load. This theory also proposes that the learning task should be of a "desirable" level of difficulty to engage and challenge students but without overwhelming them.[22]

For what types of task is EBL effective?

EBL has been successfully used for a variety of tasks from highly structured tasks to less structured ones and for a wide range of skills from psychomotor to complex cognitive tasks such as argumentation skills.[47] Classical worked-out examples in well-defined domains such as mathematics usually provide solution steps leading to the final solution in an algorithmic manner.[44] However, for ill-structured domains, where there is not only one path to the solution, another type of examples might be needed. For instance, learning with self-explaining examples has been shown to enhance skills in the domain of argumentation.[43]

Clinical reasoning represents a complex and less structured cognitive skill for which EBL could potentially be useful. However, for learning to occur, the to-be-learned skill must be observable by the learner. Hence, learning complex cognitive tasks through observation of models requires the latter to externalize their cognitive processes and the knowledge activated while performing the skill. Self-explanation might be useful for models to make explicit their ongoing clinical reasoning process and relevant knowledge representations. Self-explaining models or examples might provide relevant and useful illustration of how to link, organize and interpret the particular elements of a specific clinical disease (e.g., acute viral hepatitis) as well as how to approach or reason more globally through a type of problem (e.g., jaundice).

How to optimise the effectiveness of EBL?

To benefit from working with examples instructional design issues must receive great attention.[47,49] Instructional features associated with the use of examples appear critical. These features can be introduced either before, as a preparatory task, during, or after the observation. As previously indicated, adding self-explanation prompts to the example is a frequently used strategy that fosters learning. Another useful instructional feature is the combination of practice and example, in which students first solve the problem, followed by observation of an example. Also, the design of the example itself should take into account learners' prior knowledge. For novice learners, studying examples seems more effective compared to problem solving. The difference in the level of expertise of the model or example vs the learner seems important to consider although no systematic research has addressed this issue. Model- observer similarity appears to influence student's self-efficacy for learning and performing the task. On the opposite, a naturally performing expert who has largely automatized his or her tasks and who works at a higher level of abstraction may not be the best example for novice to learn from.[47,49] Further research is clearly needed on the level of model expertise and its effect on learning.[47]

Learning from self-explaining examples of clinicians engaged in problem solving seems also in line with recent studies on workplace learning. Indeed, results of these studies have highlighted the importance of interacting with, observing and listening to peers, expert clinicians and other professionals when aiming to improve residents' and clinicians' reasoning in practice.[50-52]

The previous review of the literature provides arguments supporting the relevance of studying self-explanation for learning clinical reasoning by medical students, and this will be summarized in the next paragraphs. It also gives the basis for our research questions that will be presented in the next section.

Developing illness scripts and learning from patient problems appear central for medical students to learn clinical reasoning. However, instructional methods that can be used in clinical teaching with proven efficacy are limited, and further research is clearly needed. Self-explanation is a research-supported strategy that fosters knowledge construction in a variety of domains and that has not yet been investigated in medicine. The benefits of this technique have been shown when used in problem solving and also when associated with worked-out examples. Self-explanation is in line with educational recommendations from research on medical expertise asking students to get involved in deliberate problem solving when facing patients problems. All these elements support the relevance of transposing self-explanation in medicine and applying it particularly to clinical reasoning for medical students. Moreover, self-explanation and example-based learning are instructional methods that could easily build on or optimize learning opportunities already available in the clinical training where students are asked to apply clinical reasoning to patients problems and are also exposed to examples of clinical reasoning from a variety of colleagues.

The present studies appear also relevant to the self-explanation research, since translational studies in representative educational contexts remain scarce. Hence, the development of easy-to-use versions of the technique and their evaluation in controlled 'classroom' settings would add to self-explanation research. Moreover, further studies are needed on the durability of the SE effect as well as on time demands associated with the technique.

Research questions

The aim of the thesis is to investigate the effect of students' self-explanation on learning clinical reasoning and to explore specific conditions that could optimize its effect. Since the clerkship represents a critical moment in the transformation of students' medical knowledge, we decided to select this particular level of training for our different studies. Our research questions and the general characteristics of the studies designed to answer them are described in the present section.

1- Is self-explanation effective for fostering learning of clinical diagnosis in the clerkship?

Does self-explanation benefit apply to learning clinical reasoning by medical students in the clerkship phase? Is self-explanation effective when used with clinical cases as the learning material? Is the effect of self-explanation influenced by students' level of familiarity with the clinical cases? Since knowledge construction and revision of mental representations of diseases are central to the development of medical expertise, and since SE is a constructive learning strategy, we hypothesized that the positive impact of this learning technique would transpose to learning clinical reasoning when used with clinical cases. We also expected that this beneficial effect would be more obvious with clinical cases less familiar to students because this 'desirable' level of difficulty would foster the generative processes of SE and create new links that would enrich students' illness scripts. We tested these hypotheses in an experimental study in which medical students used SE or not while solving two sets of clinical cases of different levels of familiarity. Learning was measured by assessing diagnostic performance on different cases one week later. Chapter 2 reports the results of this first study.

2- What is the role of biomedical knowledge in learning clinical reasoning through self-explanation?

Our first study demonstrated that self-explanation while solving clinical cases in the learning phase leads to better diagnostic performance on different cases one week later. Interestingly, this beneficial effect was only present with cases less familiar to students. For familiar cases, there was no effect of self-explanation. How to explain this different impact? What types of knowledge are activated and used by students in SE when solving cases of different levels of familiarity? It seems logical to assume that a more challenging clinical case will force the student to engage in more knowledge elaboration and presumably improve the coherence of mental representations. Since biomedical knowledge is important for the internal coherence of illness scripts, to what extent could this type of knowledge play a role when learning through self-explanation? Could biomedical knowledge be related to principle-based SE? Students' verbal protocols generated during self-explanation represent a window into the cognitive processes in which they engage while learning. To explore these questions and to provide some insight into the underlying mechanisms of self-explanation when applied to clinical reasoning, we conducted a content analysis of self-explanations generated by medical students during the first study. We adapted a coding scheme from the self-explanation literature and characterized the types of knowledge made explicit by students within their verbal protocols while solving familiar and less familiar cases. Results of this second study are reported in Chapter 3.

3- Is there an added value for learning of being exposed to self-explanation examples of clinical reasoning?

Clinical reasoning is a complex skill. There are numerous possible ways of solving usually ill-defined clinical problems. In such situations, learners can become easily overloaded cognitively. Would it help to listen to colleagues' self-explanation on the same clinical problem? In the clinical setting, students are surrounded by colleagues of different levels of expertise who engage in clinical reasoning with patients on a daily basis. This could represent an important resource of 'naturally occurring' examples for learning. However, most of the knowledge activated and illness scripts tested by clinicians are not made explicit so that a large part of the clinical reasoning is not 'visible' and yet not available for students to learn from. Self-explanation allows making explicit this ongoing process. Would listening to SE examples foster learning relative to SE alone? Does the level of expertise of the SE example impact on students' learning? We hypothesized that such explicit examples would give additional opportunities for students to deepen their understanding and critically revise their mental representations of diseases, thereby translating into better diagnostic performance. Using example-based learning as a framework, we explored these issues in the third study. Chapter 4 reports the results of this study investigating the impact of listening to peer or expert SE examples on diagnostic performance of students who had, as a preparatory task, reasoned through the same cases while self-explaining.

4- What conditions could optimize the impact of SE examples on learning clinical reasoning?

The results of the third study demonstrated that adding peer or expert SE examples to students' self-explanation provides limited benefit on diagnostic performance. These findings lead us to explore the conditions that could improve the effect of SE examples on students' clinical reasoning. We first considered the level of expertise of the example vs. the learner. Could an example of intermediate level of expertise (i.e., resident level) be more appropriate for medical students at clerkship? Would such a near-peer provide a model of optimal 'cognitive proximity' that allows progressive revision of illness scripts without the shortcuts that characterize experts? Secondly, we considered the cognitive engagement of learners while listening to the example and investigated whether the use of prompts to ensure active use the example would foster learning relative to studying the example without prompts. We hypothesized that being exposed to resident SE examples and using prompts while listening would lead to improve students' clinical reasoning. We tested these ideas in the fourth study which results are reported in Chapter 5.

Chapter 6 will finally summarize the results of the studies conducted as part of this thesis. The implications for educational practice will be discussed and directions for future research will be suggested.

References

1 Higgs J, Jones M. Chap.1, Clinical reasoning in the health professions. In : Higgs J, Jones M (Eds). Clinical reasoning in the health professions. 2nd ed. Oxford; Butterworth-Heineman Ltd. 2000; 3-14.

2 Gruppen LD, Frohna AZ. Clinical Reasoning. In: Norman GR, Van der Vleuten CPM, Newble DI, editors. International handbook of research in medical education Dordrecht (Great Britain): Kluwer Academic Publishers; 2002; 205-230.

3 Eva KW. What every teacher needs to know about clinical reasoning. Med Educ 2005;39(1):98-106.

4 Norman G. Research in clinical reasoning: past history and current trends. Med Educ 2005;39(4):418-427.

5 Schmidt HG, Rikers RMJP. How expertise develops in medicine: knowledge encapsulation and illness script formation. Med Educ 2007;41(12):1133-1139.

6 Elstein AS. Thinking about diagnostic thinking: a 30-year perspective. Adv Health Sci Educ 2009;14:7-18.

7 Mylopoulos M, Regehr G. Putting the expert together again. Med Educ 2011;45(9):920-926.

8 Charlin B, Boshuizen HP, Custers EJ, Feltovich PJ. Scripts and clinical reasoning. Med Educ 2007;41(12):1178-1184.

9 Bordage G. Prototypes and semantic qualifiers: from past to present. Med Educ 2007;41(12):1117-1121.

10 Woods NN. Science is fundamental: the role of biomedical knowledge in clinical reasoning. Med Educ. 2007;41(12):1173-1177.

11 Durning S, Artino AR, Pangaro L, van der Vleuten, Cees PM, Schuwirth L. Context and clinical reasoning: understanding the perspective of the expert's voice. Med Educ 2011;45(9):927-938.

12 Durning SJ, Artino AR, Boulet JR, Dorrance K, van der Vleuten C, Schuwirth L. The impact of selected contextual factors on experts' clinical reasoning performance (does context impact clinical reasoning performance in experts?). Adv Health Sci Educ 2012;17(1):65-79.

13 Mamede S, van Gog T, van den Berge K, Rikers RMJP, van Saase JLCM, van Guldener C, et al. Effect of Availability Bias and Reflective Reasoning on Diagnostic Accuracy Among Internal Medicine Residents. JAMA 2010;304(11):1198-1203.

14 Mamede S, Splinter TA, van Gog T, Rikers RM, Schmidt HG. Exploring the role of salient distracting clinical features in the emergence of diagnostic errors and the mechanisms through which reflection counteracts mistakes. BMJ Qual Saf 2012;21(4):295-300.

15 Rikers RMJP, Verkoeijen PPJI. Clinical expertise research: a history lesson from those who wrote it. Med Educ 2007;41:1115-1116.

16 Norman G. Building on experience--the development of clinical reasoning. N Engl J Med 2006;355(21):2251-2252.

17 Bowen JL. Educational strategies to promote clinical diagnostic reasoning. N Engl J Med 2006;355(21):2217-2225.

18 Ark TK, Brooks LR, Eva KW. The benefits of flexibility: The pedagogigal value of instructions to adopt multifaceted diagnostic reasoning strategies. Med Educ 2007;41(3):281-287.

19 Nendaz M, Charlin B, Leblanc V, Bordage G. Le raisonnement clinique: données issues de la recherche et implications pour l'enseignement. Pédagogie Médicale 2005;6(4):235-254.

20 Kassirer JP. Teaching clinical reasoning: case-based and coached. Acad Med 2010;85(7):1118-1124.

21 Bransford J, Brown A, Anderson J, Gelman R, Glaser R, Greenough W. Chap. 2. How expers differ from novice. In How people learn; National Academy Press Washington DC, USA,2000;30-50.

22 Van Merriënboer JJ, Sweller J. Cognitive load theory in health professional education: design principles and strategies. Med Educ 2010;44(1):85-93.

23 Schmidt HG, Norman GR, Boshuizen HPA. A cognitive perspective on medical expertise: theory and implications. Acad Med 1990;65(10):611-621.

24 Schmidt HG, Boshuizen HPA. On acquiring expertise in medicine. Educ Psychol Rev 1993;5(3):205-221.

25 Woods NN, Brooks LR, Norman GR. It all makes sense: biomedical knowledge, causal connections and memory in the novice diagnostician. Adv Health Sci Educ 2007;12(4):405-415.

26 Woods NN, Brooks LR, Norman GR. The role of biomedical knowledge in diagnosis of difficult clinical cases. Ad in Health Sci Educ 2007;12(4):417-426.

27 Norman G. The basic role of basic science. Adv Health Sci Educ 2012;17(4):453-456.

28 Chi MTH, Bassock M. Learning from examples via self-explanations. In: Resnick LB, editor. Knowing, learning, and instruction: essays in honor of Robert Glaser Hillsdale (NJ): Lawrence Erlbaum Associates. 1989; 251-282.

29 Roy M, Chi MTH. The self-explanation principle in multimedia learning. In: Mayer RE, editor. Cambridge handbook of multimedia learning New York, NY: Cambridge University Press. 2005; 271-286.

30 Chi MTH. Self-explaining expository texts: the dual processes of generating inferences and repairing mental models. In: Glaser R, editor. Adv Instr Psychol. Mahwah (NJ): Lawrence Erlbaum Associates; 2000; 161-238.

31 Dunlosky J, Rawson KA, Marsh EJ, Nathan MJ, Willingham DT. Improving Students' Learning With Effective Learning Techniques: Promising Directions From Cognitive and Educational Psychology. Psychol Sci in the Public Interest 2013;14(1):4-58.

32 Chi MTH, de Leeuw N, Chiu M-, Lavancher C. Eliciting self-explanations improves understanding. Cogn Sci 1994;18(3):439-477.

33 de Bruin ABH, Rikers RMJP, Schmidt HG. The effect of self-explanation and prediction on the development of principled understanding of chess in novices. Contemp Educ Psychol 2007;32(2):188-205.

34 Wong RMF, Lawson MJ, Keeves J. The effects of self-explanation training on students' problem solving in high-school mathematics. Learn Instr 2002;12:233-262.

35 Roediger III HL, Pyc MA. Inexpensive techniques to improve education: Applying cognitive psychology to enhance educational practice. J Appl Res Mem Cogn 2012;1(4):242-248.

36 Schworm S, Renkl A. Computer-supported example-based learning: When instructional explanations reduce self-explanations. Comput Educ 2006;46(4):426-445.

37 Nokes TJ, Hausmann RG, VanLehn K, Gershman S. Testing the instructional fit hypothesis: the case of self-explanation prompts. Instr Sci 2011;39(5):645-666.

38 Rittle-Johnson B. Promoting transfer: Effects of self-explanation and direct instruction. Child Dev 2006;77(1):1-15.

39 Mayer RE. Applying the science of learning to medical education. Med Educ 2010;44(6):543-549.

40 Byrne A. Mental workload as a key factor in clinical decision making. Adv Health Sci Educ 2013;18(3):537-545.

41 Renkl A. Learning from worked-out examples: A study on individual differences. Cognitive Sci 1997;21(1):1-29.

42 Nogry S, Didierjean A. Apprendre à partir d'exemples: interactions entre présentation du matériel, activités des apprenants et processus cognitifs. L'année psychologique 2006;106:105-128.

43 Schworm S, Renkl A. Learning argumentation skills through the use of prompts for self-explaining examples. J Educ Psychol 2007;99(2):285-296.

44 Atkinson RK, Renkl A, Merrill MM. Transitioning from studying examples to solving problems: effects of self-explanation prompts and fading worked-out steps. J Educ Psychol 2003;95(4):774-783.

45 Renkl A, Solymosi J, Erdmann M, Aleven V. Training principle-based self-explanations: Transfer to new learning contents. Proceedings of the 35th Annual Conference of the Cognitive Science Society; 2013.

46 Busch C, Renkl A, Schworm S. Towards a generic self-explanation training intervention for example-based learning. Proceedings of the 8th International Conference of the Learning Sciences 2008: ICLS; 2008.

47 van Gog T, Rummel N. Example-Based Learning: Integrating Cognitive and Social-Cognitive Research Perspectives. Educ Psychol Rev 2010;22:155-174.

48 Paas F, Renkl A, Sweller J. Cognitive load theory and instructional design: Recent developments. Educ Psychol 2003;38(1):1-4.

49 Rosen MA, Salas E, Pavlas D, Jensen R, Fu D, Lampton D. Demonstration-based training: a review of instructional features. Adv Hum Fact Ergon 2010;52(5):596-609.

50 Ajjawi R, Higgs J. Learning to reason: A journey of professional socialisation. Adv Health Sci Educ 2008;13(2):133-150.

51 van de Wiel, M. W., Van den Bossche P, Janssen S, Jossberger H. Exploring deliberate practice in medicine: how do physicians learn in the workplace? Adv Health Sci Educ 2011;16(1):81-95.

52 Stegeman J, Schoten E, Terpstra O. Knowing and acting in the clinical workplace: trainees' perspectives on modelling and feedback. Adv Health Sci Educ 2013;18(4):597-615.

Chapter 2

The influence of medical students' self-explanations on diagnostic performance

Published as Chamberland M, St-Onge C, Setrakian J, Lanthier L, Bergeron L, Bourget A, Mamede S, Schmidt H, Rikers R. The influence of medical students' self-explanations on diagnostic performance. Med Educ 2011;45(7):688-695.

Abstract

Background: Clinical reasoning is a highly valued attribute of physicians, but instructional approaches to foster medical students' clinical reasoning remain scarce. Self-explanation is an instructional procedure whose positive effects on learning has been demonstrated in a variety of domains but remains highly unexplored in medical education. The purpose of this study was to investigate the effect of self-explanation on students' learning of clinical reasoning during their clerkship and whether it is affected by topic familiarity.

Methods: An experimental study with a training phase and an assessment phase was conducted with 36 third-year medical students, randomly assigned to two groups. In the training phase, students solved 12 clinical cases (4 cases in a less familiar topic, 4 in a more familiar topic, and 4 fillers), either generating self-explanations (n=18) or without self-explanation (n = 18). The self-explanations were generated after minimal instructions, and no feedback was provided to students. One week later, in the assessment phase, students were requested to diagnose 12 different, more difficult cases, similarly distributed among the same more familiar topic, less familiar topic, and fillers, and their diagnostic performance was assessed.

Results: In the training phase the performance of the two groups did not differ. However, a week later in the assessment phase, a significant interaction effect was found between self-explanation and case topic familiarity, $F(1, 34) = 6.18$, $p < 0.05$. The self-explanations, compared to no self-explanation condition, led students to better diagnostic performance on subsequent clinical cases, but this effect only occurred for cases concerning less familiar topics.

Conclusion: The present study shows the beneficial influence of generating self-explanations while dealing with less familiar clinical cases. That is, generating self-explanations without feedback resulted one week later in better diagnostic performance than the control group.

Introduction

Making sound clinical judgments is considered one of the most valuable attributes of physicians, and developing students' clinical reasoning abilities appears as a central goal in most medical curricula.[1] High value is attributed to teaching and learning clinical reasoning, but devising appropriate instructional approaches has proved to be a difficult challenge.[1]

Teachers confronted with this challenge may benefit from a better understanding of the nature of clinical reasoning generated by research on medical expertise over the last three decades.[1-8] In the course of their growth towards expertise, medical students have been shown to progress through transitional stages, characterized by different ways how knowledge is structured in memory and used to solve clinical problems.[1,9] Rich causal networks that explain causes and consequences of diseases in terms of underlying pathophysiological processes characterize the first stage of knowledge organization. With repeated application of knowledge and particularly through exposure to clinical problems, this knowledge becomes "encapsulated", and illness scripts emerge. Illness scripts are cognitive structures containing limited knowledge about causal mechanisms, but a large amount of clinically relevant information on signs, symptoms and enabling conditions for the disease as it occurs in real patients. By relying on such cognitive structures and on examples of patients previously seen, expert doctors can quickly generate the most likely diagnoses for most routine problems.[1,2] In the course of their medical training, especially through clinical exposure, students are expected to build up a large set of illness scripts, which gradually increases their ability to correctly diagnose patients.

The findings of research on medical expertise have led to general suggestions to foster the development of students' clinical reasoning skills.[1-4,8] Students should, for instance, be exposed early to a variety of examples that provide an accurate representation of the range of ways that diseases occur. They should engage actively in problem-solving, reflecting and elaborating on patients' problems to gradually build up their knowledge base. Although these and other general recommendations have been frequently discussed, instructional approaches to nurture students' clinical reasoning skills are still scarce.

Stimulating students to generate self-explanations while studying a text has shown to be effective to promote learning in a variety of domains such as physics,[10,11] biology,[12] electricity and magnetism,[13] and chess.[14] Self-explanations are remarks made by, and directed to, oneself, after reading one or more statements in a text to-be-learned or a problem to-be-solved.[10-12] An example may help to clarify the concept of self-explanation. Chi and colleagues asked 8th-grade students to generate self-explanations while reading a text on the human circulatory system. A student reading the fragment "The septum divides the heart lengthwise into two sides. The right side pumps blood to the lungs, and the left side pumps blood to the other parts of the body" produced the following remarks: So the *septum is like a wall* that divides the heart into two parts…it kind of like *separates* it so *that the blood doesn't get mixed up*…".[12] Self-explanation has been shown to compel learners to attend to the material in a meaningful way, triggering several key cognitive processes, namely: generating inferences based on the information from the text (e.g., the words in italic in the example mentioned above), linking pieces of information present in the study materials, integrating new information into existing prior knowledge, and restructuring one's knowledge representations.[13]

It would be reasonable to expect self-explanation to help also medical students in acquiring knowledge required for clinical reasoning. Engaging in self-explanation could facilitate knowledge elaboration and reconstruction, leading to organization and/or enrichment of illness scripts early in clinical training. Despite constituting a promising instructional procedure, self-explanation has not, to our knowledge, been studied in the context of medical education.

When are students likely to benefit most from self-explanation? Experimental studies on self-explanation suggest that learning correlates with the number of self-explanations generated by the student[13] and the number of inferences that they contain.[10,12-14] The characteristics of clinical problems, which are the basic learning material for clinical reasoning, are likely to influence the effectiveness of self-explanation. Student's familiarity with the problem may be of special relevance. After repeated exposure to a problem, students would probably have already in memory a well-defined illness script, readily available when they encounter the problem again. Less room would be left for elaboration and reconstruction of knowledge, and, therefore, for self-explanation to play a role in learning. On the other hand, with less familiar problems, self-explanation might have a greater effect on learning, as students would generate more inferences and new links, with greater integration of new information into their prior knowledge, and enhanced enrichment of their mental representations.

We hypothesized that self-explanation while solving clinical problems would facilitate acquisition of knowledge required for clinical reasoning, leading students to better diagnostic performance in subsequent similar problems. This positive effect of self-explanation would only occur, or at least be more substantial, in problems with which students have less familiarity. We tested these ideas in an experimental study with medical students in the clerkship.

Methods

Design

The study consisted of two phases: the training phase and the assessment phase, run one week later. In the training phase, students were asked to solve familiar and less familiar problems either by generating self-explanations or without self-explanation. The primary issue was the students' diagnostic performance at the assessment phase.

Participants

Participants were 40 medical students from the University of Sherbrooke, Quebec, Canada. They were in the 3rd year of the medical undergraduate program, which comprises 4 years, with 2 ½ years of PBL followed by 18 months of clerkship. Participation was voluntary and no financial incentive was offered. Written informed consent was obtained. Data were analyzed only for the 36 students who completed both phases.

Materials

Two sets of 12 cases were used in the study, one for the training and one for the assessment phase. The template for both sets was the same: 4 cases in a less familiar clinical topic, 4 cases in a more familiar clinical topic, and 4 fillers (see appendix 1 at the end of this chapter).

Students' familiarity with a specific clinical topic was determined by prior exposure to clinical problems related to that topic during the first three years of their undergraduate program. Prior exposure was estimated by the number of PBL tutorial groups addressing related problems and the relevant clinical exposure, assessed by disease prevalence in the setting of the main clinical rotations. Based on this information, jaundice was chosen as a "less familiar" and heart failure as a "more familiar" topic for 3rd year medical students. Four variants of cases with jaundice and 4 with heart failure were constructed. Four filler cases from four other topics were produced to complete the set. These cases intercalated with the study cases in order to avoid an otherwise obvious sequence of heart failure and jaundice cases.

Cases for the training and the assessment phase were constructed addressing the same topics and subtopics (e.g., valvular disease causing heart failure). However, the final diagnoses of the cases were different for the training and the assessment phase. The cases for the later phase were purposely made more difficult, by including less typical presentations, less common final diagnoses, and/or coexisting medical conditions.

Case descriptions contained approximately 300 words and reported the chief complaint, background information, and findings from history, physical examination and laboratory tests. Three senior internists/clinical teachers (MC, LL, JS) prepared the cases. One of them wrote a first draft which was then revised iteratively by the others. A pilot test with 4 clerks who did not participate in the study showed that the cases were appropriate with respect to readability, format, and difficulty level.

In each phase, cases were presented in a booklet in random order (with the restriction that all booklets started with the same filler case and there were no two consecutive cases on the same topic).

Procedures

In the training phase, participants were randomly assigned either to the self-explanation (n= 18) or to the comparison (no self-explanation) group (n= 18).

Participants in the self-explanation group were tested individually by the experiment leaders (AB, CS, LB). First, they were provided with a definition of self-explanation and an example of the procedure. To make their task more concrete, each participant listened to a 7-minute audio example of self-explanation on a clinical case (mono-arthritis) not used in the study but with a similar format. Subsequently, they were asked to read each case, generate self-explanations out loud. They received no feedback on the quality of their self-explanations. Finally, they wrote down their responses to the following questions: Q1. What is the most likely diagnosis? Q2. What are the two main arguments supporting this diagnosis? Q3. List two plausible alternative diagnoses. The first question provided a measure of diagnostic accuracy; a rough measure of the quality of the diagnostic reasoning was to be obtained by adding the two subsequent questions.

The procedures for the training phase had been pilot tested with three clerks who did not participate in the study. The instructions prompted the participants to self-explain, and 10 minutes were sufficient for students to work out the problem in all cases. Students in the control group worked with the booklets in a collective session. They were only requested to solve the cases, without receiving any instruction on how to perform self-explanation. They first read an example of a case of mono-arthritis to become familiarized with the case and question formats. The training phase for both the self-explanation and the comparison groups lasted 2½ hours. All participants were allowed 10 minutes per case, and time was controlled by the experiment leaders. Three experiment leaders (AB, CS, LB) ran all the individual and group sessions, after having gone through a standardization exercise aimed at ensuring a uniform procedure. In the assessment phase, all participants completed the booklets in a group session. Students from both groups were instructed to solve the cases in silence. Participants were allowed two hours to complete the cases and they could move on to the next case at will. For each case, students were asked to write down their answers to the same three questions used in the training phase. At the end of the session, the students were requested to assess, on a 10-point Likert scale, their confidence in their overall diagnostic approach to jaundice and to heart failure. They were also invited to complete a brief questionnaire on their learning opportunities (i.e., current clinical rotation, individual study time, and teaching activities) during the past week relating to jaundice and heart failure. Students from the self-explanation and the comparison groups reported similar learning opportunities.

Data analysis

To evaluate students' responses, a scoring grid was developed for each question and iteratively revised by three senior internists (MC, JS, LL). Final decisions were reached by consensus. The grid comprises model answers for each question and possible score. A score on a scale of 0 - 2 was given for each answer according to the correction grid. For example, for the most likely diagnosis (Q1), 1 point was given if only the general category of diseases was correct (obstructive jaundice) and 2 points were given if the specific diagnosis was correct (choledocholithiasis). The two main arguments supporting the diagnosis (Q2) and the two plausible alternative diagnoses (Q3) were scored similarly. When students gave no, one or two arguments or plausible alternative diagnoses comprised in the correction grid, they were awarded 0, 1 or 2 points respectively. Two scores were derived from participants' answers: the diagnostic accuracy score (the score on question Q1) and the diagnostic performance score (the sum of scores on questions Q1, Q2 and Q3).

Two independent raters (MC and JS or LL), who were blinded to the participants' experimental condition, scored the responses. Interrater reliability, measured by intra-class correlations, ranged from 0.70 to 0.95. Disagreements were resolved by discussion.

Descriptive statistics were computed. Two repeated-measure ANOVAs with self-explanation (self-explanation vs. no self-explanation) as a between-subjects factor, and topic familiarity (less familiar vs. more familiar) as a within-subjects factor were performed on mean diagnostic accuracy scores and diagnostic performance scores. Significance was set at 0.05.

Results

Training phase

Table 1 and Table 2 present, respectively, the mean diagnostic accuracy scores (Q1) and the mean diagnostic performance scores (Q1+Q2+Q3) for each group on the less familiar (jaundice) and more familiar (heart failure) cases for the training phase. There was no statistically significant difference between the groups for diagnostic accuracy ($F[1, 34] = 0.00$, $p = 1.00$) and diagnostic performance scores ($F[1, 34] = 0.35$, $p = 0.56$). Differences between less familiar and more familiar cases, for diagnostic accuracy and diagnostic performance scores, were statistically significant ($F[1, 34] = 18.58$, $p < 0.05$; $F[1, 34] = 24.76$, $p < 0.05$ respectively). These results show that both groups were similar at the beginning of the study. They also indicate that the jaundice cases were, as predicted, more challenging for students. This likely reflects their limited familiarity with the topic of jaundice as compared with heart failure, as reflected by the lower scores on the former than on the latter, and confirms our distinction between familiar and non-familiar cases.

Table 1: Mean diagnostic accuracy scores* obtained by the two groups in the training phase as a function of case familiarity

Topic	Self-explanation	
	Yes (n=18)	No (n=18)
Less familiar cases (Jaundice)	5,56 (1,38)	5,61 (1,33)
More familiar cases (Heart failure)	6,61 (1,33)	6,56 (0,78)

(*)Standard deviation presented in brackets

Table 2: Mean diagnostic performance scores* obtained by the two groups in the training phase as a function of case familiarity

Topic	Self-explanation	
	Yes (n=18)	No (n=18)
Less familiar cases (Jaundice)	14,06 (3,19)	14,61 (2,35)
More familiar cases (Heart failure)	16,56 (2,83)	16,83 (1,54)

(*)Standard deviation presented in brackets

Assessment phase

Tables 3 and 4 show the mean diagnostic accuracy scores and the mean diagnostic performance scores obtained by the two groups on the less familiar and more familiar cases in the assessment phase. The main effect of self-explanation on diagnostic accuracy scores was not significant ($F[1,34] = 0.68$, $P = 0.42$), whereas the main effect of topic familiarity was significant ($F[1,34] = 24.73$, $P < 0.05$), indicating that jaundice cases were in fact more challenging than heart failure cases. More importantly, a significant interaction effect was observed ($F[1,34] = 6.18$, $P < 0.05$). Post-hoc analysis conducted on normalized data, that is, Student's T-test revealed a borderline significant difference between the self-explaining group and the no self-explaining group for the less familiar cases ($t[34] = 1.878$, $p = 0.069$) and no significant differences for the familiar cases ($t[34] = -0.741$, $p = 0.46$). These results suggest that self-explanation influences the diagnostic accuracy for less familiar cases, but not for more familiar cases.

Table 3: Mean diagnostic accuracy scores* obtained by the two groups in the assessment phase as a function of case familiarity

Topic	Self-explanation	
	Yes (n = 18)	No (n = 18)
Less familiar cases (Jaundice)	4.28 (1.56)	3.28 (1.78)
More familiar cases (Heart failure)	4.94 (1.11)	5.28 (1.27)

(*)Standard deviation presented in brackets

Similar findings were observed for diagnostic performance scores. The main effect of self-explanation on diagnostic performance scores was not significant ($F[1, 34] = 1.77$ $p = 0.19$). The main effect of case familiarity, however, was significant ($F[1, 34] = 46.94$, $p < 0.05$). This supports again the distinction between less familiar and more familiar cases. An interaction effect was observed ($F[1, 34] = 8.53$, $p < 0.05$). Post-hoc analysis conducted on normalized data, that is, Student's T-test revealed a significant difference between the self-explaining group and the no self-explaining group for the less familiar cases ($t[34] = 2.181$, $p = 0.036$) and no significant differences for the familiar cases ($t[34] = -0.773$, $p = 0.44$). These results suggest that self-explanation influences the diagnostic performance scores for less familiar cases but not for more familiar cases.

Table 4 : Mean diagnostic performance scores* obtained by the two groups in the assessment phase as a function of case familiarity

Topic	Self-explanation	
	Yes (n = 18)	No (n = 18)
Less familiar cases (Jaundice)	13.28 (3.30)	10.83 (3.15)
More familiar cases (Heart failure)	15.22 (2.60)	15.67 (1.24)

(*)Standard deviation presented in brackets

A Student t- test comparing students' confidence level in their diagnoses revealed a significant difference between students' level of confidence for unfamiliar cases (jaundice) and familiar cases (heart failure) respectively ($M = 5.33$, $SD = 1.99$; $M = 6.31$, $SD = 1.72$, $t[35] = -2.75$, $P < 0.05$), providing an additional check for our handling of case familiarity.

Discussion

This study explored the influence of self-explanation on medical students' learning of knowledge required to diagnose familiar and less familiar clinical problems. In line with our hypotheses, the findings showed that generating self-explanations while solving a clinical case led students to make better diagnoses of problems related to the same clinical topic than students who did not generate self-explanations. This only occurred when students had limited familiarity with the topic. When clinical problems were within topics with which they were already familiar, having engaged in self-explanation in previously solved problems did not make difference. The positive effect of self-explanation was apparent after one week while diagnosing more difficult problems.

The resulting difference between students who self-explained and those who did not is likely to reflect cognitive processes put into action by self-explanation.[13] When requested to generate self-explanations, students more actively attempt to make sense of the clinical findings in the case, trying to construct relationships between signs and symptoms and to link them with causal mechanisms. Students are compelled to process information more deeply, and it is likely that elaboration on the new information and knowledge reconstruction, with integration of new information into one's existing knowledge structures, takes place in a more extensive way. These processes probably favoured retention of knowledge acquired during the problem-solving phase and facilitated retrieval when students had to solve problems in a similar topic one week later.

A rich and well-organised knowledge base is central in clinical reasoning; it evolves through stages during medical training, with the emergence of illness scripts as students are exposed to patients.[1,2] Clinical experiences certainly accelerate changes in students' knowledge structures, with a more rapid move from causal networks to illness scripts.[1,9] We may reasonably assume that generating self-explanations during the process of reasoning through and diagnosing clinical cases facilitates the construction of more coherent mental representations of the diseases, possibly fostering the development of more well-organized and richer illness scripts used for clinical reasoning. As our findings suggest, this positive effect of self-explanation is likely to be more substantial when students are dealing with clinical problems in a less familiar area, for which their illness scripts may be less developed and therefore more subject to major revision.

It is noteworthy that the benefits of self-explanation emerged in the absence of any feedback on the contents of students' remarks. Students' self-generated explanations, produced after minimal instructions, were certainly not always entirely accurate, and no correction was provided. Even without feedback, simply by elaborating more extensively on the cases, students benefited from self-explanation. This finding is particularly relevant for clinical teaching. Indeed, the study has potentially important implications for clinical education. Self-explanation is an instructional procedure that can be easily introduced and implemented in many ways, even without requiring clinical teachers' supervision. It could be used by students regularly in clinical rotations as a way to reflect on less familiar problems in their patient encounters. Self-explanation could also be attempted in small groups of peers and with written clinical cases or various types of simulation as a complement to exposure to real patients.

This study has limitations. We worked with students in the third-year of their undergraduate program, and it is not clear whether the results would apply to other groups of students or residents. Our sample size was small, and the study was conducted under laboratory conditions, which restrict generalizations to real learning environments such as for example busy outpatient clinics. We cannot exclude that students in the comparison group have silently generated some explanations for themselves while solving the cases. This, however, would only make the findings stronger.

Longitudinal analysis of self-explanations could shed further light on the mechanism by which self-explanation in the training phase of our study resulted in an effect a week later when no further overt self-explanations were carried out. Other studies could explore the effect of self-explanation at various levels of medical training and in different clinical topics as well as the duration of the observed effect. Further research should also explore whether and how quantitative and qualitative differences in self-generated explanations could have a positive effect on learning, and whether self-explanation can be used in a variety of formats of case presentation. Furthermore, future studies should examine the potential role of feedback or modeling by peers on the effect of self-explanation.

References

1 Schmidt HG, Rikers RMJP. How expertise develops in medicine: knowledge encapsulation and illness script formation. Med Educ 2007;41(12):1133-1139.

2 Norman G. Research in clinical reasoning: past history and current trends. Med Educ 2005;39(4):418-427.

3 Gruppen LD, Frohna AZ. Clinical Reasoning. In: Norman GR, Van der Vleuten CPM, Newble DI, editors. International handbook of research in medical education Dordrecht (Great Britain): Kluwer Academic Publishers; 2002; 205-230.

4 Nendaz M, Charlin B, Leblanc V, Bordage G. Le raisonnement clinique: données issues de la recherche et implications pour l'enseignement. Pédagogie Médicale 2005;6(4):235-254.

5 Bordage G. Prototypes and semantic qualifiers: from past to present. Med Educ 2007;41(12):1117-1121.

6 Charlin B, Boshuizen HP, Custers EJ, Feltovich PJ. Scripts and clinical reasoning. Med Educ 2007;41(12):1178-1184.

7 Woods NN. Science is fundamental: the role of biomedical knowledge in clinical reasoning. Med Educ. 2007;41(12):1173-1177.

8 Eva KW. What every teacher needs to know about clinical reasoning. Med Educ 2005;39(1):98-106.

9 Schmidt HG, Norman GR, Boshuizen HPA. A cognitive perspective on medical expertise: theory and implications. Acad Med 1990;65(10):611-621.

10 Chi MTH, Bassock M. Learning from examples via self-explanations. In: Resnick LB, editor. Knowing, learning, and instruction: essays in honor of Robert Glaser Hillsdale (NJ): Lawrence Erlbaum Associates; 1989; 251-282.

11 Chi MTH, VanLehn KA. The content of physics self-explanations. Learn Sci 1991;11(1):69-105.

12 Chi MTH, de Leeuw N, Chiu M-, Lavancher C. Eliciting self-explanations improves understanding. Cogn Sci 1994;18(3):439-477.

13 Chi MTH. Self-explaining expository texts: the dual processes of generating inferences and repairing mental models. In: Glaser R, editor. Advances in instructional psychology. Mahwah (NJ): Lawrence Erlbaum Associates; 2000; 161-238.

14 de Bruin ABH, Rikers RMJP, Schmidt HG. The effect of self-explanation and prediction on the development of principled understanding of chess in novices. Contemp Educ Psychol 2007;32(2):188-205.

Appendix 1

Template for cases development

		Specific diagnosis	
		Training phase	**Assessment phase**
Less familiar cases			
(Jaundice)			
1	Acute viral hepatitis	Hepatitis B	Hepatitis A
2	Cirrhosis	Chronic alcoholism	Hemochromatosis
3	Obstructive jaundice	Pancreatic tumor	Choledocholithiasis
4	Hemolysis	Auto-immune, idiopathic	Cold agglutinins, Mycoplasma infection
More familiar cases			
(Heart failure)			
1	Coronary artery disease (CAD)	Acute myocardial infarction	Chronic CAD, anemia
2	Valvular disease	Aortic stenosis	Mitral insufficiency
3	Diastolic dysfunction	Hypertensive cardiomyopathy	Hypertensive cardiomyopathy, atrial fabrillation
4	Cardiomyopathy	Toxic, alcoholic	Viral myocarditis
Fillers			
(Varied topics)			
1	Acute GI bleeding	NSAID associated ulcer	Peptic ulcer
2	Fever, acute infection	Pneumonia	Acute prostatitis
3	Venous thrombosis	Acute pulmonary embolism	Paraneoplastic deep vein thrombosis
4	Acute renal failure	Hypovolemia	Acute glomerulonephritis

Chapter 3

Students' self-explanations while solving unfamiliar cases: The role of biomedical knowledge

Published as Chamberland M, Mamede S, St-Onge C, Rivard M, Setrakian J, Lévesque A, Lanthier L, Schmidt H G, Rikers, R. Students' self-explanations while solving unfamiliar cases: the role of biomedical knowledge. Med Educ 2013;47(11):1109-1116.

Abstract

Context: General guidelines for teaching clinical reasoning have received much attention, despite a paucity of instructional approaches with demonstrated effectiveness. As suggested in a recent experimental study, self-explanation while solving clinical cases may be an effective strategy to foster reasoning in clinical clerks dealing with less familiar cases. However, the mechanisms that mediate this benefit have not been specifically investigated.

Objective: To explore the types of knowledge used by students when solving familiar and less familiar clinical cases with self-explanation.

Methods: In a previous study, 36 third-year medical students diagnosed familiar and less familiar clinical cases either by engaging in self-explanation or not. Based on an analysis of previously collected data, the present study compared the content of self-explanation protocols generated by 7 randomly selected students while solving four familiar and four less familiar cases. In total fifty-six verbal protocols (28 familiar and 28 less familiar) were segmented and coded using the following categories: paraphrases, biomedical inferences, clinical inferences, monitoring statements, and errors.

Results: Students provided more self-explanation segments from less familiar cases (M = 275.29) than from familiar cases (M = 248.71, $p = .046$). They provided significantly more paraphrases ($p = .001$) and made more errors ($p = .008$). A significant interaction was found between familiarity and the type of inferences (biomedical vs. clinical, $p = .016$). When self-explaining less familiar cases, students provided significantly more biomedical inferences than familiar cases.

Conclusions: Lack of familiarity with a case, seems to stimulate medical students to engage in more extensive thinking during self-explanation. Less familiar cases seem to activate students' biomedical knowledge, which in turn helps them create new links between biomedical and clinical knowledge, and eventually construct a more coherent mental representation of diseases. This may clarify the previously found positive effect that self-explanation has on the diagnosis of unfamiliar cases.

Introduction

Accurate clinical reasoning, a highly valued physician's attribute, develops through years of practice. Knowledge derived from research on medical expertise has led to many suggestions on how to support the development of students' clinical reasoning skills.[1-3] For instance, teaching approaches should emphasize acquiring domain-specific knowledge over general problem-solving strategies, and also support the integration of biomedical with clinical knowledge. Teaching around examples, providing students with many opportunities to engage in problem solving, to reflect and elaborate on patients' problems, are approaches that have also been highlighted.[1-3] However, despite broad acceptance of these principles, instructional approaches to help teachers apply them are scarce, and their effectiveness remains to be determined.[4-6]

An effective strategy to foster the development of clinical reasoning in clinical clerks is self-explanation.[7] Generating self-explanations while diagnosing a set of clinical cases, even without receiving feedback, resulted in better diagnostic performance compared to students who did not self-explain. This positive effect was however only demonstrated with unfamiliar clinical cases. Similarly, it has been observed that the benefit of self-explanation increases when the problem at hand is complex, and its effect seems more apparent on far transfer tasks.[8,9] As an extension of the study by Chamberland and colleagues,[7] the present study explores the types of knowledge used by students when self-explaining familiar and less familiar clinical cases, and in particular the role of biomedical knowledge.

Self-explanation is a constructive learning strategy that consists of generating explanations to oneself in response to learning material.[8,10] Consequently, learners deepen their understanding of the material and make their knowledge more meaningful, while monitoring their evolving understanding. Self-explanations are not necessarily formal and complete but may rather be fragmented, incorrect or incomplete; reflecting, in fact, what the learner does and does not understand.[8]

It has been proposed that the activation of several cognitive processes when self-explaining is responsible for learners' improved understanding of the learning material.[8] That is, while self-explaining learners engage in knowledge elaboration and inference generation (i.e., drawing conclusions that go beyond what the text explicitly states). This may enable them to integrate new knowledge with prior knowledge, and to create links between pieces of information within the material. It also has been proposed that self-explanation triggers monitoring processes.[8] While trying explicitly and actively to make sense of the material, learners become more aware of what they know or understand well, but are also confronted with uncertainties, forgotten information or with the limits of their prior knowledge. Indeed, even incorrect or erroneous self-explanations may promote learning if the learner, detecting these misunderstandings, then tries to resolve them.[8] Morever, as a result of knowledge elaboration and monitoring, knowledge restructuring takes place, allowing the learner to build a more coherent and integrated representation that facilitates transfer of learning.[8]

For the acquisition of clinical reasoning skills, self-explanation could be a useful knowledge building strategy, as most theories about developing medical expertise are centred on the restructuring of medical knowledge. According to the illness script theory, medical students go through learning stages, structuring knowledge differently at each stage, to be kept in memory and used to solve clinical problems. That is, knowledge is first organized into complex causal networks that provide pathophysiological explanations for the causes and consequences of disease.[3] Later, with exposure to clinical problems and repeated application of biomedical knowledge, the latter becomes encapsulated. Further clinical experience then leads to the emergence of illness scripts, which make scant use of causal mechanisms but are rich in the risk factors, symptoms, and signs that characterize real-life clinical situations.[3]

The transition from the preclinical to clinical education (i.e., clerkship), has been associated with this shift from biomedical to clinical knowledge.[11] That is, less advanced students mainly use biomedical knowledge to understand a case whereas more experienced ones understand it in clinical terms. Biomedical knowledge used by students to solve clinical problems is not necessarily very sophisticated but as long as it provides clear, plausible and stable links between clinical features, it helps students create a coherent representation of a case.[12] Biomedical knowledge is usually phrased by students in terms of entities (e.g., bacteria, stone, carcinoma), or in terms of organs, organ systems, physiologic functions (e.g., digestion) or basic mechanisms (e.g., obstruction of the biliary tract). In contrast, clinical knowledge refers to attributes of people and their diseases, to the different ways a disease can manifest itself in the patient (i.e., signs and symptoms), and to relevant laboratory investigation and therapy.[11] Studies looking at the benefits of biomedical knowledge in the process of learning clinical reasoning in novice diagnosticians, suggest that it may help students construct more coherent mental representations of diseases, increasing retention in the longer term, and helping them to diagnose difficult cases.[13,14]

Our previous study with medical students in clerkship showed that self-explanation while diagnosing cases, compare to no self-explanation, improved diagnostic performance on new cases one week later. However, this beneficial influence was only present for less familiar cases.[7] Could self-explanation for less familiar cases support the development of a more coherent representation? To what extent could biomedical knowledge play a role in learning clinical reasoning through self-explanation in medical students? Students' verbal protocols generated during self-explanation represent a window into the cognitive processes in which they engage while learning.[15,16] The content analysis of self-explanations generated by medical students while solving clinical cases could therefore provide insight into the mechanisms that mediate the self-explanation effect on diagnostic performance.[7]

The present study attempted to better understand why self-explanation is beneficial with less familiar cases. It aimed to explore the types of knowledge students use when self-explaining by conducting a content analysis of protocols generated by students while solving familiar and less familiar cases. It was hypothesized that when reasoning on less familiar cases, students would generate more self-explanations and reactivate more biomedical knowledge than when solving familiar cases.

Methods

Participants

Thirty-six third-year medical students from the University of Sherbrooke, Quebec, Canada, participated in the initial study.[7] They had to diagnose 12 randomly presented clinical cases (four familiar, four less familiar, and four filler cases) with or without self-explanations. Recordings of self-explanations were available from 14 of the 18 students involved in the self-explanation group. Each record comprised of self-explanations while solving four familiar clinical cases and four less familiar cases. For the secondary analysis reported here, a sample of seven students (50%) was randomly selected from the 14 available students. We did not analyze the data of all 14 students because of the elaborateness analyzing these types of protocols. Accordingly, 56 protocols were transcribed and analyzed, 28 about familiar cases and 28 about less familiar cases.

Materials

Eight clinical cases concerning two different clinical topics, one familiar topic and one less familiar topic, were used in this study. The level of familiarity was established a priori for the whole group of 36 students and derived from students' prior exposure to similar clinical problems in the undergraduate PBL-curriculum. Heart failure was identified as a familiar topic and Jaundice as a less familiar topic. Four different cases for each of these two clinical topics were developed by experienced physicians. Thus, as in the initial study, familiar cases refer to Heart failure cases and less familiar cases refer to Jaundice cases. Case summaries, about 300 words, included the chief complaint, patients' background, medical history, physical examination, and the results of laboratory tests. Table 1 shows an example of a case.

Table 1: Example of a clinical case used in the study
A 76-year-old man presents with progressive jaundice. ***HPI:*** *The patient noted a gradual yellow-green discoloration of his skin over three weeks. He has no abdominal pain other than a vague epigastric discomfort which he has experienced after meals. He noticed that his urine have become dark, and his stools have become pale but he reports no diarrhea or constipation. His appetite seems to be diminished and he reports having lost 5-7 kg over the past month. He denies fever, chills, or night sweats. There is no travel history and no change in his dietary habits.* ***PMH:*** *Systolic hypertension and type 2 diabetes mellitus, both for 1 year. One episode of acute diverticulitis in 2006. Superficial thrombophlebitis of the right lower extremity 2 months ago.* ***Medications:*** *Hydrochlorothiazide 12, 5 mg QD, Metformin 250mg BID.* ***Habits:*** *A retired carpenter, he still lives in his own house. He was widowed 3 years ago. There is no history of smoking or of alcohol use.* ***Physical examination:*** *The patient's general appearance is normal except for the presence of a deeply jaundiced skin, BP 145/75, Pulse 75, afebrile, weight 75kg. There is no enlargement noted in any of the lymph node groups. Cardiac examination is within normal limits. Lung examination is normal. On abdominal examination, there is no tenderness noted. The liver and spleen are not enlarged. There are no palpable masses. The rectal examination is normal. There is no edema of the lower extremities.* ***Laboratory investigations :*** *CBC : hemoglobin 125 g/L(130-180) MCV 88 fL(80-100) WBC 6,2 X 10^9/L(3,8-10,6) Platelets 350 X10^9/L(130-400); Serum electrolytes and creatinine are normal; Fasting blood sugar is 6,9 mmol/L(3,3-6,1); AST 52 IU/L (14-50) , ALT 75 IU/L (21-72), alkaline phosphatase 625 IU/L(43-200), total bilirubin 110umol/L (3,4-17); direct bilirubin 100umol/L; albumin 33g/L (35-50); INR and PTT normal. Urinalysis: the urine is brown, testing strongly positive for bilirubin, and negative for urobilinogen.*

Procedure

In the initial study,[7] participants were tested individually. Instructions to the students were as follows. Self-explaining was defined and its application in clinical problem-solving explained to the students. They then listened to a representative 7-minute audio sample of a self-explanation on a topic that was not used in the study. They were then asked to read each case while self-explaining aloud for eight minutes, and then they had two minutes to write down their diagnosis, together with two supportive arguments and two plausible alternative diagnoses. With the students' consent, their self-explanations were audio-recorded. The research assistants, all non-clinicians, prompted students after any 10-second silence and asked them to "please continue to self-explain aloud". No feedback was given on the quality or content of self-explanations.

Analysis

Self-explanation protocol analysis

Participants' self-explanation protocols were transcribed and subsequently analyzed based on the technique described by Chi.[17] Self-explanation protocols for each of the clinical cases contained approximately 1100 words. For each protocol, we first excluded sections that corresponded to reading of the case text. The remaining verbatim was then segmented into *idea units*. An idea unit corresponds to a content segment expressing one single idea. These segments were then coded according to a scheme based on Chi[8,10] that classifies each segment into four different categories as follows: paraphrases, inferences, monitoring statements, and errors. The following paragraphs present the definitions of the mutually exclusive coding categories used in this study.

1. ***Paraphrases****:* A segment was coded as a paraphrase if the participants merely reiterated the text in their own words, i.e., no new information was added. Basic interpretation of data and basic translation into medical jargon also fell into this category.
2. ***Inferences:*** A segment was coded as an inference if it entailed elaborating on, or drawing a conclusion beyond what was said explicitly in the text.[8] Based on the content of the segment, inferences were subcategorized into biomedical knowledge or clinical knowledge.[3,11]

3. ***Monitoring statements:*** A segment was coded in this category whenever the participants stated that they did or did not understand, were confused, or had questions about the text.
4. ***Errors:*** A segment was coded in this category if it reflected clearly incorrect content. Ambiguous or partially correct segments were not scored as errors.

Table 2 illustrates examples of idea units or segments in each category.

Table 2: Examples of segments for each of the coding categories
1. *Paraphrases: In response to ... : the student said "...."*
a. *Oral temperature is 38.3 : "so he's got fever" (A102/A1)*
b. *Past cholecystectomy: "OK (...) so she's no longer got her gallbladder" (A105/A1)*
c. *Constant nausea for two weeks : " Basically she's feeling sick to her stomach" (C103/A1)*
d. *Albumin : 31 (normal range 35-50 g/L) : "Her albumin is down to 31" (C103/A1)*
e. *Thirty-four-year old patient : "We're dealing with a woman in her thirties" (E102/A1)*
2. *Inferences: biomedical knowledge:*
a. *"That could be (...) the case if there is an obstruction of (...) the bile ducts" (A102/A1)*
b. *"the liver is able to conjugate bilirubin" (A105/A3)*
c. *" (...) then she's got congestion, which can cause platelets to get trapped" (A103/A2)*
d. *"it's conjugated bilirubin that's excreted in the urine" (A105/A3)*
e. *"Fine. Is there (...) a component of (...) decreased production of coagulation factors?" (E102/A2)*
3. *Inferences: clinical knowledge:*
a. *"(...) joint pains (...) yeah (...) viral hepatitis can give you joint pains" (A102/A1)*
b. *" 10 beer a day, that's clearly above normal alcohol consumption" (A111/B4)*
c. *"(...) uh but loss of appetite (...) could go with a cancer" (A111/A2)*
d. *"there's no travel for hepatitis A" (A105/A1)*
e. *"So on physical exam, to me it really sounds like cirrhosis" (A105/A2)*
4. *Monitoring:*
a. *"Uh (...) well (...) I don't know what urobilinogen is, but fine (...)"(A102/A4)*
b. *"As to why the spleen is enlarged, I'd have trouble saying" (A105/A4)*
c. *"I am sure the joint pains (...) there's a link (...) but I can't think of it" (C103/A1)*
d. *"It really makes sense » (A103/A3)*
e. *"(...) I think that's as far as I'll get (...) for now" (E102/A4)*
5. *Errors:*

a. *"sweatiness (...) uh, it's (...) it's due to (...) uh (...) the parasympathetics" (A102/B1)*
b. *"something chronic wouldn't necessarily explain the jaundice" (A105/A2)*
c. *"pulsus paradoxus (...) uh (...) I think that's with some kind of a valvular problem" (A105/B4)*
d. *"jaundice, I think that's in Cushing's syndrome" (A111/A2)*
e. *"crackles (...) I think (...) that goes with COPD" (A111/B1)*

The coding grid was pilot tested by two investigators, both internists (MAR & MC) who applied the grid independently on six protocols and refined it through an iterative process.

The coding process was the following. Two investigators (MAR, MC) used the coding scheme to independently score eight protocols: four less familiar cases and four familiar cases. Raters agreed on coding for more than 90% of the segments, that is, they attributed the same coding to a segment. Consensus was achieved through discussion for the remaining segments. Since there was a good agreement between the raters, one investigator coded all the other protocols and discussed coding difficulties with the second rater when they arose. We used NVivo Version 8 qualitative data analysis software to facilitate the coding and subsequent frequency analysis.

Data analysis

For each protocol, all segments within each category were summed. Subsequently, data for the protocols of familiar cases and less familiar cases were separately summed. Descriptive statistics were obtained for each level of familiarity. A 2 (Familiarity: low vs. high) x 4(Category: paraphrase, inferences, monitoring statements, errors) repeated-measure ANOVA was performed with both familiarity and category as within-subjects factors. To better understand the types of knowledge used by students while self-explaining, a second two-way repeated-measure ANOVA was performed on the mean number of segments for the two types of inferences (i.e., biomedical vs. clinical) with regard to the familiarity of the cases (low vs. high). Significance level was set at

.05. Student's paired *t*-tests were conducted as post-hoc analyses to compare the number of segments in each category for familiar and less familiar cases. Bonferroni corrections were applied to the significance levels for the post-hoc analyses.

Results

Table 3 presents the mean number of segments in each coding category by topic familiarity. A two-way repeated-measure ANOVA revealed a main effect of case familiarity ($F[1, 18] = 6.27$, $p = .046$, $\eta_p^2 = .51$). Students produced more self-explanation segments on less familiar cases than on familiar ones. There was also a significant main effect of category ($F[1.054, 6.324] = 83.94$, $p < .001$, $\eta_p^2 = .93$). The interaction effect did not reach statistical significance ($p = .159$). Post-hoc analyses were conducted using Students' paired *t*-tests to compare the number of segments in each category for familiar and less familiar topics. When self-explaining on less familiar cases, students produced significantly more paraphrases ($t(6) = 5.65$, $p = .001$, $d = 2.14$), and made more errors ($t(6) = 3.87$, $p = .008$, $d = 2.45$). There was no significant difference in the number of inferences ($t(6) = 0.49$, $p = .641$) and in the number of monitoring statements ($t(6) = 2.01$, $p = .091$) generated by students in the familiar and less familiar condition.

Table 3: Mean number of segments in each category as a function of topic familiarity

Category of segment	Topic familiarity Mean (SD)	
	Less familiar	More Familiar
Paraphrases	72.00 (9.66)	55.00 (9.38)
Inferences	191.00 (44.82)	186.29 (54.92)
Monitoring	7.57 (5.38)	4.14 (2.73)
Errors	4.71 (2.50)	3.29 (1.70)
Total	275.29 (47.20)	248.71 (51.91)

The Table 4 presents the mean number of segments for both types of inferences by topic familiarity. A two-way repeated-measure ANOVA revealed a significant main effect of type of inference ($F[1, 6] = 98.21$, $p < .001$, $\eta_p^2 = .94$) but the main effect of familiarity was not significant ($F[1, 6] = 0.24$, $p = .641$). There was however a significant interaction between familiarity and type of inference ($F[1, 6] = 11.03$, $p = .016$, $\eta_p^2 = .65$).

Table 4: Mean number of segments of each type of inference as a function of topic familiarity

Type of Inference	Topic familiarity Mean (SD)	
	Less familiar	More Familiar
Biomedical	35.29 (11.83)	10.71 (5.09)
Clinical	155.71 (37.51)	175.57 (51.99)
Total	191.00 (44.82)	186.29 (54.92)

Discussion

Several studies from various disciplines have shown that learners develop a deeper understanding of instructional materials through self-explanation during learning.[8-10] A first study on self-explanation in the context of clinical reasoning has replicated these results.[7] This study, which involved medical students generating self-explanations while solving cases, resulted one week later in better diagnostic performance compared to a control group. This positive effect was only shown with less familiar cases. In order to get a better understanding about our initial findings, the present study analysed the content of students' self-explanation protocols. It aimed to compare the types of knowledge used by students diagnosing familiar and less familiar clinical cases, and explored the potential role of biomedical knowledge in the observed benefit of self-explanation.

The results indicate that a less familiar case stimulates the production of a significantly higher number of self-explanation segments. Unfamiliarity seems to act as a trigger for students to engage in more active thinking; the greater diagnostic challenge encourages them to generate more self-explanations, and eventually leads to better learning. This is in agreement with previous studies showing a positive relationship between learning and the number of self-explanations.[8]

The total number of inferences generated by students is similar for familiar and less familiar cases. This result contrasts with previous studies showing that the more inferences the students' self-explanations contain, the better they learn.[8] However, the analyses of the two different types of inferences, biomedical knowledge and clinical knowledge, provide additional insight into learners' cognitive mechanisms during self-explanation. When solving less familiar cases, students generated significantly more biomedical inferences than with familiar cases. Previous studies have shown that biomedical knowledge helps students develop a coherent and stable mental representation of disease, thus enabling them to retain clinical knowledge over time, and maintain diagnostic accuracy on challenging cases.[12] Furthermore, studying problems with their underlying mechanisms in addition to their clinical features, made students subsequently better able to apply their knowledge to diagnose unusual cases.[13] Based on these findings from the literature, it appears that, with less familiar cases, self-explanation helps students apply biomedical knowledge and create new links with clinical knowledge. The resulting more coherent mental representation of disease may then be retrieved more easily during future diagnostic problem-solving, allowing for a clearer picture when the clinical features are uncharacteristic or unorganised. It is important to note here that in the learning phase of our first study, students who engaged in self-explanation had received *no* content-type feedback and thus, without any new external information, they must have somehow worked with, and reorganized, their own prior knowledge.

Previous studies on medical expertise development have shown that less advanced students use more biomedical knowledge while solving problems,[11,18] but they did not explore whether an association existed between this use and learning, that is, better diagnostic performance in future cases. Although measuring the amount of learning was not part of the present study, our previous study[7] clearly showed that self-explanation in the less familiar cases fostered learning. The results of the present study provide, therefore, insights into the role of biomedical knowledge in learning while solving unfamiliar case with self-explanations. Also, most studies on medical expertise have used offline measures (e.g., free recall) to reconstruct the students' mental processes, and the present study is one of the few that uses an online measure, i.e., the types of knowledge used by students while solving the cases.

The greater number of errors in less familiar cases, while few in absolute numbers, probably reflects the fact that specific knowledge is still being actively constructed. Moreover, incorrect self-explanations may foster learning if the student, detecting the error or misunderstanding after a while, then tries to resolve it with additional self-explanations. Similarly, the significantly increased number of paraphrases in the less familiar topic may signal that students' specific knowledge is less elaborate so that they initially tend to stay closer to the text while self-explaining. We assume that in the learning phase, when specific knowledge is less elaborate, there may be more room for self-explanation to play a role in learning.

Self-explanation might be seen not only as a knowledge building strategy but also as a reflective strategy. Recent studies have shown that Internal Medicine residents, who were encouraged to use structured reflection during clinical reasoning, had better diagnostic accuracy on complex and unusual cases but not on routine clinical cases.[19] Structured reflection was also recently used as a learning strategy for clerks, and compared with generation of an immediate diagnosis or generation of a differential diagnosis. In this study, clerks using structured reflection significantly outperformed the other two groups on diagnosing new clinical cases one week later.[6] Self-explanation, though less structured, might represent an alternative reflective approach for clerks working through their cases.

Some aspects of the present study represent innovations with respect to the growing research literature on self-explanation. Medical education and clinical reasoning have been added only recently to the list of domains for research on self-explanation. Also, designing appropriate learning material for self-explanation has recently received much attention from researchers.[15,20-23] To our knowledge, clinical cases as the learning material and students' familiarity with the material as a variable have not been previously studied. The present study is also a first step to investigate the underlying mechanisms of self-explanations in clinical reasoning. However, the limited sample size and the experimental context of the present study may limit generalisation to the real clinical learning environment and hence more research is necessary.

The results of this study suggest that, for medical students at the clerkship level, self-explanation as a learning strategy for clinical reasoning works better with less familiar cases because it provides opportunities to link biomedical to clinical knowledge, which may lead to a coherent representation of disease. The level of familiarity for students may be an important issue in designing the appropriate learning material for self-explanation and clinical reasoning. Cases chosen should be challenging enough to force students to revisit underlying basic biomedical knowledge. The addition of explicit prompts to that effect may be useful. Further studies could examine more directly the evolution of medical knowledge over time with self-explanation. Also, more studies are needed to explore self-explanation as a strategy to enhance reflective approaches in clinical reasoning.

Ethical approval

This study was approved by "*Comité d'Éthique à la Recherche en Éducation et Sciences Sociales* » of the Université de Sherbrooke.

Acknowledgments

Funding for this project was received from the *Fonds de développement pédagogique 2010*, *Société des Médecins de l'Université de Sherbrooke* (SMUS) and the *Société des Médecins de l'Université de Sherbrooke* Research Chair in Medical Education held by Christina St-Onge.

References

1 Eva KW. What every teacher needs to know about clinical reasoning. Med Educ 2005;39(1):98-106.

2 Norman G. Research in clinical reasoning: past history and current trends. Med Educ 2005;39(4):418-427.

3 Schmidt HG, Rikers RMJP. How expertise develops in medicine: knowledge encapsulation and illness script formation. Med Educ 2007;41(12):1133-1139.

4 Kassirer JP. Teaching clinical reasoning: case-based and coached. Acad Med 2010 2010;85(7):1118-1124.

5 Nendaz M. Éducation et qualité de la décision médicale: un lien fondé sur des preuves existe-t-il? Rev Med Interne 2011;32(7):436-442.

6 Mamede S, van Gog T, Moura AS, de Faria R, Peixoto JM, Rikers RM, et al. Reflection as a strategy to foster medical students' acquisition of diagnostic competence. Med Educ 2012;46(5):464-472.

7 Chamberland M, St-Onge C, Setrakian J, Lanthier L, Bergeron L, Bourget A, et al. The influence of medical students' self-explanations on diagnostic performance. Med Educ 2011;45(7):688-695.

8 Chi MTH. Self-explaining expository texts: the dual processes of generating inferences and repairing mental models. In: Glaser R, editor. Advances in instructional psychology. Mahwah (NJ): Lawrence Erlbaum Associates; 2000; 161-238.

9 Wong RMF, Lawson MJ, Keeves J. The effects of self-explanation training on students' problem solving in high-school mathematics. Learn Instr 2002;12:233-262.

10 Roy M, Chi MT. The self-explanation principle in multimedia learning. The Cambridge handbook of multimedia learning. New York, NY: Cambridge University Press; 2005; 271-286.

11 Boshuizen HPA, Schmidt HG. On the role of biomedical knowledge in clinical reasoning by experts, intermediates and novices. Cognitive Sci 1992;16:153-184.

12 Woods NN. Science is fundamental: the role of biomedical knowledge in clinical reasoning. Med Educ 2007;41(12):1173-1177.

13 Woods NN, Brooks LR, Norman GR. The role of biomedical knowledge in diagnosis of difficult clinical cases. Adv Health Sci Educ 2007;12(4):417-426.

14 Woods NN, Brooks LR, Norman GR. It all makes sense: biomedical knowledge, causal connections and memory in the novice diagnostician. Adv Health Sci Educ 2007;12(4):405-415.

15 Butcher KR. Learning from text with diagrams: promoting mental model development and inference generation. J Educ Psychol 2006;98(1):182-197.

16 de Bruin ABH, Rikers RMJP, Schmidt HG. The effect of self-explanation and prediction on the development of principled understanding of chess in novices. Contemp Educ Psychol 2007;32(2):188-205.

17 Chi MTH. Quantifying qualitative analysis of verbal data: A practical guide. J Learn Sci 1997;6(3):271-315.

18 Schmidt HG, Boshuizen HPA. On acquiring expertise in medicine. Educ Psychol Rev 1993;5(3):205-221.

19 Mamede S, Schmidt HG, Penaforte JC. Effect of reflective practice on the accuracy of medical diagnoses. Med Educ 2008;42:468-475.

20 Ainsworth S, Loizou AT. The effects of self-explaining when learning with text or diagrams. Cognitive Sci 2003;27(4):669-681.

21 Ainsworth S, Burcham S. The impact of text coherence on learning by self-explanation. Learn Instru 2007;17(3):286-303.

22 Yeh Y, Chen M, Hung P, Hwang G. Optimal self-explanation prompt design in dynamic multi-representational learning environments. Comput Educ 2010;54:1089-1100.

23 De Koning BB, Tabbers HK, Rikers, R. M. J. P., Paas F. Improved effectiveness of cueing by self-explanations when learning from a complex animation. Appl Cogn Psychol 2011;25:183-194.

Chapter 4

Is there an added value of observing peers or experts' examples of self-explanation on medical students' diagnostic performance?

Chamberland M, Mamede S, St-Onge C, Setrakian J, Schmidt HG. Does medical students' diagnostic performance improve by observing examples of self-explanation provided by peers or experts? Submitted for publication

Abstract

Background/ Purpose: Educational strategies that promote the development of clinical reasoning in students remain scarce. Generating self-explanations (SE) engages students in active learning and was recently shown as an effective technique to improve clinical reasoning in clerks. Example-based learning has been shown to support the development of knowledge representation in other domains. The purpose of this study was to investigate the added value of combining student's SE and observation of peer's or expert's SE examples on their diagnostic performance.

Methods: 53 third-year medical students were assigned to peer SE example, expert SE example or control (no example) group. All participants solved a set of four clinical cases (training cases) after self-explanation and again after listening to a peer or expert SE example or after a control task. One week later, they solved again the four training cases and a new set of four different cases (transfer cases). Diagnostic performance and diagnostic accuracy scores were assessed on each moment.

Results: The main effect of group was not significant for both diagnostic accuracy and diagnostic performance scores on training cases. However, differences in the magnitude of improvement between the different groups suggest that SE examples provided some added value. Combined intervention led to significantly better diagnostic accuracy (peer SE $p = .007$, expert SE $p < .001$) whereas SE alone resulted in borderline improvement (control $p = .022$). Peer SE examples were as effective as expert SE examples. On transfer cases one week later, there was no difference in diagnostic accuracy scores ($p = .060$) and in diagnostic performance scores ($p = .940$) between the three groups.

Conclusions: Combining students' SE with SE examples improves diagnostic reasoning on identical cases one week later but makes no difference on transfer cases when compared to SE alone. The added value of peer SE examples was equivalent to expert examples and appears limited, suggesting that students' SE mainly drives the observed effect.

Introduction

Over the last decades, research has successfully explored multiple facets of clinical reasoning, an essential skill for physicians.[1-5] Authors agree that experts' knowledge base is extensive, includes several types of knowledge, and is organised in such way that makes it usable in daily problem solving.[3,6,7] The development of clinical reasoning requires time, is critically dependent on exposure to multiple examples and on the repeated practice of solving clinical cases.[2,3,8] Clinical exposure alone is insufficient. To develop their knowledge base, medical students must be involved in the problem solving process with opportunities for elaboration and reflection on patient encounters.[3,4] While clinical rotations provide many opportunities for clinical reasoning and for observing peers', colleagues' and expert clinicians' reasoning,[9,10] further strategies are needed to engage students in "deliberate" clinical reasoning. Self-explanation appears to be a promising technique in this regard.[11] Another strategy, that of observing examples, has been largely used to support development of accurate knowledge representation in memory.[12,13] In this paper, we explore the utility of combining self-explanation and observation of colleagues' self-explanation as learning tools for clinical reasoning.

Self-explanation (SE) is a learning technique wherein learners generate for themselves explanations about pieces of information in a text to be learned or a problem to be solved.[14-17] Through self-explanation, students engage in knowledge elaboration, generation of inferences, integration of new information with prior knowledge, monitoring and consequent knowledge reconstruction.[15,16] The positive effects of SE on learning have been shown in a variety of domains[15,16] including, more recently, in

Medicine.[11,18] In an experimental study, students who generated self-explanations while solving clinical cases demonstrated better diagnostic performance one week later when tested on different, and more difficult, cases than students who did not self-explain. The positive effect of SE was seen only on cases of a less familiar clinical topic.[11] Studies in other domains also find greater benefit with complex problems and application tasks differing from the initial learning task.[15] According to a subsequent related study, lack of familiarity seemed to act as a trigger for medical students to engage in more active thinking when they self-explained while diagnosing cases, as they reactivated more biomedical knowledge to make sense of the patients' findings, possibly creating new links between biomedical and clinical knowledge, thereby constructing a more coherent mental representation of diseases.[19,20]

It is relevant for research and educational practice to explore conditions that maximise the effects of SE as a promising technique for developing medical students' clinical reasoning. Combining SE and examples or models of clinical reasoning may provide such condition. Example-based learning (EBL) is the process of learning by studying examples or observing models performing a skill. The benefits on learning while working with examples is attributed to the fact that it provides some guidance which lowers the cognitive load imposed on students . Relieved of the need to search for every procedural step, students can then devote their cognitive capacity to studying and understanding the proposed solution.[12,21,22] This in turn helps students construct appropriate knowledge representations of the skill, which then guides performance of that skill in the future.[12]

EBL has been successfully used for a variety of tasks, from highly to less structured, and for a wide range of skills, from psychomotor to complex cognitive.[12] For EBL to succeed, the skill to be learned must be observable by the learner. Learning complex cognitive tasks through observation of models requires the latter to externalize cognitive processes and knowledge activated while performing the skill. This can be done for example by thinking aloud or writing down the actions. SE may represent an alternative way for subjects to make explicit their ongoing clinical reasoning process and relevant knowledge representations. For optimal effectiveness of observing examples, learning design issues must also receive great attention.[12,13] Differences between models' and observers' expertise level appear particularly relevant. A peer model has limited knowledge but is cognitively closer so may allow the student to relate to it more easily. In contrast, naturally performing experts have extensive knowledge, from which students could benefit, but, on the other hand, having largely automatized their task, work at higher levels of abstraction. Also important to consider are instructional features associated with the examples, ensuring students are cognitively engaged while observing, for instance by combining practice and example, in which students first solve the problem, then observe an example.

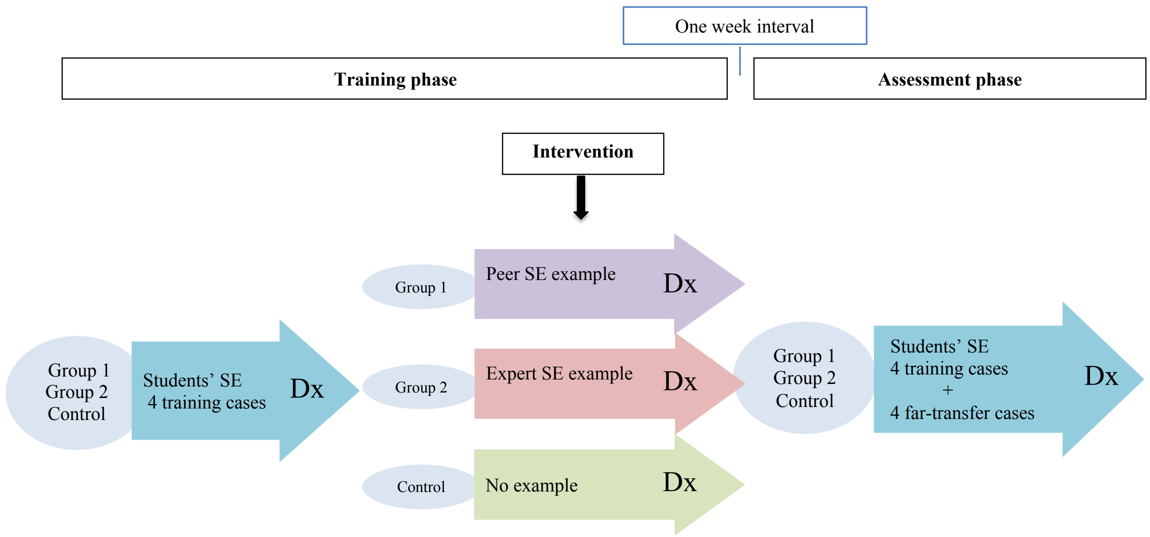
Both SE and EBL have been shown to contribute to the development of knowledge representations. Clinical reasoning is a complex skill that relies on well-developed mental representations of diseases. The present study examined the added value for learning clinical reasoning of combining clerks' SE with observation of SE examples. Moreover, since the benefit of the model or example appears to depend of its expertise level relative to the student' one, we investigated whether examples from peers or experts would lead to similar or different effect on students' diagnostic performance. We hypothesized that observing explicit examples would give additional opportunities for students to extend their understanding and critically revise their own knowledge representations, translating into better diagnostic performance. We also hypothesized that because of their cognitive proximity, peer models would be as good as expert models.

Methods

Design

This mixed-design experiment comprised two phases. In the training phase, participants were assigned either to the peer-SE group, to the expert-SE group, or to the control group. They solved a set of 4 clinical cases twice: after having self-explained and then again after having listened to an example of SE from a peer or an expert (peer- or expert-SE groups), or without listening to any example (control group). In the assessment phase, one week later, all participants had to solve the same 4 cases again (training cases) and a new set of 4 more difficult cases (transfer cases). Figure 1 summarizes the study design.

Figure 1. Study Design



Participants

Participants were 53 third-year medical students from the *Université de Sherbrooke* in Québec, Canada. The undergraduate program comprises four years, with 2 ½ years of PBL followed by 18 months of clerkship. Students in their first eight months of clerkship, in two consecutive cohorts (academic year 2011-12, and academic year 2012-13), were invited by email to participate in the study. Participation was voluntary, without financial incentive. Written informed consent was obtained. Ethics approval was obtained from the *Comité d'Éthique de la Recherche, Éducation et Sciences Sociales* of Université de Sherbrooke.

In the first cohort, 151 students were approached for the study. Forty students accepted and were randomly assigned to the peer or to the expert SE group for the training phase. Thirty-seven completed the assessment phase (peer-SE group = 18; expert-SE group = 19). In the second cohort, 21 students were invited to participate. Eighteen students accepted the invitation and 16 completed the two phases of the study. These students were assigned to the control group (n = 16).

Materials

Eight written clinical cases, all addressing the topic of jaundice were used for this study. Jaundice was a rather unfamiliar topic to the 3rd-year medical students involved.[11] The topic was broken down into four broad categories of diseases with different pathophysiological mechanisms: acute hepatitis, chronic liver disease, obstructive jaundice and hemolysis. A set of four cases, one per category, was used in the training phase (training cases). In the assessment phase, the training cases were again used as well as a second set of four different cases, one per category again, but with different diagnoses from the training cases (transfer cases). (See Appendix 1 at the end of this chapter)

Case descriptions of approximately 300 words including chief complaint, background information, and findings from history, physical examination and laboratory tests were developed and used in a previous study.[11]

In the training phase, two versions of booklets, each with a different case order, were distributed alternately to the recruited students. Similarly, in the assessment phase, clinical cases were presented in a booklet using again two differently ordered versions. The training cases were presented first, followed by the transfer cases with three intercalated filler cases on unrelated clinical topics.

As peer and expert SE examples, we used audio-recorded SE. To reflect the variety of examples possibly encountered in the clinical environment, SE examples from three different peers and three different experts in Internal Medicine, were prepared as follows. In individual sessions, clinical clerks and internists, not involved in the study were first introduced to SE, then asked to self-explain on each of the four training cases. Experts were specifically instructed to self-explain at their level of expertise rather then think or talk as clinical teachers. All audiotapes were anonymous. Their speed was adjusted to create equally long (8 minutes) audio examples. Written consent was obtained from peers and experts.

Appendix 2 provides typical transcripts of peer and expert SE (see appendix 2 at the end of this chapter). Expectably, there were notable differences between the peers' and the experts' SE examples. Experts generated very early a problem representation including key elements for one or a few likely diagnoses. Additional clinical data in the case were used mainly to confirm early diagnoses or quickly rule out alternatives. Experts' examples contained almost no explicit reference to underlying mechanisms, no errors, almost no ambiguities or hesitations, and very few paraphrases. In contrast, peers mainly analysed isolated clinical data, did not quickly recognize key elements and considered all along numerous and varied diagnoses. They referred to underlying mechanisms, made some erroneous interpretations, raised questions, expressed hesitations and used frequent paraphrases.

Procedure

A research assistant tested all participants individually. Students were first provided with a general definition of SE and then listened to a 7-minute audio example of SE on a clinical case (mono-arthritis) not used in the study but with a similar format. Subsequently, they were asked to read each case, generate self-explanations out loud for eight minutes, and take two minutes to write down their responses to the following three questions:

Q1. What is the most likely diagnosis?

Q2. What are the two main arguments supporting this diagnosis?

Q3. List two plausible alternative diagnoses.

The first question provided a measure of diagnostic accuracy; combination of the three questions was intended to provide a rough measure of the quality of the diagnostic reasoning.

Participants of the peer-SE and expert-SE groups were then instructed to listened respectively to the eight- minute recorded peer or expert SE, and thereafter to take two minutes to answer again the same three questions. This procedure was repeated for all four training cases. Each participant was exposed to a random sample from all of the three peers or the three experts to reflect the variety of examples in the real learning environment. As to the control group, in an effort to prevent further SE on their part, students they were invited to move to the next page of their booklet to solve a word puzzle for 8 minutes. Time was strictly controlled. The training phase lasted 1.5 hour.

One week later, participants were met individually for the assessment phase, which was identical for the three groups. First, participants were asked to read the four cases used in the training phase (training cases), generate self-explanations, and answer again the three questions regarding their diagnosis. Second, participants were asked to solve in silence the four transfer cases with three filler cases interpolated. Time to solve each case was not controlled but participants were allowed up to two hours for the whole assessment phase.

At the end of the assessment phase, students completed a brief questionnaire about potentially relevant learning opportunities (i.e., current clinical rotation, individual study time, and teaching activities related to jaundice) during the week of the study. The different groups reported similar opportunities. Four research assistants ran all the sessions, after having gone through a standardization exercise, to ensure a uniform procedure.

Data analysis

A scoring grid, developed and validated in a previous study,[11] was used to evaluate students' answers for each question. Each answer was scored as 0, if it was incorrect, 1, if partially correct, and 2, if entirely correct. Two scores were derived from participants' answers: the diagnostic accuracy score (the score on question Q1) and the diagnostic performance score (the sum of scores on questions Q1, Q2 and Q3). For each participant, the scores of the four cases (either training or transfer cases) were summed. The scores were then expressed as a percentage of the maximum score (8, for the diagnostic accuracy, and 24 for the diagnostic performance). One rater (MC) scored the responses of all students from all groups. In the previous study, two independent raters scored students' responses. Inter-rater reliability, measured by intra-class correlations, ranged from 0.70 to 0.95.[11] Compared to students' responses from the previous study, no new responses were provided by participants in the present study.

Descriptive statistics were computed. To assess the comparability of the groups, two separate one-way ANOVAs were performed on the mean scores obtained for diagnostic accuracy and diagnostic performance before the intervention. For the training cases, two separate repeated-measure ANOVAs with group (peer SE, expert SE and control) as a between-subjects factor, and performance moment (three performance moments: before and after the intervention in the training phase and one week later in the assessment phase) as a within-subjects factor were performed on mean diagnostic accuracy scores and diagnostic performance scores. For transfer cases in the assessment phase, two separate one-way ANOVAs with group as a between-subjects factor were performed on mean diagnostic accuracy scores and diagnostic performance scores. Significance was set at 0.05.

Results

Tables 1 and 2 present mean scores obtained, respectively, on diagnostic accuracy and diagnostic performance as a function of performance moment and experimental condition on training cases. No significant differences between the groups were found before the intervention, either in diagnostic accuracy score (F[2, 50] = 1.06, p =.354) or in diagnostic performance score: (F[2, 50] = 0.19, p =.828).

Table 1. Mean Diagnostic Accuracy Scores (*SD*) as a function of performance moment for each group on training cases and p-values for score differences between performance moments for each group.

Group (N)	Before	After	One-week	Before vs. After	Before vs. One-week	After vs. One –week
Peer SE (18)	70.83 (16.61)	82.64 (9.72)	85.42 (9.82)	.007	.004	.298
Expert SE (19)	74.34 (13.48)	87.50 (9.32)	87.50 (9.32)	<.000	.003	1.000
Control (16)	78.13 (13.31)	78.13 (13.31)	86,72 (13.28)	1.000	.022	.022

Significance level p = 0.017

For the diagnostic accuracy score, Mauchly's test indicated that the assumption of sphericity had been violated, X^2 (2) = 12.66, p = .002, therefore, the multivariate tests are reported (ϵ = .82). The repeated-measure ANOVA revealed a significant main effect of performance moment (V = 0.37, F[2, 49] = 14.45, p < .001). The main effect of group was not significant (F[2, 50] = 0.66, p = .520), but there was a significant interaction effect ($V = 0.23$, $F[4, 100] = 3.30$, $p = .014$). To better understand these primary findings, *post hoc* analyses were conducted using paired t-tests within each group (with Bonferroni correction). The p-values are presented in Tables 1. In both the peer- and the expert-SE groups, students' diagnostic accuracy scores improved significantly immediately after listening to the SE example ($p = .007$, $p < .001$ respectively), and then remained unchanged one week later ($p = .298$, $p = 1$ respectively). The control group showed a borderline but delayed improvement, i.e., one week later ($p = .022$). Three One-way ANOVAs on mean diagnostic accuracy scores at each performance moment were also conducted as *post hoc* analyses. A significant difference between the groups was noted only immediately after the intervention ($F[2, 50] = 3.29$, $p = 0.045$. This difference was observed between the expert SE group and the control group ($p = .041$)

Table 2. Mean Diagnostic Performance Scores (*SD*) as a function of performance moment for each group on training cases and p-values for score differences between performance moments for each group.

Group (N)	Before	After	One-week	Before vs. After	Before vs. One-week	After vs. One -week
Peer SE (18)	60.88 (13.19)	70.37 (9.99)	71.53 (8.84)	.002	.008	.622
Expert SE (19)	60.09 (9.03)	70.61 (6.73)	69.74 (8.08)	<.000	.001	.607
Control (16)	62.50 (12.64)	66.15 (13.25)	67.45 (8.90)	.021	.047	.525

Significance level $p = 0.017$

For the diagnostic performance scores, Mauchly's test also indicated that the assumption of sphericity had been violated (X^2 [2] = 12.44, *p* = .002) therefore, the multivariate tests are reported (ϵ = .82). A significant main effect of performance moment was observed (*V* = 0.46, *F*[2, 49] = 21.27, *p* < 0.001). The main effect of group was not significant (*F*[2, 50] = 0.30, *p* =.744) and there was no significant interaction effect (*V* = 0.12, *F*[4, 100] = 1.60, *p* = .179). *Post hoc* analyses using paired *t*-tests within each group are presented in Table 2. The diagnostic performance scores in the peer and the expert-SE groups improved significantly immediately (*p* = .002, *p* < .001 respectively) and remained stable one week later (*p* = .622, *p* = .607 respectively). For the control group, the immediate improvement was borderline significant (*p* = .021) and remained stable (*p* = .525).

Table 3 presents mean diagnostic accuracy scores and mean diagnostic performance scores on transfer cases for each group. No significant differences emerged between the groups either in diagnostic accuracy scores (*F*[2, 50] = 0.49, *p* = 0.616) or in diagnostic performance scores (*F*[2, 50] = 0.06, *p* = 0.941).

Table 3. Mean Diagnostic Accuracy Scores (*SD*) and Diagnostic Performance Scores (*SD*) for each group on Transfer cases one week later

Group	Mean Diagnostic Accuracy Scores	Mean Diagnostic Performance Scores
Peer SE	56.25 (17.81)	58.56 (11.39)
Expert SE	60.53 (21.76)	59.87 (13.41)
Control	53.91 (20.78)	58.85 (10.74)

Discussion

The present study investigated the impact on students' diagnostic performance of listening to peer or expert SE examples after having themselves self-explained while diagnosing clinical cases. We assessed the short term and long-term (one-week) effect on the training cases and the long-term (one-week) effect on transfer cases. It was hypothesized that listening to SE examples would add to students' SE and support their knowledge construction thus translating into better subsequent performance.

The results of this study showed that for the training cases, students' diagnostic accuracy and diagnostic performance increased significantly after students' SE, whether or not it was followed by listening to SE models. Although the main effect of group was not significant, a closer look at the changes within each group leads to some interesting additional observations. First, differences in the magnitude of improvement suggests in fact an added value to being exposed to SE models. Combining SE models to students' own SE led to significant improvement, while the improvement with students' SE alone was only borderline. Second, the time frame of the improvement differed. Combining SE models with students' own SE led to immediate improvement in diagnostic accuracy while improvement of students' SE alone was delayed. This is in line with other studies on medical students' clinical reasoning in which the effect of deep processing of the information either by elaboration or structured reflection requires time and may even lead to poorer performance initially, followed by significant improvement later on.[23-25] Third, the peer SE and the expert SE groups' outcomes were identical. While SE models led to significant improvement, the type of SE model (peer vs. expert) did not make any difference on students' performance. Peers' examples were as good as experts' examples. For transfer cases one week later, no added value of SE models was noted. For this task that reflects deeper learning than memorization and retention,[26] students' SE alone was as effective as the combination with SE models.

Thus the added value of SE models was altogether subtle, only evident on training cases, and expert SE models were not more effective than peer SE models. Apparently, students' own SE was in large part responsible for the overall improvement across all groups, adding further evidence to the positive influence of this learning technique in Medicine.[11,18,19]

Why do SE models not add much to students' performance? The explanation may lie in the nature of the examples used in this study. In the worked-example literature, examples are usually ideal ones, didactically designed and presenting only steps relevant to the task.[12] In contrast, in our study, we used natural "raw" examples of SE, as they might occur in clinical setting. We deliberately choose to use non-didactically designed examples of clinical reasoning to be able to transpose more easily the results of the study to the clinical settings relevant to the clerkship. The level of expertise of the example may also play a role. We used examples from peers (third-year medical students), whose SE included irrelevant details and even uncorrected errors. Despite their cognitive proximity, participants at the exact same level may have little to learn from such examples. As to the expert SE examples, while it might be counter-intuitive that students would not learn from an expert's "flawless" clinical reasoning, experts behaving naturally may not be the best examples for novices.[12,13] Experts use fast, largely non-analytic reasoning, tend to skip steps and to reason at a higher level of abstraction,[7] which may be difficult for students to relate to their own knowledge.

Another possible explanation for the limited impact of SE models might be related to the degree of students' cognitive involvement while listening to the examples.[12,13] Participants were informed that they would listen to an example of SE from someone else and that they would have to solve the problem again. They were not given prompts or other specific tasks to ensure that they listened actively. They may have been passive, even though their prior SE on the same case was expected to act as a preparatory task which would help them to focus on the example that followed.

Finally, clinical reasoning is a complex cognitive task, in contrast to more structured tasks and procedural skills for which models and examples have been more often used.[12,13] Measuring an impact of observing examples may be a matter of dosing, meaning that examples may have to be multiple, varied, repeated and spaced over time.

This study has limitations. Students in the control group were recruited consecutively and were not randomized in contrast to students in the peer- and expert-SE groups. However, all participants were at the same level of training from the same program. We used SE examples of peers (third year medical students) and experts, and the results may differ if examples of intermediate levels of expertise (e.g., residents) are tested.

Finding ways of keeping students cognitively active during the clerkship and designing activities that maximise learning from unplanned activities in clinical settings remain a challenge for clinical teachers and educators. While recent studies suggest an important role of observing colleagues for the development of clinical reasoning in workplace, little is known on how to maximise learning from these naturally occurring models. SE seems to be a promising individual learning tool for clinical reasoning in clerkship, but there seems to be a limited value of adding SE examples, at least natural examples from peers or experts and without further instructions. Even though this study showed partly negative findings, it has potentially important implications since medical students in the clerkship spend significant amount of time listening to more implicit examples of clinical reasoning from colleagues. We should find better ways to seize learning opportunities from observing others. Future studies should examine the impact of SE examples of other levels of expertise and investigate additional strategies that could help students actively process and use natural examples of clinical reasoning.

References:

1 Gruppen LD, Frohna AZ. Clinical Reasoning. In: Norman GR, Van der Vleuten CPM, Newble DI, editors. International handbook of research in medical education Dordrecht (Great Britain): Kluwer Academic Publishers; 2002; 205-230.

2 Norman G. Research in clinical reasoning: past history and current trends. Med Educ 2005;39(4):418-427.

3 Schmidt HG, Rikers RMJP. How expertise develops in medicine: knowledge encapsulation and illness script formation. Med Educ 2007;41(12):1133-1139.

4 Eva KW. What every teacher needs to know about clinical reasoning. Med Educ 2005;39(1):98-106.

5 Mylopoulos M, Regehr G. Putting the expert together again. Med Educ 2011;45(9):920-926.

6 Charlin B, Boshuizen HP, Custers EJ, Feltovich PJ. Scripts and clinical reasoning. Med Educ 2007;41(12):1178-1184.

7 Bordage G. Prototypes and semantic qualifiers: from past to present. Med Educ 2007;41(12):1117-1121.

8 Kassirer JP. Teaching clinical reasoning: case-based and coached. Acad Med 2010 2010;85(7):1118-1124.

9 Ajjawi R, Higgs J. Learning to reason: A journey of professional socialisation. Adv Health Sci Educ 2008;13(2):133-150.

10 van de Wiel, Margje WJ, Van den Bossche P, Janssen S, Jossberger H. Exploring deliberate practice in medicine: how do physicians learn in the workplace? Adv Health Sci Educ 2011;16(1):81-95.

11 Chamberland M, St-Onge C, Setrakian J, Lanthier L, Bergeron L, Bourget A, et al. The influence of medical students' self-explanations on diagnostic performance. Med Educ 2011;45(7):688-695.

12 van Gog T, Rummel N. Example-Based Learning: Integrating Cognitive and Social-Cognitive Research Perspectives. Educ Psychol Rev 2010;22:155-174.

13 Rosen MA, Salas E, Pavlas D, Jensen R, Fu D, Lampton D. Demonstration-based training: a review of instructional features. Human Factors: Hum Fac Erg Soc 2010;52(5):596-609.

14 Chi MTH, Bassock M. Learning from examples via self-explanations. In: Resnick LB, editor. Knowing, learning, and instruction: essays in honor of Robert Glaser Hillsdale (NJ): Lawrence Erlbaum Associates; 1989; 251-282.

15 Chi MTH. Self-explaining expository texts: the dual processes of generating inferences and repairing mental models. In: Glaser R, editor. Advances in instructional psychology Mahwah (NJ): Lawrence Erlbaum Associates; 2000; 161-238.

16 Dunlosky J, Rawson KA, Marsh EJ, Nathan MJ, Willingham DT. Improving Students' Learning With Effective Learning Techniques Promising Directions From Cognitive and Educational Psychology. Psychol Sci Public Interest 2013;14(1):4-58.

17 Fonseca BA, Chi MT. Instruction based on self-explanation. In handbook of research on learning and instruction 2011:296-321.

18 Larsen DP, Butler AC, Roediger III HL. Comparative effects of test-enhanced learning and self-explanation on long-term retention. Med Educ 2013;47(7):674-682.

19 Chamberland M, Mamede S, St-Onge C, Rivard M, Setrakian J, Lévesque A, et al. Students' self-explanations while solving unfamiliar cases: the role of biomedical knowledge. Med Educ 2013;47(11):1109-1116.

20 Woods NN. Science is fundamental: the role of biomedical knowledge in clinical reasoning. Med Educ 2007;41(12):1173-1177.

21 Van Merriënboer JJ, Sweller J. Cognitive load theory in health professional education: design principles and strategies. Med Educ 2010;44(1):85-93.

22 Renkl A. Toward an Instructionally Oriented Theory of Example-Based Learning. Cognitive Sci 2014;38(1):1-37.

23 Mamede S, van Gog T, Moura AS, de Faria R, Peixoto JM, Rikers RM, et al. Reflection as a strategy to foster medical students' acquisition of diagnostic competence. Med Educ 2012;46(5):464-472.

24 Woods NN, Brooks LR, Norman GR. It all makes sense: biomedical knowledge, causal connections and memory in the novice diagnostician. Adv Health Sci Educ 2007;12(4):405-415.

25 Woods NN, Brooks LR, Norman GR. The role of biomedical knowledge in diagnosis of difficult clinical cases. Adv Health Sci Educ 2007;12(4):417-426.

26 Mayer RE. Applying the science of learning to medical education. Med Educ 2010;44(6):543-549.

Appendix 1. Template for clinical cases development

Broad category of diseases	Specific diagnosis	
	Training cases	Transfer cases
Acute hepatitis	Viral Hepatitis B	Viral Hepatitis A
Chronic liver disease	Chronic alcoholism	Hemochromatosis
Obstructive jaundice	Pancreatic tumor	Choledocholithiasis
Hemolysis	Auto-immune, idiopathic	Cold agglutinins, Mycoplasma infection

Appendix 2 Illustrative extracts from the peers and the experts SE examples

Sections of the text in *italic* represent self-explanations of the expert or the peer. The other parts of the text correspond to sections of the clinical case description.

Expert SE example:
(Cas A3): Dx Pancreatic cancer

> Il s'agit d'un homme de 76 ans qui consulte pour ictère progressif. *Alors, c'est un patient assez âgé* qui note une coloration jaune-verdâtre de sa peau d'apparition graduelle sur trois semaines, *donc déjà un ictère qui semble assez intense et sur une durée de trois semaines, donc quand même quelque chose d'assez subaigu*. Mis à part un malaise épigastrique vague en postprandial, il ne se plaint pas de douleur abdominale. Il a remarqué que ses urines étaient plus foncées, ses selles plus pâles, *donc vraiment des évidences d'obstruction des voies biliaires assez importantes pour avoir des selles acholiques,* sans diarrhée ni constipation associées. Son appétit semble diminué, il dit avoir perdu possiblement cinq à sept kilos depuis le dernier mois. *Donc, vraiment, on pense tout de suite à une étiologie néoplasique avec une atteinte de l'état général, baisse de l'appétit, perte de poids, malaise épigastrique, donc on pense tout de suite à un cancer du pancréas avec une obstruction des voies biliaires…* (Extrait AE2 GB1 Cas A3)

Peers SE example
(Cas A3): Dx: Pancreatic cancer

> Un homme de 76 ans, ..consulte pour un ictère… progressif. …le patient a noté une coloration ..jaune-verdâtre de sa peau, ...d'apparition graduelle sur trois semaines….*graduelle sur trois semaines. Euh…ok, un ictère…un ictère encore qu'est-ce qui peut faire ça… y'a toutes les hépatites c'est sur qui faut penser. Euh…ça peut être une un hypersplénisme aussi. Ok c'est surtout ça on va voir y vont probablement parler des causes d'hépatites.* Mis à part un malaise épigastrique vague…*malaise épigastrique vague…malaise bon épigastrique* vague en post prandial, il ne se plaint pas de douleur abdominale. *Malaise épigastrique en post prandial…ça peut être une gastrite, ça peut être euh… …ça peut être au niveau de des voies biliaires, un problème une euh une lithiase peut-être euh…ouais ça peut être une lithiase, ça peut être euh au niveau du du pancréas peut-être euh…*Il a remarqué que ses urines étaient plus foncées *ok. Urines plus foncées ça ça va en fonction de…*, et ses selles plus pâles sans diarrhée ni constipation. *Ça …ça va en fonction là euh…euh d'une hyperbilirubinémie*. Son appétit semble diminué, appétit diminué et y'a perdu cinq à sept kilos depuis l'dernier mois. Il n 'a pas noté de fièvre, de frissons ni de sudations nocturnes. *Ok, ça ça ça va moins… euh un peu… en fonction …d'une hypothèse néoplasique. J'pense entre autres .. à un cancer d'la tête du pancréas, mais…c'est très euh…pas très fiable les sudations nocturnes*. (Extrait AE2 A105 Cas A3)

Chapter 5

Self-explanation in learning clinical reasoning: the added value of residents' examples and prompts

Chamberland M, Mamede S, St-Onge C, Setrakian J, Bergeron L, Schmidt HG Self-explanation in learning clinical reasoning: the added value of examples and prompts. Med Educ (In press).

Abstract

Context: Recent studies suggest that self-explanation (SE) while diagnosing cases fosters development of medical clerks' clinical reasoning; however, conditions to optimize the impact of SE remain unknown. The example-based learning framework justifies exploring the use of students' SE combined to studying examples. This study aimed at assessing the impact on medical students' learning of clinical reasoning of 1) combining students' SE with listening to residents' SE-examples, and 2) adding prompts while working with examples.

Methods: This study consisted of a training phase and an assessment phase, one week later. In the training phase, 54 medical students were randomly assigned to one of three groups. In all groups, students firstly solved four clinical cases using SE. Subsequently, Group 1 listened to residents' SE-examples with prompts; Group 2 listened to residents' SE-examples without prompts, while the control group solved word puzzles. Then, all students solved again the same four cases. One week later, all students solved four similar and four different cases. Students' diagnostic performance and diagnostic accuracy scores were assessed for each case at each moment.

Results: Although all groups' diagnostic accuracy scores on similar cases improved significantly between the training and the assessment phase, Group 1 showed a significantly higher diagnostic performance score after one week than the control group (p = .037). On different cases, Group 1 obtained significantly higher diagnostic accuracy

(*p* = .011) and diagnostic performance (*p* <.001) scores than the control group and significantly higher diagnostic performance score than Group 2 (*p* = .018).

Conclusion: For medical students in clerkships, SE seems an effective technique for learning clinical reasoning. Its impact is increased significantly by confrontation with residents' SE-examples and prompts. While students' exposure to examples of clinical reasoning is important, being "active processors" of these examples appears to be critical to learning from them.

Introduction

Although clinical reasoning is viewed as a complex, multidimensional and integrated skill, a well-organised medical knowledge base remains at its core.[1,2] One of the major foci of clinical education is to expand, revise and refine this knowledge base, in large part through the process of clinical reasoning when encountering patients' problems.[1-3] Thus, strategies to foster learning from exposure to clinical problems are required[3] but little is known about them.[4] The use of self-explanation (SE) while solving clinical cases has been shown to be effective for medical students at the clerkship level and seems a promising technique to support learning of clinical reasoning in context.[5] In addition, recent studies have highlighted the importance of interacting with, and observing peers (students, residents) and expert clinicians for the improvement of residents' and clinicians' reasoning in practice.[6,7] Combining SE with modelling by residents might be relevant to support students' clinical reasoning. Residents have been recognized as important models in the education of medical students.[8] However, little is known about their specific contribution to the development of students' clinical reasoning. In the present paper, we explore the potential benefits of SE and active or prompted observation of resident models on students' diagnostic performance in clerkship.

Self-explanation is an active learning activity that consists of generating explanations to oneself when working through learning materials.[9-11] While self-explaining, learners engage in knowledge elaboration, integration, and monitoring, allowing them to revise their knowledge and build a more coherent representation that facilitates transfer of learning.[9] The benefit of SE on learning has been demonstrated in various domains.[9]

More specifically in medical education, it has been shown that, when using SE to solve paper cases, clerks improved their diagnostic performance on new cases of the same clinical topic one week later, compared to students who did not use SE.[5] Since knowledge restructuring and the emergence of illness scripts are critical to the development of clinical reasoning in students,[2] it has been proposed that generating SE during the process of reasoning through, and diagnosing, cases may foster the development of better organised and richer illness scripts used for clinical reasoning.[5] The beneficial effect was observed only with unfamiliar cases and not with familiar ones. Unfamiliar cases seem to encourage students to reactivate biomedical knowledge, potentially creating new links between biomedical and clinical knowledge, thus leading to a more coherent mental representation of diseases.[12,13]

The use of prompts, which are specific instructions that require learners to process the example or the content in a specific way, has been shown to enhance the effect of SE on learning[14,15] 'Justification prompts' require students to generate the principal justification and to focus on the underlying concepts. Examples of this type of prompt would be: *What principle is being applied here? This particular choice is correct because...*Transposed to clinical reasoning, this type of prompt might facilitate activation of biomedical knowledge, for instance pathophysiological mechanisms, while solving the problem and potentially lead to new links with clinical knowledge. On the other hand, 'Mental-model revision prompts' help students highlight discrepancies between their knowledge representation and the observed model. Examples of this type of prompt would be: *How does it relate to what you already know? Does it help you gain more insight on how to* *solve the problem?*[15] When applied to clinical reasoning, comparing and contrasting student's own mental representation of diseases to an example from a colleague might assist revision of knowledge.

Observing models has also been shown to foster construction of mental representations in general.[16] Otherwise, for clinical reasoning, it has been suggested that when reasoning is made explicit in clinical practice, it not only becomes exposed to self-critique and to feedback from others, it also becomes available to others as a potentially useful example to learn from.[6] The process of learning or acquiring a skill by observing examples or models of that skill is called example-based learning (EBL).[16] It has been suggested that EBL promotes the construction of appropriate cognitive representations that guide later performance. EBL has been used for a wide range of tasks from psychomotor skills to highly and less structured cognitive skills.[16] Hence, EBL may be relevant for learning clinical reasoning. According to the EBL framework, the skill in the example must first be "salient" and "visible" for the learner. Second, the difference between the model's and the learner's level of expertise is also worth considering.[16,17] A relatively small gap separating the model from the learner may support learner's self-efficacy (learner's judgment of his capacity to attain the observed performance) and clarify outcome expectations. It may as well provide social (i.e. feeling at ease) and cognitive congruence.[18,19] On the other hand, an expert model largely automatized and working at a higher level of abstraction may be difficult for students to follow. Third, to optimize learning when working with examples, students should engage in cognitive activities that may occur before, during or after the observation.

A recent study investigated the added value of listening to peers' (clerk) or experts' SE to the effect of SE on medical students' learning of clinical diagnosis.[20] As compared to a control group, there was only a small benefit of being exposed to peer or expert SE when tested on the same cases one week later and no effect when tested on different and more difficult cases. The authors suggested that using examples of intermediate level of expertise, such as residents' (rather than peer or expert) examples, and prompting students while listening could have produced better outcomes. These ideas were tested in the present study whose purpose was to assess the impact on medical students' learning of clinical diagnosis 1) of combining students' SE with listening to residents' SE examples and 2) of adding prompts while working with SE examples.

Methods

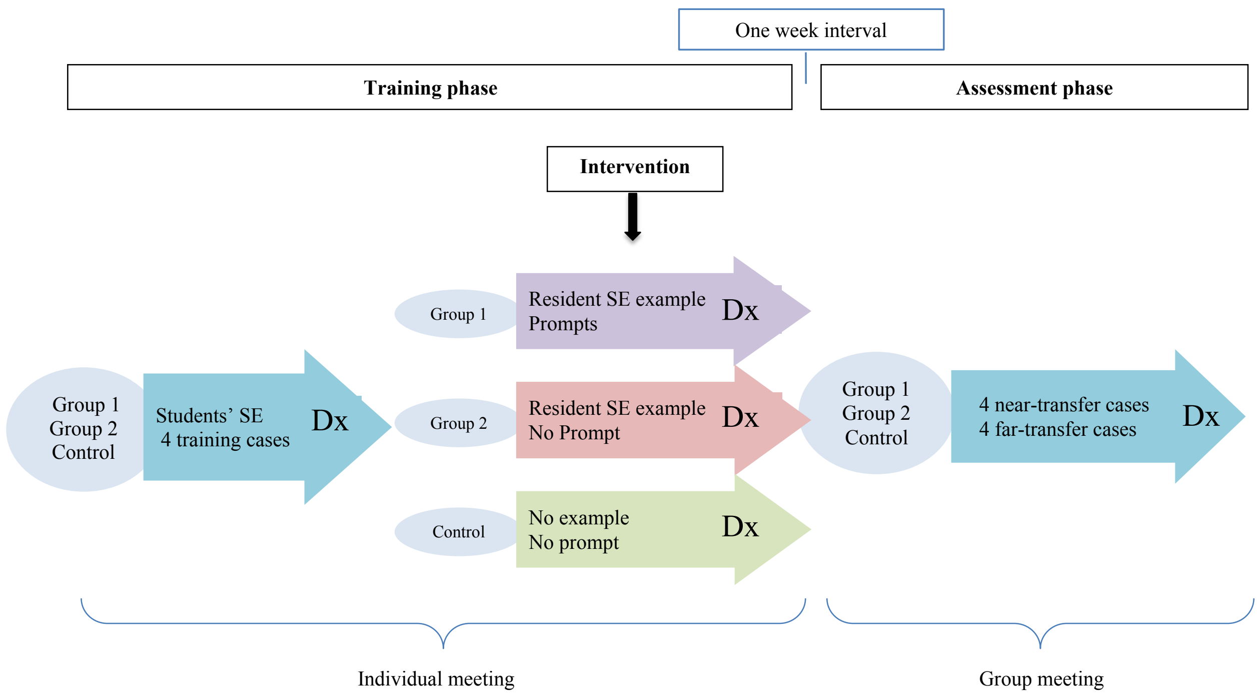
Design

A mixed-design was used for this experimental study that comprised two phases, a training phase and an assessment phase run one week later. In the training phase, participants were randomly assigned to one of three groups. In each group, the students first solved four clinical cases using SE. Then, Group 1 listened to residents' SE examples of the same cases with prompts, Group 2 listened to residents' SE examples without prompts while the control group solved word puzzles. Subsequently, all students solved again the same four cases. One week later, all students solved four similar cases (near-transfer cases) and four different cases (far-transfer cases).

Students' diagnostic performance was assessed on each case and at each performance moment.

Figure 1 illustrates the study design.

Figure 1. Study Design



Participants

Participants were 3rd year medical students from the Université de Sherbrooke undergraduate program which consists of 2 ½ years of problem-based learning followed by 18 months of clerkship. At the time of the study, participants were engaged in their first 8 months of clerkship. All students on clinical rotations within the departments of Medicine and Paediatrics from June to August 2013 were invited to participate in the study. Participation was voluntary and no financial incentive was offered. Written informed consent was obtained. From the 60 students invited to participate, 58 accepted and were randomly assigned to one of three groups (Group 1: Resident SE example with prompts (n = 19), Group 2: Resident SE example without prompt (n = 18), control group (n = 17)). Data were analysed for the 54 students who completed the two phases of the study.

Ethics approval was obtained by the *Comité d'Éthique de la Recherche, Éducation et Sciences Sociales* de l'Université de Sherbrooke.

Materials

Clinical cases

Twelve clinical cases, all related to the topic of jaundice, were used for the study. They consisted of four training cases, four near-transfer cases and four far-transfer cases. Case descriptions were approximately 300 words long and included the chief complaint, background information, and findings from history, physical examination and laboratory tests. Training cases and far-transfer cases have been developed and used in previous studies.[5,12] Near-transfer cases were developed and revised by two senior internists/clinical teachers (MC, JS) for this study.

The topic of jaundice was broken down into the following four broad disease categories according to pathophysiological mechanism: acute hepatitis, chronic liver disease, obstructive jaundice and hemolysis. Each set of four cases included one case in each of the four categories. The near-transfer cases were similar to the training cases with the same key elements and final diagnoses. Only superficial data irrelevant to the diagnosis were changed from the initial cases (e.g., gender, age, background information). Far-transfer cases however, presented different clinical scenarios and different final diagnoses (see Appendix 1 at the end of this chapter). The latter were also more difficult due to a less typical presentation, less common final diagnosis, or comorbidity.

In the training phase, cases were presented in a booklet. Cases were displayed in the same specific order in half of the booklets while they were provided in the reverse order in the other half. These two different booklets were distributed to recruited students on an alternate basis. In the assessment phase, for transfer cases, we used a similar strategy to assemble two differently ordered booklets in which we intercalated four filler cases of other clinical topics.

Residents' self-explanation examples

To develop the residents' SE examples, three second-year Internal Medicine residents from the Université de Sherbrooke were recruited on a voluntary basis. Compared to the participants, they had two additional years of training. After a brief introduction to SE, they were asked to self-explain while going through each of the four training cases but without providing at the end their final diagnostic opinion. The SE was audio-recorded and anonymized. For each of the four cases, the research team selected among the three available recordings the most elaborate example for the study. Sound tracks of the four selected audiotapes were modified to prevent recognition. Their speed was also adjusted to create equal-length audio examples of eight minutes. Written consent was obtained from residents.

Prompts

Two different types of prompts, 'justification prompts' and 'mental-model revision prompts' were designed in order to support students' active listening of residents' SE examples.

A total of 12 prompts, six of each type were incorporated into the four resident SE recordings (see Appendix 2 at the end of this chapter). Hence, for each resident SE recording, three prompts were inserted at "natural" moments of the clinical reasoning process. After each prompt, a 35-second sequence of silence was incorporated into the sound track, providing students with strictly controlled time to respond to the prompt. To keep time on task equal for students listening to Resident SE examples without prompt, similar sequences of silence were added at the same moments of the resident SE recordings.

We pilot tested the materials with 3 medical students not involved in the study, and minor adjustments were made to ensure clarity of materials and instructions.

Procedure

Training phase

In this phase, a research assistant met each participant individually. After a brief introduction to SE, the technique was illustrated to students with a 7-minute audio example of SE on a clinical case not used in the study (mono-arthritis). Then, they were asked to solve the first training case, while self-explaining out loud for eight minutes. They were then allowed two minutes to write down their answers to the next three questions:

Q1. What is the most likely diagnosis?

Q2. What are the two main arguments supporting this diagnosis?

Q3. List two plausible alternative diagnoses.

Participants in Group 1 then listened to the eight-minute Resident SE example on the same training case. After each prompt, students had 35 seconds to verbalize their answers to the prompt. At the end of the recording, they had again two minutes to answers the same three questions regarding their diagnosis.

Participants in Group 2 listened to the eight-minute Resident SE example without prompts. They were advised that a few silent sequences were included in the sound track but without further specific instructions. They had to keep silent during the sequences. They were then allowed two minutes to answer the three questions.

Participants in the control group were invited after the case to move to the next page of their booklet and to solve a word puzzle for eight minutes. This task was intended to equate time on task and to avoid students engaging in additional SE about the case.[21] Then, they were allowed two minutes to answer the three questions.

This procedure was repeated for all four training cases.

At the end of the session, the research assistant asked the student open-ended questions on his/her perceived learning experience with the approaches used in the session.

The training phase lasted two hours for each group and was audio-recorded.

Assessment phase

One week later, participants from all groups gathered for the 2-hour assessment phase supervised by a research assistant. Participants were requested to solve in silence 12 cases presented in a booklet: four near-transfer cases; four far-transfer cases and four intercalated fillers. For each case, they answered again the three questions regarding their diagnoses. At the end of the session, participants completed a brief questionnaire on their learning opportunities relating to jaundice (i.e., current clinical rotation, individual study time, and teaching activities) that occurred during the preceding week. Students reported similar opportunities in each group.

Two research assistants, who had participated in a standardisation exercise, ran all the individual and group sessions according to written protocols.

Data analysis

For all cases (training, near-transfer and far-transfer cases), and all three questions, each participant's answer was scored on a 3-point scale (0, 1, 2 points, in which 0 means it was incorrect, 1, partially correct, and 2, entirely correct). For the training cases and the far-transfer cases, participants' answers to the three questions on diagnosis were assessed using a scoring grid developed and validated in a previous study,[5] and one rater (MC), who was blind to the participants' condition, scored all the responses. In the previous study, scoring of the cases by two raters had shown inter-rater reliabilities, measured by intra-class correlations ranging from 0.70 to 0.95. Distinctly, for the near-transfer cases, which had not been previously used, two independent raters (MC and JS) scored the responses without being aware of the condition under which they had been given. Inter-rater reliabilities, measured by intra-class correlations, ranged from 0.69 to 1.00. Disagreements were resolved by discussion.

Two measurements were derived from participants' answers: the diagnostic accuracy score (the score on question Q1) and the diagnostic performance score (the sum of scores on questions Q1, Q2 and Q3), that reflected respectively accuracy of the diagnosis and the quality of diagnostic reasoning. The scores on each set of 4 cases were summed and then expressed as a percentage of the total score.

Descriptive statistics were computed. To evaluate groups' comparability, two separate one-way ANOVAs, with group as a between-subjects factor, were performed on the mean diagnostic accuracy score and on the mean diagnostic performance score obtained before the intervention. Two separate repeated-measures ANOVAs with group as a between-subjects factor (resident SE with prompt; resident SE without prompt; control) and performance moment as a within-subjects factor (before the intervention in the training phase; after the intervention in the training phase; one-week later test) were conducted on mean diagnostic accuracy scores and diagnostic performance scores for training and near-transfer cases. Two one-way ANOVAs with group as a between-subjects factor were performed on mean diagnostic accuracy scores and on mean diagnostic performance scores on far-transfer cases. Significance level was set at 0.05 for all comparisons.

Results

Table 1 presents mean diagnostic accuracy scores and Table 2 mean diagnostic performance scores on training and on near-transfer cases as a function of performance moment for each group. Two separate one-way ANOVA on the mean diagnostic accuracy score and on the mean diagnostic performance score obtained before the intervention did not show significant differences between the groups (respectively, $F(2, 51) = 0.61$, $p = .546$; $F(2, 51) = 0.70$, $p = .507$), which shows that groups were comparable.

Table 1. Mean Diagnostic Accuracy Scores (*SD*) as a function of performance moment for each group on training cases and near transfer cases and p-value for score differences between performance moments for each group.

Group (N)	Before (Training cases)	After (Training cases)	One-week (Near transfer cases)	Before vs. After	Before vs. One-week	After vs. One-week
Group1 (19) Resident SE with prompt group	73.03 (17.31)	83.55 (11.07)	82.24 (16.31)	.016	.035	.716
Group 2 (18) Resident SE without prompt group	69.44 (17.79)	84.72 (8.08)	83.33 (11.34)	.002	.004	.607
Control (17)	66.18 (20.62)	67.65 (20.76)	77.21 (16.08)	.431	.001	.003

Significance level $p = 0.017$

For the mean diagnostic accuracy score, the repeated-measures ANOVA revealed a significant main effect of performance moment ($F(2, 102) = 18.26$, $p < .001$). The main effect of group was not significant although borderline ($F(2, 51) = 2.61$, $p = .083$). There was a significant interaction effect ($F(4, 102) = 2.58$, $p <= .042$). To better understand these primary findings, *post hoc* analyses were conducted using paired *t*-tests within each group and each performance moment. The results are presented in the right section of Table 1. Bonferonni corrections were used (α = .017). In both Group 1 and 2 students' diagnostic accuracy scores improved significantly and immediately after listening to the example and were maintained one week later. For students in the control group, the improvement was also significant but delayed one week later.

Table 2. Mean Diagnostic Performance Scores (*SD*) as a function of performance moment for each group on training cases and near transfer cases and p-value for score differences between performance moments for each group.

Group (N)	Before (Training cases)	After (Training cases)	One-week (Near transfer cases)	Before vs. After	Before vs. One-week	After vs. One-week
Group1 (19) Resident SE with prompt group	57.24 (10.47)	67.76 (7.96)	69.74 (7.46)	.001	<001	.243
Group 2 (18) Resident SE without prompt group	56.48 (12.80)	67.13 (8.68)	67.13 (8.44)	<.001	.004	1.000
Control (17)	52.70 (13.58)	55.64 (12.92)	63.97 (11.87)	.138	.001	.009

Significance level $p = 0.017$

For the mean diagnostic performance scores, the repeated-measures ANOVA revealed a significant main effect of performance moment ($F(1, 102) = 32.44$, $p < .001$). The main effect of group was significant ($F(2, 51) = 3.76$, $p = .030$). There was no significant interaction effect ($F(4, 102) = 1.99$, $p = .102$). *Post hoc* analyses revealed that Group 1 performed significantly better than the control group ($p = .037$), without other significant differences between the groups (Group 1 vs. Group 2: $p = 1.00$; Group 2 vs. control: $p = .120$). *Post hoc* analyses using paired *t*-tests were conducted within each group and results are presented in the right section of Table 2. Students in both Groups 1 and 2 improved significantly and immediately; their diagnostic performance scores then remained stable one week later. For students in the control group, no improvement was noted immediately but a significant increase of the score appeared one week later. Table 3 presents mean diagnostic accuracy scores and mean diagnostic performance scores on transfer cases one week later for each group.

Table 3. Mean Diagnostic Accuracy Scores (*SD*) and Diagnostic Performance Scores (*SD*) as for each group on Transfer cases one week later

Group (N)	Mean Diagnostic Accuracy Scores	Mean Diagnostic Performance Scores
Group1 (19) Resident SE with prompt group	68.42 (18.80)	66.89 (8.94)
Group 2 (18) Resident SE without prompt group	53.47 (18.59)	55.56 (13.63)
Control (17)	47.06 (25.21)	49.02 (13.22)

A one-way ANOVA on mean diagnostic accuracy scores revealed a significant difference between the groups; $F(2, 51) = 4.98$, $p = .011$). *Post hoc* analysis revealed that Group 1 performed significantly better compared to the control group ($p = .011$). No other significant difference was noted between the groups (Group 1 vs. Group 2 $p = .104$; Group 2 vs. control $p = 1$). A separate one-way ANOVA on mean diagnostic performance scores also revealed a significant difference between the groups on transfer cases ($F(2,51) = 10.22$, $p < .001$). *Post hoc* analysis revealed that Group 1 performed significantly better than the control group ($p < .001$); there was also a significant difference between Group 1 vs. 2. ($p = .018$) but no difference between Group 2 vs. the control group ($p = .344$).

Discussion

This experimental study with SE by medical clerks explored the added value of listening to a resident SE example with or without prompts.

The results first demonstrate that all groups, including the control group with SE alone, improved significantly on both diagnostic accuracy and diagnostic performance scores on near-transfer cases. This supports the growing evidence that this technique, even without external feedback, is effective for learning clinical reasoning at clerkship level.[5] Second, observing resident SE example and being prompted while doing so improved students' diagnostic performance score on near-transfer cases one week later compared to the control group. Third, for performance on far-transfer cases, which reflects deep and meaningful learning,[22] the impact gets even stronger. Indeed, Group 1 with the combined intervention, performed significantly better on both scores compared to the control group. Moreover, for the diagnostic performance score, Group 1 was significantly better than the two other groups.

These results reinforce the importance of the chosen level of expertise of examples[16] relative to the learners. In a previous study, listening to peer or expert SE examples of clinical reasoning had not produced performance improvements to the same extent.[20] Junior residents represent near-peers for medical clerks. Their clinical reasoning is close to, or cognitively congruent with, the students' own so that they can easily relate to it and appreciate similarities and differences.[8,18] At the same time, the residents' more developed reasoning acts as a source of new information to learn from. At the end of the session, the research assistant asked verbally to the students open-ended questions on their perceived learning experience with the techniques used in the session. Their role in learning was highly appreciated by students in this study. Students reported that listening to residents' examples helped them further elaborate on their own ideas. They also reported that it helped them confirm their reasoning and complete their final diagnostic opinion and argumentation with some ideas that they had not raised by themselves.

Furthermore, students must be engaged cognitively to gain from working with even the best suitable example. In our study, students' SE was used as a preparatory task, designed to make the students cognitively ready for the example that followed. The incorporation of only three general prompts to each of the four resident's examples interestingly had an additional impact. Justification and mental model revision prompts presumably engaged students in additional SE, while listening to the example, thereby supporting deep processing of the residents' examples. This finding further reinforces the importance of stimulating students to reactivate underlying pathophysiological mechanisms when trying to make sense of the information while solving unfamiliar cases.[12,23] The significant difference observed between Groups 1 and 2 on diagnostic performance score on far-transfer cases further emphasizes the important role played by prompts.

Interestingly, the dynamics of improvement on near-transfer cases in the control group with SE alone and in the two other groups exposed to examples were different. For the latter two groups, the improvement was immediate and maintained over time whereas for SE alone, it took one week to appreciate the full impact, suggesting again deeper data processing in the course of a week. Other studies have shown this delayed effect of SE or structured reflection on medical students' diagnostic reasoning.[20,21] Listening to models seemed to accelerate the effect albeit with a ceiling on further improvement. However the scores obtained after the intervention in the training phase were very high, which left no floor for extra gain. Perhaps an additional improvement after one week could be observed if students work with more difficult cases in the training phase.

This study has limitations. Since it was conducted under well-controlled conditions, generalisation to real and busy clinical training environments may be restricted. Participants were third-year medical students, and the same results may not apply to learners at other levels of training.

This study has implications for practice. SE is an easy, inexpensive and effective way to ensure students' cognitive engagement while solving cases in clerkship. Moreover, SE seems to be a useful technique to make reasoning explicit and available for learning by colleagues, especially near peers. Natural examples of clinical reasoning, although not didactically designed, are useful and could be available in the clinical learning environment without too much preparation, even without the intervention of clinical teachers. Students' exposure to adapted examples of clinical reasoning is important, but being an "active processor" of these examples seems critical. Prompts used in this study were general and could be applied to any clinical problem.

Future studies could aim at transposing these ideas to concrete activities with real clinical situations. Exploring the impact of similar techniques with other tandems of near peers such as senior residents and clinical teachers would also deserve further investigation.

References

1 Norman G. Research in clinical reasoning: past history and current trends. Med Educ 2005;39(4):418-427.

2 Schmidt HG, Rikers RMJP. How expertise develops in medicine: knowledge encapsulation and illness script formation. Med Educ 2007;41(12):1133-1139.

3 Eva KW. What every teacher needs to know about clinical reasoning. Med Educ 2005;39(1):98-106.

4 Kassirer JP. Teaching clinical reasoning: case-based and coached. Acad Med 2010 2010;85(7):1118-1124.

5 Chamberland M, St-Onge C, Setrakian J, Lanthier L, Bergeron L, Bourget A, et al. The influence of medical students' self-explanations on diagnostic performance. Med Educ 2011;45(7):688-695.

6 Ajjawi R, Higgs J. Learning to reason: A journey of professional socialisation. Adv Health Sci Educ 2008 May;13(2):133-150.

7 van de Wiel, Margje WJ, Van den Bossche P, Janssen S, Jossberger H. Exploring deliberate practice in medicine: how do physicians learn in the workplace? Adv Health Sci Educ 2011;16(1):81-95.

8 Sternszus R, Cruess S, Cruess R, Young M, Steinert Y. Residents as role models: impact on undergraduate trainees. Acad Med 2012;87(9):1282-1287.

9 Chi MTH. Self-explaining expository texts: the dual processes of generating inferences and repairing mental models. In: Glaser R, editor. Advances in instructional psychology. Mahwah (NJ): Lawrence Erlbaum Associates; 2000; 161-238.

10 Roy M, Chi MTH. The self-explanation principle in multimedia learning. In: Mayer RE, editor. Cambridge handbook of multimedia learning New York, NY: Cambridge University Press; 2005; 271-286.

11 Dunlosky J, Rawson KA, Marsh EJ, Nathan MJ, Willingham DT. Improving Students' Learning With Effective Learning Techniques Promising Directions From Cognitive and Educational Psychology. Psychol Sci in the Public Interest 2013;14(1):4-58.

12 Chamberland M, Mamede S, St-Onge C, Rivard M, Setrakian J, Lévesque A, et al. Students' self-explanations while solving unfamiliar cases: the role of biomedical knowledge. Med Educ 2013;47(11):1109-1116.

13 Woods NN, Brooks LR, Norman GR. The role of biomedical knowledge in diagnosis of difficult clinical cases. Adv in Health Sci Educ 2007;12(4):417-426.

14 Schworm S, Renkl A. Learing Argumentation Skills Through the Use of Prompts for Self-Explaining Examples. Educ Psychol 2007;99(2):285-296.

15 Nokes TJ, Hausmann RG, VanLehn K, Gershman S. Testing the instructional fit hypothesis: the case of self-explanation prompts. Instruc Sci 2011;39(5):645-666.

16 van Gog T, Rummel N. Example-Based Learning: Integrating Cognitive and Social-Cognitive Research Perspectives. Educ Psychol Rev 2010;22:155-174.

17 Rosen MA, Salas E, Pavlas D, Jensen R, Fu D, Lampton D. Demonstration-based training: a review of instructional features. Human Factors: Hum Fac Erg Soc 2010;52(5):596-609.

18 Lockspeiser TM, O'Sullivan P, Teherani A, Muller J. Understanding the experience of being taught by peers: the value of social and cognitive congruence. Adv Health Sci Educ 2008;13(3):361-372.

19 Ten Cate O, Durning S. Peer teaching in medical education: twelve reasons to move from theory to practice. Med Teach 2007 Sep;29(6):591-599.

20 Chamberland M, Mamede S, St-Onge C, Setrakian J, Schmidt H. Is there an added value of observing examples of self-explanation on medical students' diagnostic performance? submitted.

21 Mamede S, van Gog T, Moura AS, de Faria R, Peixoto JM, Rikers RM, et al. Reflection as a strategy to foster medical students' acquisition of diagnostic competence. Med Educ 2012;46(5):464-472.

22 Mayer RE. Applying the science of learning to medical education. Med Educ 2010;44(6):543-549.

23 Woods NN. Science is fundamental: the role of biomedical knowledge in clinical reasoning. Med Educ 2007;41(12):1173-1177.

Appendix 1. Clinical cases used in the study

Broad categories of diseases	Specific diagnosis		
	Training cases	Near-transfer cases	Far-transfer cases
1-Acute hepatitis	Viral Hepatitis B	Viral Hepatitis B	Viral Hepatitis A
2-Cirrhosis	Chronic alcoholism	Chronic alcoholism	Hemochromatosis
3-Obstructive jaundice	Pancreatic tumor	Pancreatic tumor	Choledocholithiasis
4-Hemolysis	Auto-immune, idiopathic	Auto-immune, idiopathic	Cold agglutinins, Mycoplasma infection

Appendix 2. Types of prompts used in the study

Justification prompts :

1. What principle is being applied here?
2. Do you agree with this interpretation? Explain
3. How do you justify this interpretation?
4. On what pathophysiological mechanisms, does this interpretation is based?

Mental-model revision prompts :

1. How does this reasoning relate to yours?
2. How does this interpretation compare to what you already know?
3. How does this analysis help you gain more insight on how to solve the problem?
4. What new information does this provide for you?

Chapter 6

Summary of main findings, implications for medical education and directions for further research

This thesis explored the use of self-explanation by medical students as a tool supporting the learning of clinical reasoning in the clerkship. Chapter 1 presented the conceptual frameworks of medical expertise development and self-explanation which guided this research. The relevance of transposing the latter learning strategy for clinical reasoning, as well as exploring conditions to optimize its effect was also discussed in this first part of the thesis. Then, each of the next four chapters adressed one research question and described in details the related study that was designed and completed to provide plausible responses. The four research questions were the followings : (1) Is self-explanation effective for fostering learning of clinical reasoning in the clerkship? (2) What is the role of biomedical knowledge in learning clinical reasoning through self-explanation? (3) Is there an added value for learning of being exposed to self-explanation examples of clinical reasoning? (4) What conditions could optimize the impact of SE examples on learning clinical reasoning? The present and final chapter summarizes the main research findings, discusses implications for medical education and suggests issues for further research.

Summary of the main findings

First Study

Is self-explanation effective for fostering learning of clinical reasoning in the clerkship?

Clinical reasoning is at the heart of medicine and developing students' clinical reasoning abilities appears as a central goal in medical curricula. Researchers on medical expertise has successfully explored and identified multiple facets of clinical reasoning, but they all agree on the centrality of knowledge. Experts' knowledge base, which is extensive and well organized, is at the core of clinical reasoning.[1-4] According to the most prevalent theory of medical expertise,[1] medical students turn into experts by going through transitory stages, each stage characterized by a different way in which knowledge is structured, kept in memory and used to solve clinical problems. The first stage is characterised by elaborate causal networks that explain causes and consequences of diseases in terms of underlying pathophysiological processes. In the second stage, biomedical knowledge becomes compiled into a limited number of summarizing concepts through knowledge encapsulation. The emergence of illness scripts is the hallmark of the third stage. Illness scripts are cognitive structures representing diseases containing a large amount of clinically relevant information such as enabling conditions, the fault or malfunction and its consequences in terms of symptoms and signs.[1] Encapsulated biomedical knowledge provides coherence of the scripts by allowing expectations on acceptable and physiologically plausible values of its attributes and by explaining the relationships between them.[1,2] Exposure to clinical problems leads to activation of relevant illness scripts and instantiation, which means that the characteristics of the patient are included in the script and encoded as a practical example of the disease. Repetition of this process leads to the fourth stage of the development in which clinician's knowledge is now enriched by numerous instantiated scripts, which provide concrete examples of particular diseases available for future problem solving. So, in the course of their medical training, especially through repeated clinical exposure, students are expected to expand and reorganize their knowledge and to build up a large set of illness scripts, which gradually increase their ability to correctly diagnose patients. Clinical exposure during the clerkship gives students their first significant exposure to patients' problems as they occur in practice and, therefore, the opportunity to elaborate, construct and refine their illness scripts by using and integrating this experiential knowledge.[5] However, for students to learn from their clinical experience, they have to be actively engaged in the problem solving process and knowledge construction.[6,7] Still, educational methods with proven effectiveness to support the learning of clinical reasoning in practice remain scarce.[7] Designing educational methods that promote this effortful and deliberate learning from clinical examples during the clerkship is highly relevant.

Self-explanation is an instructional strategy coming from cognitive psychology and educational psychology, with proven effectiveness in other domains[8,9] that could be explored to support learning clinical reasoning by medical students in clerkship. Self-explanation (SE) is a learning technique wherein learners generate for themselves explanations about pieces of information in a text to be learned or a problem to be solved.[8,10] As a result of knowledge elaboration, organisation, integration and monitoring, SE supports knowledge restructuring, allowing the learner to revise and build a more coherent and integrated knowledge representation that facilitates transfer of learning. Since SE is known to support knowledge construction and revision of mental representations,[8] it is reasonable to think that, when transposed to clinical problem solving, this method could help students develop their clinical reasoning. Even though the positive effects of SE on learning have been shown in a variety of domains[8,10] at least experimentally, there is hardly any research on diagnostic problem-solving and SE and none in medicine, SE literature provides some suggestions on conditions that could increase its positive effect on learning. The benefit of SE seems more important when the problem at hand is complex, and its effect seems more apparent on far transfer tasks, that is when the application task is different than the learning task.[8] Also, verbalization of self-explanation out loud appears important to produce the full self-explanation effect.[9] We explored these ideas in the first study detailed in Chapter 2.

The purpose of the first study was to assess the benefit of using SE while diagnosing clinical cases, on subsequent diagnostic performance of medical students. Also, since SE seems more effective on complex learning materials, this study also investigated if the effect of using SE would differ according to students' level of familiarity with the clinical topics. To our knowledge, this is the first study to explore the benefit of SE in medical education and hence on learning clinical reasoning.

We conducted an experimental study comprising a training phase and an assessment phase, which took place one week later. In the training phase, 36 third-year medical students were randomly assigned to one of two groups: diagnosing using SE or not. Students were met individually and diagnosed 12 clinical cases (4 cases in a less familiar topic, 4 in a more familiar topic, and 4 fillers), either generating self-explanations (n=18) or without self-explanation (n = 18). Students' familiarity with a specific clinical topic was determined by prior exposure to clinical problems related to that topic during the first three years of their undergraduate program. The self-explanations were generated after minimal instructions consisting of a definition of SE with a brief description and an illustration with a 7 –minute audio recording of SE used with an unrelated clinical case. Time was strictly controlled insuring equate time on task. No feedback on the quality or the content of SE was provided to students. One week later, in the assessment phase, all students were requested to diagnose in silence 12 different, more difficult cases, similarly distributed among the same more familiar topic, less familiar topic, and fillers. Each time students had to solve cases, their diagnostic performance on each case was assessed using three open-ended questions asking for 1) their final diagnosis, 2) the two main arguments supporting their diagnosis and 3) two plausible alternative diagnoses. According to a correction grid, each answer was scored as 0, if it was incorrect, 1, if partially correct, and 2, if entirely correct. Two scores were derived from participants' answers: the diagnostic accuracy score (the score on question Q1) and the diagnostic performance score (the sum of scores on questions Q1, Q2 and Q3).

The results showed that the main effect of SE on both scores was not significant. However, the main effect of topic familiarity was significant (Dx accuracy: $F[1,34] = 24.73$, $P < 0.05$; Dx performance: ($F[1, 34] = 46.94$, $p < 0.05$), indicating that less familiar cases were, as expected, more challenging for students than familiar cases. More importantly, for both scores, a significant interaction effect was observed (Dx accuracy: $F[1,34] = 6.18$, $P < 0.05$;Dx performance: ($F[1, 34] = 8.53$, $p < 0.05$)). Post-hoc analysis revealed that, for less familiar cases, the SE group performed borderline significantly better on diagnostic accuracy score ($t[34] = 1.878$, $p = 0.069$) and significantly better on diagnostic performance score ($t[34] = 2.181$, $p = 0.036$) compared to the group who did not self-explained. However, no difference between the two groups on either score was observed for the familiar cases.

The results of this first study showed the benefit for medical students of using SE with clinical cases of less familiar topics but not for familiar ones. This benefit was observable one week after the intervention and on transfer tasks using different and more difficult cases, which reflects meaningful learning. Since the effect of SE presumably occurs through knowledge revision and restructuration, we may assume that, when transposed to clinical reasoning, students' SE may facilitate the construction of more coherent mental representations of the diseases, possibly fostering the development of more well-organized and richer illness scripts. This positive effect of SE is likely to be more substantial when students are dealing with clinical problems in a less familiar area, for which their illness scripts may be less developed and therefore more subject to major revision. Working with more challenging cases, may also compel students to engage in more knowledge elaboration. Since biomedical knowledge gives the internal coherence of illness scripts, to what extent could this type of knowledge play a role when learning through self-explanation for students at clerkship level? This was the subject of our second study.

Second study

What is the role of biomedical knowledge in learning clinical reasoning through self-explanation?

The second study, reported in Chapter 3, explored this question by looking at the content of self-explanation protocols produced by medical students during the first study. Students' verbal protocols generated while self-explaining represent a window into the cognitive processes in which they engage while learning thus their analysis could provide some insight into the underlying mechanisms of SE when applied to clinical reasoning. In this second study, we investigated the types of knowledge used by students when self-explaining familiar and less familiar clinical cases, and in particular the role of biomedical knowledge. The content of SE protocols generated by 7 randomly selected students while solving four familiar and four less familiar cases were compared using a coding scheme from the SE literature[8,11] adapted to medical knowledge. In total fifty-six verbal protocols (28 familiar and 28 less familiar) were segmented and coded using the following categories: paraphrases, biomedical inferences, clinical inferences, monitoring statements, and errors. Paraphrases are statements in which students only reiterate the text in their own words without adding new information. In contrast, inferences entail that students elaborate on, draw a conclusion or add information beyond what is said explicitly in the text. Biomedical knowledge refers mainly to underlying pathophysiological mechanisms whereas clinical knowledge points to attributes of people and their diseases, to signs and symptoms, and to relevant laboratory investigation.

The results showed that students provided overall more self-explanation segments when dealing with less familiar cases (M = 275.29) compared to familiar ones (M = 248.71, p = .046). There was no significant difference in the total number of inferences ($t(6) = 0.49$, p = .641). However, a significant interaction was found between familiarity and the type of inferences (biomedical vs. clinical) ($F[1,6] = 11.03$, $P < 0.016$). When self-explaining less familiar cases, students provided significantly more biomedical inferences than familiar cases.

These data suggest that unfamiliarity acts as a trigger for students to engage in more active thinking; the greater diagnostic challenge encourages them to generate more self-explanations, and eventually leads to better learning. This is in line with previous studies showing that the benefit of self-explanation increases when the problem at hand is complex.[8,12] This is also in agreement with other studies showing a positive relationship between learning and the number of self-explanations.[8] Even more interesting is the potential contribution of biomedical knowledge to the benefit of SE. Studies looking at the benefits of integrating relevant biomedical knowledge in the process of learning clinical reasoning in novice diagnosticians, suggest that it may help students construct more coherent mental representations of diseases, increasing retention in the longer term, and helping them to diagnose difficult cases.[4,13,14] Similarly, self-explanation when used while solving less familiar cases seem to activate students' biomedical knowledge, which could in turn help them create new links between biomedical and clinical knowledge, and eventually construct a more coherent illness scripts or representation of a disease.

Students' level of familiarity with clinical cases may be an important issue to be considered for designing appropriate clinical cases to be used with SE for learning clinical reasoning. It is reasonable to suggest that cases should be challenging enough to force students to revisit underlying basic biomedical knowledge while solving them.

Third study

Is there an added value for learning of being exposed to self-explanation examples of clinical reasoning?

Clinical reasoning is a complex and ill structured skill. There are numerous possible ways of solving problem. In such situations, learners can become easily overloaded cognitively. Would listening to a colleague' self-explanation example dealing with the same clinical problem provide some additional guidance to students? Self-explanation has been used with worked-out examples, which are examples providing the solution steps of the problem. Example-based learning (EBL) refers to this process of learning by studying examples or observing models performing a skill, including a cognitive skill.[15] However, learning from examples is effective only if learners explain the rationale underlying the presented solution to themselves, that is when they self-explain.[16] On the other hand, learning complex cognitive tasks through observation of models requires the latter to externalize their cognitive processes and the knowledge activated while performing the skill. Hence, Self-explanation might be useful for models to make explicit their ongoing clinical reasoning process and relevant knowledge representations. Another issue that appears particularly relevant to consider and to explore is the difference in the level of expertise between the model, or the example, and the observer or the student. Despite its limited knowledge, a peer model has the theoretical advantage of being cognitively closer to the student so that he or she may relate to it more easily. In contrast, even though naturally performing experts have extensive knowledge, from which students could benefit, they have largely automatized their task, and work at higher levels of abstraction.[15]

Self-explanation and example-based learning appear to represent two complementary instructional methods that could be used together to support knowledge construction and revision of mental representations of diseases. Moreover, these two instructional methods could easily build on learning opportunities already available in clinical training settings where students are asked to apply clinical reasoning to patients problems and are also exposed to examples of clinical reasoning from a variety of colleagues.

The third study, reported in Chapter 4, was designed to investigate the added value of combining students' SE and listening of an audio-recorded peer or expert SE example on students' diagnostic reasoning.

In a two-phase experimental study, 53 third-year medical students were randomly assigned, in the learning phase, either to peer SE, expert SE or control group. In the training phase, all participants diagnosed a set of four clinical cases (training cases) after self-explanation, and again after either listening to a peer SE example, listening to an expert SE example or doing crosswords as a control task. Time was strictly controlled. In the assessment phase, one week later, participants from all groups diagnosed again the same four training cases and a new set of four different cases of different diseases (transfer cases). Building on findings from the first study, all cases used in this study were of a less familiar clinical topic. To assess students' diagnostic performance on each case and in each phase, we used the assessment strategy previously described in the first study, and computed diagnostic accuracy and diagnostic performance scores.

On training cases, although the main effect of group was not significant for both diagnostic accuracy and diagnostic performance scores, differences in the magnitude of improvement suggest that there is some added value in being exposed to SE examples. Combined intervention led to significantly better diagnostic accuracy and diagnostic performance scores overtime (peer SE $p = .007$, expert SE $p<.001$) whereas SE alone resulted in borderline improvement (control $p=.022$). However, the type of SE examples (peer or expert) did not make any difference on students' diagnostic reasoning. Peer SE examples were as effective as expert SE examples. On transfer cases one week later, there was no difference in diagnostic accuracy scores ($p = .060$) and in diagnostic performance scores ($p = .940$) between the three groups.

These results suggest that there is an added-value of combining students' SE with listening to a peer or expert SE example but that this benefit is subtle, probably occulted by the concomitant effect of students' SE and only seen when assessed on the same cases. This benefit does not translate when performance is assessed using different cases one week later, suggesting that students did not engage that much in additional deep processing when listening to the example.

Why SE models did not add much to students' SE on clinical reasoning? Partial explanation may lie in the level of expertise of the SE examples used in the study. Peers SE included irrelevant details and even uncorrected errors. Participants or observers were as novice as the one in the example and may have had little to learn from it. On the other end of the spectrum, experts behaving naturally may not be the best examples for novices since they use fast, largely non-analytic reasoning, and tend to reason at a higher level of abstraction, making it be difficult for students to follow.[15,17] Another possible explanation for the limited impact of SE models might have been related to the degree of students' cognitive involvement while listening to the examples. In this study, participants were only informed that they would listen to an example of SE from someone else and that they would have to solve the problem again. They were not given specific tasks to ensure they would actively listen, even though their own SE was expected to prepare them to focus on the example that followed.

Fourth study

What conditions could optimize the impact of SE examples on learning clinical reasoning?

The results of the third study lead us to further explore some conditions that could enhance the benefit of combining students' SE and working with SE examples from colleagues.

Adding prompts while working with the example is a strategy that has been used to get the observer active, fostering additional SE, and consequently supporting learning.[12,16,18] Prompts are specific instructions or requests that stimulate learners to self-explain, and that require them to process the content of the material in a specific way that presumably supports the underlying mechanisms of SE.[16] Also, considering the relative level of expertise between the model and the student, examples of intermediate level, for instance junior residents, might represent an interesting compromise in terms of cognitive proximity and knowledge development. We explored these ideas in the fourth study presented in Chapter 5.

The purpose of the fourth study was to assess the impact on students' clinical reasoning of combining students' SE with listening of Residents' SE examples, with or without adding prompts while working with examples.

This study consisted of a training phase and an assessment phase that took place one week later. Participants were 54 medical students who were randomly assigned, in the training phase, to one of three groups. In the training phase, students had to solve four clinical cases using SE. Then, Group 1 had to listen to audio-recorded residents' SE examples with prompts, Group 2 had to listen to residents' SE examples without prompts while the control group did crosswords. All students then solved again the same four cases. Time was strictly controlled. In the assessment phase one week later, all students solved in silence four similar cases (near transfer cases) and four different cases (far transfer cases). As for the previous studies, student's diagnostic performance and diagnostic accuracy scores were assessed using open-ended questions for each case and on each moment. All cases were about the topic of jaundice, a less familiar topic for students. Compared to training cases, the similar or near transfer cases presented the same basic clinical elements and final diagnoses. Clinical scenarios were modified by changing only superficial data not relevant to diagnosis (e.g., sex, age, background information). In contrast, far transfer cases presented completely different clinical scenarios as well as final diagnoses and were also more difficult. Two types of prompts were incorporated into the residents' SE examples: the 'justification prompts' looking at the underlying pathophysiological mechanisms, and the 'mental-model revision prompts' inviting students to compare their knowledge representation to the one presented in the example.

The results showed that although all groups had significant improvement between the first performance moment and one week later on both scores on similar cases, Group 1 (resident SE + prompt) showed significantly better diagnostic performance score compared to control group ($p = .037$). On far transfer cases one week later, the impact gets even stronger. Group 1 (resident SE+ prompt) performed significantly better on both scores compared to the control group (diagnostic accuracy $p = .011$; diagnostic performance $p <.001$) and also significantly better on diagnostic performance score compared to Group 2 (resident SE –no prompt) ($p = .018$). Also worth mentioning is the different dynamics of improvement on similar cases in the control group (with SE alone) and in the two other groups exposed to examples. For these latter groups the improvement was immediate and maintained one week later whereas for SE alone, it took one week to appreciate its full impact suggesting again deep data processing. Similar results about the time pattern of improvement were also observed in the third study.

Again in this study, students' SE alone appears as an effective technique for learning clinical reasoning. Moreover, the impact is significantly increased when combined to residents' SE examples and prompts. This suggests that junior residents' examples represent for clerks relevant models of clinical reasoning to learn from when made explicit by SE. It also suggests that the use of prompts helps students being an "active processor" of these examples.

General discussion

The studies conducted for this thesis allowed us to provide plausible answers to each of the four research questions we have formulated. Self-explanation is an effective strategy for learning clinical reasoning at clerkship. Its benefit is apparent while working through less familiar cases and gets stronger on transfer cases. Unfamiliarity with cases appears to stimulate students to activate more biomedical knowledge while solving the case and this in turn may help creating more coherent representation of diseases. Listening to peer or experts SE examples, without further interaction, seems to have only little additional impact on students' diagnostic performance whereas listening to residents' SE examples combined with the use of prompts add significantly to the effectiveness of students' SE.

More than being just a simple successful transposition of the use of self-explanation to a new domain, that is medicine, we think that the reported studies and their results represent a rather unique contribution to the field of teaching and learning clinical reasoning in medical education for the following reasons. In the first chapter of this thesis, we discussed the importance for students to practice with clinical problems in order to develop progressively their medical knowledge and structures and consequently their clinical reasoning. We also mentioned the scarcity of proven effective instructional approaches to make them learn more from their exposure to patient problems. In this respect, our studies on self-explanation open a new line of research and provide potentially new practical ways to help students benefit from clinical problems they encounter in their training. Our research is the first one exploring self-explanation and clinical reasoning and showing its benefit. Our second study is also the first one to explore the types of knowledge activated by self-explanation and to document the potential role of biomedical knowledge in the self-explanation effect on clinical reasoning. In the third and fourth studies, the use of self-explanation as a strategy to transform an implicit complex cognitive task into an explicit example to be used for learning represent another original aspect of our research. The issue of which models are most effective for learning is still a matter of debate,[15] hence, our last two studies using models of three distinct levels of expertise add to our understanding of what could be an adapted model for learners. Also, prompts have not been studied extensively and our fourth study provides additional evidence of their usefulness as well as practical applications for learning clinical reasoning.

Implications for medical education

The results of our research have potentially important practical implications for medical education in relation to learning clinical reasoning by medical students in the clerkship.

First, self-explanation appears to be an effective and practical way to engage students in active and "deliberate" problem solving, which supports the learning of clinical reasoning from clinical cases. As shown in study 1,3 and 4, SE can be used after minimal instructions, is rather inexpensive and does not need sophisticated technology and could then be readily implemented. Students' SE impacts positively on diagnostic performance even without specific feedback and could even be used by students without the need for direct clinical teachers' supervision. Even though we used written clinical cases as learning materials in our studies, this technique could presumably apply to real clinical case narratives or descriptions used in real practice. Self-explanation could be presented to medical clerks as an individual learning tool to be used after a patient encounter to deepen their understanding of the clinical problem. It could also be used informally in dyad or in small group, as in a teaching unit, where students have to report the medical history of a patient they just evaluated. Asking another student to self-explain the case could represent an alternative to the traditional case discussion. Otherwise, self-explanation could be incorporated as a specific effective ingredient in more formal learning sessions as a complement to clinical exposure. However, as shown in our first study, SE is not a panacea and its positive impact on learning depends on the level of student's familiarity with the clinical topic. Hence, if students decide to invest time in self-explaining with patients' problem in the clinical settings, they should select challenging cases for which there is room for illness scripts enrichment and prior knowledge revision. Similarly, if SE is used in more formal learning sessions, the level of students' familiarity with the topic is important to consider in the design of appropriate clinical cases.

Second, the results of study 2 and 4 add to the important role of biomedical knowledge while learning clinical reasoning with cases, at least for novice diagnosticians such as medical students at clerkship level. Biomedical knowledge provides internal coherence of illness scripts and allows progressive construction and enrichment of knowledge useable for future application. When self-explaining, it appears crucial to support students activating relevant biomedical knowledge when needed and linking it with prior clinical knowledge or new information provided by the case. As discussed in study 2, students' unfamiliarity with the clinical case seems to lead "spontaneously" to activation of biomedical knowledge. Otherwise, in study 4, students were explicitly asked to go back to relevant pathophysiological mechanisms using justification prompts when listening to SE examples. In light of these findings, it would seem appropriate to include in students' SE training sessions or materials for clinical reasoning, specific instructions that reinforce the relevance of activation of prior biomedical knowledge when needed, that is either to resolve unclear or difficult issues in the case or to test the coherence of their explanations.

Third, results of studies 3 and 4 on the use of SE examples provide potentially interesting information on conditions to optimise learning from "natural" examples or models of clinical reasoning available in the clinical settings. We deliberately choose to use non-didactically designed examples of clinical reasoning to be able to transpose more easily the results of the studies to the clinical settings relevant to the clerkship. While recent studies suggest an important role of observing colleagues for the development of clinical reasoning in workplace,[19,20] little is known on how to maximise learning from these models. Building on SE and example-based learning frameworks, we have explored different issues: the use of SE to make clinical reasoning, an ill-defined cognitive task, "visible" and accessible to others for learning; the use of SE examples of different levels of expertise (peer, resident, expert clinician); the use of students' cognitive activities either before listening to the SE examples (student'SE) or concurrently with the use of prompts. Our research findings have the following practical implications. Firstly, self-explanation seems to be a practical alternative to explicit ongoing clinical reasoning for others and has the potential to be also beneficial for the self-explainers themselves. Secondly, peer or even expert SE examples does not appear to lead to meaningful learning if students just listen to them. Even though this is a negative finding, and that might seem provocative at first sight, it has potentially important implications since medical students in the clerkship spend significant amount of time passively listening to implicit clinical reasoning of colleagues. We should find better ways to seize learning opportunities from observing others. Thirdly, results of the study 4 suggest that residents' examples of clinical reasoning made explicit by SE may represent better-adapted examples for students. This finding is interesting since, despite the high interest in medical education for the role of residents as teachers, the contribution of residents as cognitive models for students' clinical reasoning development has not been specifically explored so far.

Students working with residents should be encouraged to see them also as cognitive models for clinical reasoning. Fourthly, to maximise learning from SE examples, students have to get engaged cognitively for instance by self-explaining the case before, and actively process the examples and the use of prompts seems to support this additional deep processing. In our studies, we used two types of general or content-free prompts, justification and mental –model revision prompts, which may apply to any clinical problem. Justification prompts again invite students to reactivate biomedical knowledge whereas mental-model revision prompts force them to compare and contrast their representation made explicit by prior self-explanation with the one presented. Training students to use content-free prompts on their own may be an interesting avenue to make them active listeners.

Finally, It is worth discussing one aspect of the method used in our studies to assess students' clinical diagnostic performance, that is the use of two different scores; the diagnostic accuracy score and the diagnostic performance score. Initially, we were not sure about the relevance of having both scores instead of just the diagnostic accuracy score. However, since our participants were novice diagnosticians, we felt that maybe the final diagnostic label only would not capture enough the improvement in students' diagnostic reasoning. Indeed, in the three studies in which the two scores were used; the diagnostic performance score appeared to be more sensitive to detect students' improvement. This may suggest that to better appreciate the clinical reasoning of the students, we should ask them not only to provide their final diagnosis, but also to discuss supportive arguments and plausible alternatives. In a busy clinic, these three simple questions could be easily included systematically in cases discussions.

Limitations of the studies

These studies have nevertheless limitations. We conducted all the research with only one level of learners, that is third-year medical clerks, and our results might not apply to other learners. Also, medical students involved in our studies came from a problem-based learning undergraduate curriculum in which learners are expected to practice knowledge elaboration in tutorials and are asked to explicit their ideas. This might partly explain why SE was easy to learn and use by these students and this may not be the case with students in traditional or less learner-centered educational contexts. Although the task (clinical reasoning) and the material used (clinical cases), were closely related to the educational context of medical clerks, the controlled conditions of our experiments may nevertheless limit somehow generalisation of the findings to busy clinical settings.

Based on our conceptual framework, we hypothesized that SE and EBL would support knowledge restructuring and revision of mental representation of diseases on which students would base their subsequent clinical reasoning. For practical reasons, and similarly to many research on clinical reasoning, we substituted direct observation of knowledge restructuring with outcome measures of diagnostic performance. Strictly speaking, changes of knowledge structures were not scrutinized but inferred from improved diagnostic performance.

In our studies 3 and 4 on SE examples, the experimental conditions did not allow the students to exchange or discuss with the colleague, either a peer, an expert, or a resident, providing the example. Hence, our results cannot be directly transposed into clinical contexts where these interactions occur.

Directions for further research

Self-explanation is a learning technique that allows students to engage actively in clinical reasoning while working with clinical cases. Our studies are the first to explore SE in medicine. In this respect, even though this thesis provides some answers on its optimal use by students in the clerkship, it also raises many questions and unsolved issues for future research.

A first issue requiring further investigation refers to implementation of self-explanation into practical activities in clinical training. Even though we have already discussed some general practical implications of our findings, further research is needed on the development and implementation of concrete learning activities that incorporate SE and SE examples in clinical training, in particular in the clerkship. In designing or planning these activities we have to take advantage of already available resources for instance the real patients cases and the colleagues of different levels, but also take into consideration the various constraints of the clinical settings in particular time constraint, types of patients, and real clinical exposure of clerks. To better assess the impact of these activities, further investigation should not only look at students' diagnostic performance but also better explore their appreciation of these techniques on learning.

A second line of research emerges from our studies and refers to the investigation of conditions that maximise SE benefits on learning clinical reasoning. First, the type of learning materials used with SE for clinical reasoning deserves more studies. In this thesis, we used paper clinical cases as learning materials and it would be relevant to examine if other types of learning material closer to real patients problems would be appropriate or even more effective for learning clinical reasoning in practice. Learning materials could include for instance students' reports of real clinical cases, standardized patients, virtual cases, or real patients. Second, the question of the number and variety of cases necessary to impact on learning with SE needs to be further examined. The development of clinical reasoning in general needs repeated practice with a variety of cases. When SE is used for learning clinical reasoning on a specific topic, for instance jaundice, is there a minimum number of cases or a critical variety of cases referring to different but related pathophysiological mechanisms to which students should be exposed to maximise the benefits of the instructional approach? In our studies, students had to solve with self-explanation four different cases on the same clinical topic (e.g. jaundice) but each of them involving different broad categories of diseases and a variety of related underlying dysfunctions. Is this a mandatory condition to significantly impact on learning? Providing answers to these questions would have implications for designing and implementing SE in the clerkship. Third, the addition of direct or delayed content-related and corrective feedback after SE and its impact on learning has not been fully investigated. In fact, specific content feedback is rarely given during the task so that this technique may not require in general direct teacher intervention. Specific feedback is however recognized as a powerful teaching tool in general but how its combination with self-explanation would modify the impact on learning? Limited data suggest that the effect of self-explanation might decrease when students can access explanations during the task. Providing explanations too soon may presumably lead to decrease students' deliberate engagement in finding their own answers.[21] Further research could help clarify this issue.

A third question to be further explored refers to the effects of SE on knowledge structures used for clinical reasoning. Since clinical reasoning involves activation of specific knowledge structures, in particular illness scripts, and since SE is a knowledge building strategy, we hypothesised that students' improvement in diagnostic performance shown in our studies reflected enrichment and revision of knowledge relevant to the clinical problem but these changes were not directly examined. For students at clerkship level, activation of biomedical knowledge and possibly linking with clinical knowledge seems to mediate somehow the positive effect of SE on clinical reasoning. Does the role of biomedical knowledge differ according to students' level of training? Further studies are needed to better understand the impact of SE on specific knowledge structures as well as to shed more light on the mechanisms underlying the self-explanation effect on clinical reasoning. This would inform on effective strategies maximizing its benefit.

Finally, this thesis just began to explore the use self-explanation examples for learning clinical reasoning by students and this clearly opens a new line of investigation looking at the optimal conditions to learn from naturally occurring examples in clinical settings. Our results suggest that cognitive proximity between SE examples of clinical reasoning (e.g. residents) and learners (e.g. medical clerks), when combined with prompts positively influence learning. In clinical training, other tandems of such near-peers exist for instance junior-senior residents and senior residents-expert clinicians. Would our findings also apply to them? Would students benefit from SE in refining and extending progressively their clinical reasoning along the continuum observing models of increasing expertise? These questions have important practical implications and deserve further investigations. The experimental method that we used in our studies on SE examples constrained the possible interactions that the learners could have with the models. However, in the clinical settings, students work with these colleagues and would have the opportunity to exchange and discuss with them. What kind of interactions would be most effective for learning by stimulating students to engage in active knowledge construction while providing just enough guidance? Answering these questions would help to seize and capitalize on learning opportunities available in clinical settings. Moreover, the positive impact of residents'

SE examples on students' learning also reinforce the importance of pursuing research on the specific contribution of residents' cognitive role model for clinical reasoning.

References

1 Schmidt HG, Rikers RMJP. How expertise develops in medicine: knowledge encapsulation and illness script formation. Med Educ 2007;41(12):1133-1139.

2 Charlin B, Boshuizen HP, Custers EJ, Feltovich PJ. Scripts and clinical reasoning. Med Educ 2007;41(12):1178-1184.

3 Bordage G. Prototypes and semantic qualifiers: from past to present. Med Educ 2007;41(12):1117-1121.

4 Woods NN. Science is fundamental: the role of biomedical knowledge in clinical reasoning. Med Educ. 2007;41(12):1173-1177.

5 Norman G. Building on experience--the development of clinical reasoning. N Engl J Med 2006;355(21):2251-2252.

6 Norman G. Research in clinical reasoning: past history and current trends. Med Educ 2005;39(4):418-427.

7 Kassirer JP. Teaching clinical reasoning: case-based and coached. Acad Med 2010 2010;85(7):1118-1124.

8 Chi MTH. Self-explaining expository texts: the dual processes of generating inferences and repairing mental models. In: Glaser R, editor. Advances in instructional psychology. Mahwah (NJ): Lawrence Erlbaum Associates; 2000; 161-238.

9 de Bruin ABH, Rikers RMJP, Schmidt HG. The effect of self-explanation and prediction on the development of principled understanding of chess in novices. Contemp Educ Psychol 2007;32(2):188-205.

10 Dunlosky J, Rawson KA, Marsh EJ, Nathan MJ, Willingham DT. Improving Students' Learning With Effective Learning Techniques: Promising Directions From Cognitive and Educational Psychology. Psychol Sci in the Public Interest 2013;14(1):4-58.

11 Roy M, Chi MT. The self-explanation principle in multimedia learning. The Cambridge handbook of multimedia learning. New York, NY: Cambridge University Press; 2005; 271-286.

12 Wong RMF, Lawson MJ, Keeves J. The effects of self-explanation training on students' problem solving in high-school mathematics. Learn Instru 2002;12:233-262.

13 Woods NN, Brooks LR, Norman GR. It all makes sense: biomedical knowledge, causal connections and memory in the novice diagnostician. Adv Health Sci Educ 2007;12(4):405-415.

14 Woods NN, Brooks LR, Norman GR. The role of biomedical knowledge in diagnosis of difficult clinical cases. Adv in Health Sci Educ 2007;12(4):417-426.

15 van Gog T, Rummel N. Example-Based Learning: Integrating Cognitive and Social-Cognitive Research Perspectives. Educ Psychol Rev 2010;22:155-174.

16 Schworm S, Renkl A. Learning argumentation skills through the use of prompts for self-explaining examples.J Educ Psychol 2007;99(2):285.

17 Rosen MA, Salas E, Pavlas D, Jensen R, Fu D, Lampton D. Demonstration-based training: a review of instructional features. Human Factors: Hum Fac Erg Soc 2010;52(5):596-609.

18 Chi MTH, de Leeuw N, Chiu M-, Lavancher C. Eliciting self-explanations improves understanding. Cognitive Sci 1994;18(3):439-477.

19 Ajjawi R, Higgs J. Learning to reason: A journey of professional socialisation. Adv Health Sci Educ 2008;13(2):133-150.

20 van de Wiel, Margje WJ, Van den Bossche P, Janssen S, Jossberger H. Exploring deliberate practice in medicine: how do physicians learn in the workplace? Adv Health Sci Educ 2011;16(1):81-95.

21 Schworm S, Renkl A. Computer-supported example-based learning: When instructional explanations reduce self-explanations. Comput Educ 2006;46(4):426-445.

Appendices

Appendix 1

Clinical cases used in the studies

Cases used in the training phase :

Jaundice cases : Study 1, Study 3, Study 4
Cardiac failure cases : Study 1
Filler cases : Study 1

Cases used in the assessment phase :

Jaundice cases :
Far transfer cases : Study 1, Study 3, Study 4
Near transfer cases : Study 4

Cardiac failure cases :
Far transfer cases : Study 1
Filler cases : Study 1, Study 3, Study 4

Cases used in the training phase

Jaundice cases

A 1 #1

Une patiente de 34 ans consulte pour ictère et nausée.

HMA : Depuis 2 semaines, la patiente présente des nausées persistantes sans vomissement associé. Depuis 3-4 jours, elle a noté que ses yeux sont jaunes et ses urines plus foncées. Elle se plaint de douleur épigastrique d'intensité légère, sans irradiation et de fatigue depuis la dernière semaine. Ses selles sont normales. Elle croit avoir fait de la fièvre avec frilosité à quelques reprises dans la dernière semaine. Elle se plaint d'arthralgies diffuses sans gonflement ni rougeur depuis 2 jours.

Antécédents : Cholécystectomie pour une cholécystite aigue il y a 2 ans;
Migraines pour lesquelles elle prend du Propranolol 160 mg die
Pas d'autres médicaments ni produits naturels. Pas de transfusions.

Habitudes de vie : Elle ne fume pas mais consomme occasionnellement de la marijuana et 5-6 bières la fin de semaine; n'a jamais utilisé de drogues intraveineuses. Caissière dans un supermarché. Séparée de son conjoint depuis 2 ans et a eu quelques partenaires depuis la dernière année. Elle porte 2 tatouages faits il y a une quinzaine d'années. Pas de voyage récent.

Examen physique : TA 100/60, le pouls 65 /min, température buccale est de 38,3,
On note un ictère des sclérotiques et de la peau. Les muqueuses sont sèches. Les aires ganglionnaires sont normales. L'examen cardio-pulmonaire est sans particularité. À l'examen de l'abdomen, le péristaltisme est normal, le foie est sensible à la palpation et percuté sur 14 cm en midclaviculaire. Il n'y a pas de splénomégalie ni masse palpable. Les membres inférieurs sont sans oedème et on remarque 2 tatouages à la jambe droite.

Bilan para clinique : La formule sanguine, les électrolytes et la créatinine et la glycémie sont normaux. L'albumine est à 31 (35-50 gr/L), AST à 430 (14-50 UI/L), ALT 650 (21-72 UI/L), phosphatase alcaline à 375 (43-200UI/L) GammaGT 102 (8-78 UI/L); bilirubine totale 58 (3,4-17 umol/L) bilirubine conjuguée à 36; INR et PTT normaux.

A 2 #1

Une femme de 62 ans est amenée par sa fille à l'urgence pour ictère et asthénie progressive.

HMA : Sa fille a remarqué chez sa mère une perte de capacité progressive depuis la dernière année et un teint jaunâtre depuis 3 semaines. Son appétit est moins bon depuis les derniers mois mais son poids est stable et elle n'a pas fait de fièvre. Elle ne se plaint pas de nausées, ni de vomissement et les selles sont normales. Elle a cependant noté une augmentation du volume abdominal avec léger inconfort et de l'oedème des membres inférieurs.

Antécédents : Obésité de longue date, diabète depuis l'âge de 40 ans, dyslipidémie; ulcère gastrique hémorragique en 1999. Médicaments : Glyburide 5 mg BID, Metformine 1000mg BID, Fenofibrate 160 mg die

Habitudes de vie : Agente d'immeuble à la retraite, elle a toujours consommé régulièrement de l'alcool. Depuis le décès de son mari il y a 4 ans, sa consommation aurait augmenté de façon significative. Elle fume 1 paquet de cigarettes par jour depuis la vingtaine, ne prend pas de drogues. Vit seule dans son appartement.

Examen physique : La patiente parait asthénique et plus âgée, TA 130/85, le pouls régulier à 90, la température buccale 36,4. Poids 95kg. Le teint est ictérique avec quelques ecchymoses aux membres supérieurs. On note quelques angiomes stellaires sur le thorax. Les veines jugulaires ne sont pas distendues et les aires ganglionnaires sont normales. L'auscultation pulmonaire est normale. L'abdomen est souple globuleux avec flancs bombants et probable matité déclive. Le foie semble de volume normal et la rate est palpable à 3 cm sous le rebord costal. On note un œdème à godet bilatéralement jusqu'aux genoux.

Bilan para clinique : formule sanguine : hémoglobine à 92 (130-180 gr/L), un VGM à 103 (80-100), des globules blancs à 5,2 (3,8-10,6) des plaquettes à 80 (130-400); les électrolytes , créatinine sont normaux; la glycémie à jeûn est à 7,2;(3,3-6,1) AST 255 (14-50 UI/L) , ALT 112 (21-72 UI/L), phosphatase alcaline 155 (43-200UI/L); bilirubine totale 75 (3,4-17 umol/L) conjuguée à 44; albumine à 23 (35-50 gr/L); INR à 1,4 (0,9-1,2); TTPa 36(23-32sec).

A3 #1

Un homme de 76 ans consulte pour ictère progressif

HMA : Le patient a noté une coloration jaune-verdâtre de sa peau d'apparition graduelle sur 3 semaines. Mis à part un malaise épigastrique vague en post prandial, il ne se plaint pas de douleur abdominale. Il a remarqué que ses urines étaient plus foncées et ses selles plus pâles sans diarrhée ni constipation associée. Son appétit semble diminué et dit avoir perdu possiblement 5 à 7 kg depuis le dernier mois. Il n'a pas noté de fièvre, pas de frissons ni sudations nocturnes. Pas de voyage ni de changements des habitudes alimentaires.

Antécédents : HTA systolique et diabète type 2 depuis 1 an. Diverticulite aigue en 2006. Thrombophlébite superficielle membre inférieur droit il y a 2 mois. Médicaments : Hydrochlorothiazide 12,5 mg die, Metformine 250 mg BID.

Habitudes de vie : Menuisier à la retraite, vit toujours dans sa maison, veuf depuis 3 ans. Il ne fume pas et ne prend pas d'alcool.

Examen physique : patient en bon état général, TA 145/75, pouls 75/min, Afébrile, poids 75kg. Ictère franc au niveau de la peau. Aires ganglionnaires libres d'adénopathies. L'examen du cœur et des poumons est normal. À l'examen de l'abdomen, il n'y a pas de zone douloureuse à la palpation. Le foie et la rate semblent de volume normal et il n'y a pas de masse palpable. Le toucher rectal est normal. Les membres inférieurs sont sans œdème.

Bilan para clinique : FSC : hémoglobine 125 (130-180) VGM 88 (80-100) GB 6,2 (3,8-10,6) plaquettes 350 (130-400); les électrolytes, la créatinine sont normaux; la glycémie à jeûn à 6,9 (3,3-6,1); AST 52 (14-50 UI/L) , ALT 75 (21-72 UI/L), phosphatase alcaline 625 (43-200 UI/L), bilirubine totale 110 (3,4-17 umol/L); conjuguée 100; albumine 33 (35-50gr/L); INR et TTPa normaux. À l'analyse, l'urine est brune, fortement positive pour la bilirubine et négative pour l'urobilinogène.

A 4 # 1

Un patient de 50 ans consulte pour ictère et fatigue

HMA : le patient se plaint de fatigue progressive depuis 2 mois et d'une coloration jaune de la peau depuis une semaine. Il n'a pas noté de douleur abdominale, son appétit et son poids sont stables. Il n'a pas de symptômes digestifs particuliers, ses selles et son urine sont de coloration normale. Il n'a pas présenté de fièvre, frisson ou sudations mais se plaint de dyspnée à l'effort depuis 2 semaines sans toux ni douleur thoracique.

Antécédents : appendicectomie en bas âge, Thyroïdite de Hashimoto avec hypothyroïdie supplémentée depuis 10 ans. Pas d'antécédents familiaux particuliers. Médicaments : levothyroxine 0,1 mg die, acétaminophène prn, pas de médicaments sans ordonnance
Habitudes de vie : le patient fume un paquet par jour depuis 30 ans, ne prend pas de drogue ni alcool, n'a pas eu de relations sexuelles à risque élevé; travailleur de la construction; pas de voyage récents

Examen physique : TA 130/80 pouls 105/min Température 37,8 ; eupnéique au repos ; saturation 98% air ambiant. Ictère de la peau et des sclérotiques. Pâleur des téguments. Aires ganglionnaires libres d'adénopathies. L'examen du cœur démontre un souffle systolique 2/6 en para sternal gauche non irradié et les bruits sont normaux. L'auscultation pulmonaire est normale. L'abdomen est souple et sans hépatomégalie ou masse. Une pointe de rate est palpable à l'inspiration profonde. Pas d'œdème périphérique.

Bilan para clinique : FSC : hémoglobine 62 (130-180), VGM 102 (80-100), GB 11 (3,6-10,6) plaquettes 400 (130-400); la créatinine, les électrolytes et la glycémie sont normaux; AST 48 (14-50UI/L), ALT 60 (21-72 UI/L), phosphatase alcaline 198 (43-200 UI/L), bilirubine totale 68 (3,4-17 umol/), conjuguée 5; INR et TTPa normaux; l'analyse d'urine est négative pour la bilirubine et fortement positive pour l'urobilinogène

Cardiac failure cases

B 1 #1

Un homme de 59 ans consulte à l'urgence pour dyspnée importante

HMA : Depuis 2 mois, le patient a noté un essoufflement progressif survenant d'abord en montant les escaliers, et au moindre effort depuis la dernière semaine. Les deux dernières nuits ont été particulièrement difficiles, le patient éprouvant même de l'essoufflement en position couchée l'obligeant à s'asseoir dans son fauteuil pour dormir. Il n'a pas noté de toux ni d'expectorations. Il a utilisé du salbutamol en inhalation, qu'il prend au besoin pour son asthme, sans résultat. il a également noté depuis 24 heures, 4-5 épisodes d'oppressions thoraciques d'intensité modérée durant 5 à 10 minutes. Pas de palpitations ni syncope. Il a fait un rhume la semaine dernière spontanément résolue.

Antécédents : Hypertension depuis une vingtaine d'années et apparemment bien contrôlée avec du Diltiazem 240 mg die. Asthme saisonnier pour lequel il utilise par périodes des stéroïdes en aérosol doseur et du salbutamol

Habitudes de vie : Homme d'affaires; fumeur de ½ paquets de cigarettes/j ; une consommation d'alcool par jour; bonne alimentation

Examen physique : TA à 100/60, pouls régulier à 105/min, le patient est moite, RR 28/min, dyspnéique au repos avec une saturation à 88% à l'arrivée à l'air ambiant et 92% avec 2l/min par lunette nasale; température à 36,5 buccal. Les jugulaires sont non distendues. Les bruits cardiaques sont normaux avec présence d'un B3. On note la présence d'un souffle systolique 2/6 à l'apex irradié vers l'aisselle. À l'examen pulmonaire, on note des crépitants aux tiers inférieurs bilatéralement et des sibilances expiratoires. L'abdomen est normal. Les membres inférieurs sont normaux.

Bilan para clinique : la formule sanguine, les électrolytes, la créatinine et la glycémie sont normaux. L'ECG, montre des ondes q en inférieur et des inversions de l'onde T de v2 à v6 avec un sous décalage de 2 mm en v3,v4,v5. Les troponines sont élevées à 0,12. La radiographie pulmonaire démontre un flou péri hilaire, des lignes septales et un léger épanchement pleural droit

B 2 #1

Un homme de 59 ans consulte pour dyspnée progressive

HMA : Le patient se plaint d'une dyspnée d'installation progressive depuis 6 mois qui est passée d'une classe fonctionnelle I/IV à II/IV. Par ailleurs, il est un peu moins actif qu'avant; alors qu'il marchait facilement une heure par jour, voilà maintenant qu'il doit s'arrêter après 15 minutes parce qu'il est essoufflé. Il n'a pas d'orthopnée ni de dyspnée paroxystique nocturne. Il n'a pas eu de douleur thoracique depuis son ancien infarctus en 2000 et nie toute palpitation. Il n'a pas de toux ni d'expectorations et n'a pas fait de fièvre, de frissons ou sudations nocturnes.

Antécédent : Infarctus du myocarde en 2000, traité par thrombolyse avec fraction d'éjection normale en post-infarctus. HTA contrôlée. Médicaments : ASA 80 mg die, Amlodipine 10 mg die

Habitudes de vie : Le patient ne fume pas; prend 1 à 2 verres de vin par jour; ne consomme pas des drogue ou de produits naturels. Professeur de math au collège.

Examen physique : TA 120/60, pouls à 102/minute, RR 18/min, saturation 94% air ambiant. L'examen des téguments est normal. L'examen du cou montre un souffle carotidien droit et des veines jugulaires normales. L'examen cardiaque montre un rythme régulier; B1normal, B2 diminué; pas de B3 ni B4; souffle systolique crescendo-decrescendo au foyer aortique 3/6 irradié vers la base du cou. L'examen pulmonaire est normal. L'abdomen est souple et sans viscéromégalie. On note un léger œdème des membres inférieurs bilatéralement.

Bilan para clinique : La FSC , les électrolytes, la créatinine et la glycémie sont normaux. Les troponines sont normales. L'ÉCG montre un rythme sinusal à 95/min, une hypertrophie ventriculaire gauche avec des anomalies non spécifiques de la repolarisation en V4-V6. La radiographie pulmonaire montre une cardiomégalie et un infiltrat interstitiel léger aux bases.

B 3 #1

Une femme de 63 ans consulte à l'urgence pour augmentation de sa dyspnée

HMA : Depuis 3 mois, la patiente a noté une augmentation de sa dyspnée progressivement passant d'une classe fonctionnelle de II/IV à III/IV. Depuis 1 mois, elle est plus essoufflée la nuit, doit dormir avec 2 oreillers et présente une toux sèche nocturne. Depuis 3 jours, sa condition s'est nettement détériorée avec l'apparition d'une dyspnée au repos. Elle n'a pas présenté de douleur thoracique, ni de syncope mais se plaint de palpitations persistantes. Elle a fait un rhume, au cours du dernier mois qui est rentré dans l'ordre spontanément. Elle n'a pas fait de fièvre, frissons, expectorations.

Antécédents : HTA depuis l'âge de trente ans chroniquement difficile à contrôler. Son monitoring à domicile indique des valeurs oscillant autour de 175/100. Hystérectomie salpingo-ovariectomie bilatérale en 2005 compliqué d'un œdème pulmonaire transitoire en post-opératoire. L'échographie cardiaque avait démontré une fraction d'éjection normale du ventricule gauche. Médicaments : Ramipril 10 mg die, Nifédipine 60 mg die, Hydrochlorithiazide 25 mg die, Métoprolol 100 mg BID.

Habitudes de vie : A cessé de fumer il y a 20 ans; ne prend pas d'alcool, diète hyposodée, marchait régulièrement avant les derniers 3 mois. Retraitée.

Examen physique : Patiente dyspnéique à la mobilisation TA 185/105 aux 2 bras, pouls 110/min, RR 24/min, saturation à 90% air ambiant, Afébrile. Pas de distension des jugulaires; Cœur : rythme irrégulièrement irrégulier à 85/min, B1 et B2 normaux, pas de B3 ni souffle. Poumons : Diminution du murmure vésiculaire base droite avec matité, crépitants aux tiers inférieurs bilatéralement. L'examen de l'abdomen est normal. Pas d'œdème des membres inférieurs.

Bilan para clinique : FSC normale; créatinine 130 umol/L (clairance estimée à 50 ml/min); électrolytes sont normaux. Les troponines sont normales. L'ÉCG démontre un rythme irrégulièrement irrégulier à 84 /min avec des QRS étroits et une absence d'ondes P, des signes suggestifs d'hypertrophie ventriculaire gauche. À la radiographie pulmonaire. On note une accentuation de la trame interstitielle et des épanchements pleuraux plus marqués à droite; l'index cardio-pulmonaire est normal.

B 4 #1

Un homme de 49 ans consulte pour dyspnée et œdème des membres inférieurs

HMA : Le patient se plaint depuis 6 mois d'une dyspnée progressive qui est passée d'une classe fonctionnelle de II/IV à IV/IV avec orthopnée et dyspnée paroxystique nocturne depuis 2 semaines. Il présente aussi des oedèmes des membres inférieurs de plus en plus importants depuis un mois. Il se dit très fatigué, avec moins d'appétit mais aurait pris du poids récemment. Il n'a pas présenté de douleur thoracique, de palpitations ni syncope. Il présente une toux chronique avec expectorations blanchâtres le matin et n'a pas fait de fièvre.

Antécédents : Appendicectomie en bas âge. Pas de suivi médical. Pas de médicaments sur base régulière ni produits naturels.

Habitudes de vie : Éthylisme chronique depuis plusieurs années avec consommation jusqu'à 10 bières/j. Pas de drogues. Fume 2 paquets/j depuis 30 ans. Ancien journalier d'une papetière, sans emploi depuis 4 ans.

Examen physique : Patient négligé, facilement dyspnéique TA 109/61, pouls 104/ min, RR 28/min saturation 90% air ambiant, afébrile, absence de pouls paradoxal. Les jugulaires sont distendues; pas de souffle carotidien. Cœur : rythme cardiaque régulier, B1et B2 normaux. Présence d'un B3, pas de B4 ni de souffle. L'apex est étalé et déplacé sur la ligne axillaire antérieure. L'auscultation pulmonaire démontre une diminution du murmure vésiculaire aux deux bases et des crépitants aux tiers inférieurs bilatéralement de même que des sibilances expiratoires. L'abdomen est globuleux sans hépatosplénomégalie mais on se questionne sur la présence d'ascite. Aux membres inférieurs, on note un œdème à godet important bilatéralement jusqu'à mi-cuisse.

Bilan para clinique : FSC hémoglobine 128 (130-180) VGM 102, GB et plaquettes normaux. La créatinine et les électrolytes sont normaux. Les enzymes hépatiques et l'albumine sont normaux. Les troponines sont normales. L'ÉCG montre un rythme sinusal à 105/min. La radiographie pulmonaire montre une hyperinflation , une cardiomégalie, un infiltrat interstitiel aux 2 bases et un épanchement pleural droit modéré.

Filler cases

C 1 #1

Une patiente de 70 ans consulte à l'urgence pour faiblesse généralisée.

HMA : Depuis 2 jours, la patiente présente une faiblesse généralisée importante, relativement subite, qu'elle a remarquée au lever. La veille, elle avait ressenti une nausée persistante sans douleur abdominale et avait remarqué que ses selles étaient abondantes, avec une odeur inhabituelle et de couleur noir goudron. Elle rapporte des épisodes répétés de lipothymie depuis hier mais pas de syncope franche. Ses selles aujourd'hui ont la même coloration noire. Elle a de plus noté un filet de sang rouge à deux reprises. Il n'y a pas eu de vomissement associé. Depuis 6-7 jours, elle avait noté une inappétence à tous les aliments. Son poids est stable. Une gonalgie gauche récente l'avait menée chez son médecin. Celui-ci avait prescrit du naprosyn qu'elle prend régulièrement depuis un mois.

Antécédents : Appendicectomie il y a 33 ans;
Hypertension artérielle traitée à l'hydrochlorothiazide 25mg die. Ostéoarthrose genou gauche traitée au naprosyn 250mg BID depuis un mois.
Pas d'autres médicaments ni produits naturels

Habitudes de vie : Elle ne fume pas mais consomme deux verres de vin blanc par jour. Elle est retraitée et habite seule chez elle.

Examen physique : TA 100/60 couchée, 86/60 debout, le pouls 100 /min, la température buccale est de 37,3. On note une pâleur des conjonctives et des plis palmaires. Les muqueuses sont sèches. Les aires ganglionnaires sont normales. L'examen cardio-pulmonaire est sans particularité. À l'examen de l'abdomen, le péristaltisme est normal, on note une sensibilité épigastrique à la palpation profonde. Le foie et la rate sont sans particularités. Pas de masses palpables. Les membres inférieurs sont sans œdème.

Bilan para clinique : La formule sanguine démontre une hémoglobine à 90 g/L (130-180), un VGM à 80 (80-100), des GB et des plaquettes normales; les électrolytes, la créatinine et la glycémie sont normaux. L'albumine est à 38 (35-50 gr/L), le bilan hépatique, l'amylase et la lipase sont normaux. INR 1,0 (0,9-1,2) TTPa 30 (23-32sec)

C 2 #1

Un homme de 72 ans présente une fièvre trois jours après une colectomie gauche pour néo du colon.

HMA : L'infirmière a remarqué qu'aujourd'hui le patient paraissait essoufflé et abattu. Il tousse d'ordinaire tous les matins, avec des expectorations blanches. Cet après-midi, sa toux semblait augmentée, plus creuse et avec des expectorations jaunâtres et quelques filets de sang. Pas de symptômes d'aspiration en mangeant ou en buvant. Frissons en début de soirée avec fièvre objectivée à 39 buccal. Pas de douleur pleurétique. Pas de douleur à la miction, pas d'écoulement visible de la plaie, pas d'augmentation de la douleur post-opératoire. Pas de douleur aux mollets.

Antécédents : Obésité de longue date, bronchite chronique connue depuis deux ans. Médicaments : pompe d'Ipratropium 4 fois par jour, salbutamol 4 fois par jour.

Habitudes de vie : Comptable à la retraite, il n'a jamais consommé d'alcool mais fume un paquet de cigarettes par jour depuis 40 ans.

Examen physique : Le patient paraît dyspnéique et fatigué, TA 140/88, le pouls régulier à 100, la température buccale 39,0. Respirations à 28. Les veines jugulaires ne sont pas distendues et les aires ganglionnaires sont libres. L'auscultation pulmonaire rapporte des crépitants à la base gauche plus marqués qu'à droite et quelques sibilances expiratoires. L'abdomen est souple, avec une sensibilité appropriée à l'état post-opératoire récent et la plaie est intacte. Le foie et la rate ne semblent pas augmentés de volume. On note un œdème minime aux deux membres inférieurs.

Bilan para clinique : formule sanguine : hémoglobine à 118 (130-180 gr/L), un VGM à 82 (80-100), des globules blancs à 18,2 (3,8-10,6) des plaquettes à 180 (130-400); les électrolytes, la glycémie, la créatinine sont normaux. Les enzymes hépatiques sont normaux, de même que l'amylase et la lipase. L'analyse d'urine est normale.

C 3 #1

Un patient de 65 ans consulte à l'urgence pour hémoptysie et douleur thoracique.

HMA : Le patient présente des hémoptysies depuis 2 jours, en petite quantité. Il a aussi présenté une douleur thoracique accompagnée de sudations apparue subitement ce matin alors qu'il travaillait dans son jardin. La douleur est décrite en « coup de poignard » et exacerbée par l'inspiration profonde et est surtout présente en antérieur à gauche. Cette douleur, persistante depuis, n'est pas modifiée par le changement de position. Elle lui semble différente de ses douleurs angineuses, qui sont plutôt serratives. Il se dit un peu plus essoufflé, mais n'a pas présenté de toux ni d'orthopnée. Il n'a pas de douleur ou d'œdème aux membres inférieurs. Perte de poids de 5 kg depuis 2 mois qui semble s'être stabilisée. Il revient d'un voyage à Tahiti il y a 2 semaines.

Antécédents : infarctus aigu du myocarde il y a 10 ans avec angor résiduel, traitée par Aspirine, Metoprolol SR 100 mg die et Ramipril 10 mg die. Dyslipidémie sous Atorvastatine 10 mg die. Emphysème modéré, Carcinome prostatique traité par prostatectomie radicale il y a 4 mois.

Habitudes de vie : Tabac cessé depuis 10 ans (30 paquets-année). Pas de prise d'alcool. Il est retraité.

Examen physique : TA 140/80 bilatéralement, pouls 116/min, fréquence respiratoire 24/min, saturation O2 91% à l'air ambiant, température buccale 38,3°. Les muqueuses sont normales. Il n'y a pas de distension des veines jugulaires. L'examen cardiaque démontre un B2 pulmonaire est augmenté. L'examen pulmonaire et abdominal est normal. Les membres inférieurs sont normaux.

Bilan para clinique : La formule sanguine, les électrolytes, la créatinine et le glucose sont normaux; INR 1,1 (0,9-1,2) TTPa 30 (23-32sec). L'analyse d'urine est normale. Les troponines sont normales. ECG : tachycardie sinusale à 113/min avec axe droit et extrasystoles auriculaires fréquentes.

C 4 #1

Un patient de 76 ans est référé de l'urgence pour insuffisance rénale.

HMA : Le patient présente depuis 6 jours un tableau de diarrhée liquide importante (jusqu'à 10 selles/j) sans rectorragie ou méléna. Il accuse des douleurs abdominales crampiformes légères, soulagée par la défécation. Il n'a pas de nausée ou vomissement mais s'est très peu alimenté. Son épouse a présenté un tableau digestif similaire quelques jours auparavant. Depuis 2 jours, il se dit de plus en plus faible et ce matin, il a noté que ses urines étaient très foncées et peu abondantes. Il n'a pas fait de température et ne se plaint pas de dysurie. Il présente cependant depuis quelques années une diminution du jet et de la nycturie.

Antécédents : Dyslipidémie sous Atorvastatine 40 mg die. HTA sous Ramipril 10 mg die. Pas d'autres médicaments ni produits naturels.

Habitudes de vie : Il ne fume pas et ne prends pas d'alcool; n'a jamais utilisé de drogues intraveineuses.

Examen physique : TA 100/60, pouls 90 /min, température buccale 36,9°. Orienté dans les 3 sphères. Les muqueuses sont sèches. Les aires ganglionnaires sont normales. L'examen cardio-pulmonaire est sans particularité. L'examen de l'abdomen est normal. Le toucher rectal montre une prostate légèrement augmentée de volume. Les membres inférieurs sont normaux.

Bilan para clinique : La formule sanguine, les électrolytes et la glycémie sont normaux. La créatinine est à 260 (60-120 μmol/L), l'urée à 25 (2-8 mmol/L). L'albumine est à 33 (35-50 gr/L), le bilan hépatique est normal. L'analyse d'urine montre une protéinurie 1+ et la densité urinaire est à 1030. La microscopie montre des cylindres hyalins en petite quantité.

Cases used in the assessment phase

Jaundice cases ; far transfer cases

A 1 #2

Une femme de 55 ans est dirigée à l'urgence par son médecin de famille pour ictère

HMA : La patiente a noté l'apparition d'une jaunisse depuis 3 jours. Elle est nauséeuse depuis une semaine, a vomi une fois et accuse une douleur sourde à l'hypochondre droit. Elle a noté des selles plus molles et plus pâles depuis 3 jours. Ses urines sont plus foncées sans symptômes irritatifs par ailleurs. Elle a eu des frissons, mais n'a pas mesuré sa température. Elle ne se souvient d'aucun évènement récent expliquant ses symptômes. Elle mange souvent au restaurant et dans des buffets. Elle n'a pas eu de contacts infectieux particuliers.

Antécédents : Angor stable et dyslipidémie traités depuis 6 mois; arthrose lombaire. Médicaments : ASA 80 mg die, Simvastatine 40 mg HS, Métoprolol 12,5 mg BID, Ramipril 5 mg die, Suppléments de calcium et de vitamine D, Ibuprofène prn, pas de médicaments sans ordonnance

Habitudes de vie : Elle prend 2-3 consommations d'alcool le week end, ne fait pas usage de drogues, a un partenaire stable depuis plus de 30 ans. Elle a fait un voyage en France il y a 4 mois. Elle est enseignante au primaire

Examen physique : TA 125/60, pouls 80/min, température buccale 37,2 On note un ictère conjonctival et de la peau; l'examen des aires ganglionnaires est normal; l'examen cardio pulmonaire est normal; on note une légère sensibilité à la percussion du foie et absence d'hépato splénomégalie ou de masse abdominale; on remarque quelques varices aux membres inférieurs avec trace d'oedème

Bilan para clinique : FSC, électrolytes, glycémie, créatinine normaux; ALT 420 (21-72 UI/L), AST 830 (14-50 UI/L), Phosphatase alcaline 750 (43-200 UI/L), gammaGT 230 (8-78 UI/L), Bilirubine totale 66 (3,4-17umol/L), bilirubine conjuguée 54, Albumine 33 (35-50gr/L), INR et TTPa normaux. L'analyse d'urine démontre un taux augmenté de bilirubine et la présence d'urobilinogène

A 2 #2

Un homme de 59 ans consulte pour ictère et fatigue

HMA : Le patient a noté l'apparition d'un ictère conjonctival depuis 1 mois. Il se plaint également d'une asthénie progressive depuis environ 3 mois. Son appétit est légèrement diminué et il aurait perdu 3kg depuis la même période. Il n'a pas fait de fièvre, n'a pas de nausée, ni vomissement ni douleur abdominale; il n'a pas présenté de diarrhée ou constipation. À la revue des systèmes, il se plaint d'arthralgies au niveau des mains depuis 4-5 ans.

Antécédents : HTA essentielle depuis 25 ans, obésité; diabète type 2 depuis 4 ans traité par diète seulement, cure d'hernies inguinales il y a 6 ans. Il a déjà fait une hépatite A au retour d'un voyage au Mexique il y a 10 ans. Au niveau familial, son père est décédé à 76 ans d'un problème hépatique. Le patient a une soeur de 65 ans diabétique et un frère de 67 ans avec insuffisance cardiaque. Médicaments : Aténolol 50 mg die, Amlodipine 5 mg die, Losartan 100 mg die, acétaminophène prn (env. 10 co/sem) de longue date pour ses douleurs articulaires.

Habitudes de vie : le patient ne fume pas, prend 1 verre de vin par jour, ne prend pas de drogues ou de produits naturels. Il est pharmacien et vit avec la même conjointe depuis 15 ans.

Examen physique : TA 146/98, pouls 80/min, afébrile, poids 105kg. L'examen des téguments révèle un érythème palmaire bilatéral, un ictère et une hyperpigmentation diffuse. On note un ictère conjonctival. L'examen du cou, du cœur et des poumons est normal. Il n'y a pas d'adénopathies. L'abdomen est globuleux, le foie est percuté sur 12 cm en mid claviculaire et la rate est palpable à 2 cm sous le rebord costal. Il n'y a pas de matité déclive. Les membres inférieurs sont normaux.

Bilan para clinique : FSC : hémoglobine à 130 (130-180gr/l), VGM 97, GB 6,2 (3,8-10,6), plaquettes 95 (130-400); la créatinine, les électrolytes sont normaux, la glycémie à jeûn est à 6,8 (3,3-6,1 mmol/L); AST 82 (14-50 UI /L); ALT 86 (21-72 UI/L); phosphatase alcaline 164 (43-200UI/L); bilirubine totale 56 (3,4-17 umol/L) conjuguée 40; albumine 29 (35-50gr/L); INR 1,4 (0,9-1,2), TTPa 36 (23-32 sec)

A 3 #2

Un patient de 58 ans consulte pour ictère

HMA : Le patient rapporte l'apparition d'un ictère conjonctival au cours des derniers jours. Il se plaint également de malaises abdominaux intermittents crampiformes à l'hypochondre droit, sans irradiation dorsale, d'une perte d'appétit et d'une fatigue depuis une semaine. Son poids est stable. Il a présenté un épisode de frisson hier en soirée avec possiblement de la fièvre mais non objectivée. Il lui est arrivé à deux reprises au cours des deux derniers mois d'avoir des épisodes de douleur similaire et nausée après les repas avec parfois des vomissements alimentaires mais le tout rentrait dans l'ordre en quelques heures. Les selles sont plus pâles mais leur fréquence est inchangée. Son urine lui semble plus foncée sans difficulté mictionnelle associée.

Antécédents : Angine instable il y a 8 mois qui a nécessité un triple pontage aorto-coronarien. Son évolution a été très satisfaisante et il a repris son travail comme électricien. Depuis cette hospitalisation, il prend de l'aspirine 80mg die et de l'atorvastatine 80 mg die

Habitudes de vie : Il ne fume plus depuis sa chirurgie et consomme de 2 bières par jour depuis une dizaine d'années. Il ne consomme pas de drogues et partage sa vie avec sa conjointe depuis 33 ans.

Examen physique : patient en bon état général, la TA est à 150/85, le pouls régulier à 84/minute, la température buccale est à 38,4 Poids 85 kg. On note un ictère des sclérotiques et de la peau de même qu'une contracture de Dupuytren à la main gauche. L'examen cardio-pulmonaire est sans particularité. À l'examen de l'abdomen, le péristaltisme est normal. On note une sensibilité à l'hypochondre droit, sans défense ni ressaut et sans signe de Murphy. Le foie n'est pas palpable et est percuté sur 10 cm en midclaviculaire. Il n'y a pas de splénomégalie ni de masse palpable. Au toucher rectal, les selles sont pâles.

Bilan para clinique : FSC hémoglobine à 132 (130-180 gr/L) VGM à 90 (80-100), GB 13,6 (3,8-10,6) avec prédominance neutrophilique, plaquettes 176 (130-400); les électrolytes et la créatinine sont normaux; AST 90 (14-50UI/L); ALT 105 (21-72 UI/L), phosphatase alcaline 630 (43-200 UI/L), bilirubine totale 60 (3,4-17 umol/L), conjuguée à 48. Amylase normale. L'analyse d'urine est positive pour la bilirubine et négative pour l'urobilinogène.

A 4 #2

Une femme de 30 ans consulte pour ictère et fièvre

HMA : la patiente a noté depuis hier un ictère conjonctival et une fatigue importante. Depuis une semaine, elle présente une toux sèche, de la fièvre et des frissons. Elle se dit également plus essoufflée depuis 48 hres. Elle n'a pas faim, se dit nauséeuse mais n'a pas vomi et ne présente pas de douleur abdominale. Elle n'a pas noté de changement au niveau des selles ou des urines. Elle prend de l'ibuprofène aux 4-6 hres depuis les derniers jours et du sirop antitussif pour tenter d'améliorer ses symptômes. Pas de contacts infectieux.

Antécédents : grossesse normale en 2008, découverte fortuite d'une cholé lithiase asymptomatique à l'échographie à ce moment. Pas d'antécédents familiaux particuliers. Médicaments ; anovulants

Habitudes de vie : pas de tabac ni alcool, pas d'usage de drogues; partenaire stable depuis 6 ans; étudiante au doctorat en biologie; pas de voyage récent

Examen physique : patiente affaissée, TA 110/75 pouls 110/min, eupnéique au repos, saturation 94% air ambiant, température 38,7. Ictère de la peau et des sclérotiques. Pâleur des conjonctives. Les muqueuses sont normales. Les aires ganglionnaires sont normales. L'examen cardio-pulmonaire est normal sauf pour des crépitants à la base gauche. L'abdomen est souple, non sensible et sans hépato splénomégalie. Pas d'oedème périphérique

Bilan para clinique : FSC : hémoglobine 78 (130-180), VGM 99 (80-100), GB 12,6 (3,8-10,6), plaquettes 233 (130-400); la créatinine, les électrolytes et la glycémie sont normaux; AST 45 (14-50UI/L), ALT 60 (21-72 UI/L), phosphatase alcaline 100 (43-200 UI/L); bilirubine totale 66 (3,4-17 umol/L), conjuguée 7 : INR et TTPa normaux; analyse d'urine est négative pour la bilirubine.

Jaundice cases ; near transfer cases

A5#2

Un patient de 60 ans consulte pour ictère et nausée

HMA : Le patient se plaint des nausées persistantes sans vomissement depuis 2 semaines. Depuis 3-4 jours, il a noté que ses yeux sont jaunes. Il ne se plaint pas de douleur épigastrique mais est fatigué depuis une semaine. Ses selles sont normales. Ses urines lui semblent plus foncées. Il s'est senti frileux à deux reprises mais n'a pas pris sa température. Depuis 2 jours, il a noté une douleur au niveau des articulations des poignets et des mains.

Antécédents : Cholécystectomie pour une cholécystite aigue il y a 20 ans;
Hypertension artérielle pour laquelle il prend du ramipril 10 mg die.
Pas d'autres médicaments ni de produits naturels. Pas de transfusions.

Habitudes de vie : Il ne fume pas, ne consume pas de drogues mais boit 1-2 bières par jour. Entrepreneur en construction. Veuf depuis 5 ans et a eu trois partenaires depuis la dernière année, sa dernière rencontre remonte à environ 2mois lors d'un voyage en Californie. Il porte un tatouage au bras droit qui date d'une trentaine d'années.

Examen physique : TA 130/80, le pouls 75 /min, température buccale est de 38,3. On note un ictère des sclérotiques et de la peau. Les muqueuses sont normales. Les aires ganglionnaires sont libres. L'examen cardio-pulmonaire est sans particularité. À l'examen de l'abdomen, le péristaltisme est normal, le foie est sensible à la palpation et percuté sur 13 cm en midclaviculaire. Il n'y a pas de splénomégalie ni masse palpable. Les membres inférieurs sont sans œdème. Présence d'un tatouage au bras droit. Pas de synovites.

Bilan para clinique : La formule sanguine, les électrolytes et la créatinine et la glycémie sont normaux. L'albumine est à 31 (35-50 gr/L), AST à 532 (14-50 UI/L), ALT 703 (21-72 UI/L), phosphatase alcaline à 245 (43-200UI/L) Gamma GT 104 (8-78 UI/L); bilirubine totale 72 (3,4-17 umol/L) bilirubine conjuguée à 58; INR et PTT normaux.

A6#2

Un homme de 68 ans est amené par son épouse à l'urgence pour ictère et asthénie progressive

HMA : Son épouse a remarqué chez le patient une diminution progressive de ses capacités depuis six mois Il mange moins mais n'a perdu que 2 kg. Depuis 1 mois, son teint est devenu jaunâtre. Pas de fièvre, de nausées, de vomissements, selles normales. Le patient a noté une augmentation du volume abdominal avec un vague inconfort et un œdème des membres inférieurs, d'apparition récente.

Antécédents : Hypertension et dyslipidémie depuis l'âge de 40 ans; Hémorragie digestive en 1995 sur des angiodysplasies. Médicaments : Atorvastatine 20 mg die, Ramipril 10 mg die, amlodipine 10 mg die.

Habitudes de vie : Comptable à la retraite, il a toujours consommé régulièrement de l'alcool. Depuis le décès accidentel de son fils aîné il y a trois ans, sa consommation aurait augmenté de façon significative selon l'épouse. Il ne fume pas, ne prend pas de drogues. Vit avec son épouse dans une maison.

Examen physique : Le patient paraît asthénique et plus âgé, TA 140/90, pouls régulier à 88, la température buccale 37,0. Poids 78 kg. Le teint est ictérique. On note quelques angiomes stellaires sur le thorax et quelques ecchymoses aux membres supérieurs. Les veines jugulaires ne sont pas distendues et les aires ganglionnaires sont normales. L'auscultation cardio-pulmonaire est normale. L'abdomen est souple et globuleux avec flancs proéminents et matité déclive. Le foie semble de volume normal et la rate est palpable à 2 cm sous le rebord costal. On note un œdème à godet symétrique aux membres inférieurs.

Bilan para clinique : formule sanguine : hémoglobine à 90 (130-180 gr/L), un VGM à 102 (80-100), des globules blancs à 5,4 (3,8-10,6) des plaquettes à 75 (130-400); les électrolytes , créatinine sont normaux; la glycémie à jeûn est à 7,2;(3,3-6,1) AST 215 (14-50 UI/L) , ALT 120 (21-72 UI/L), phosphatase alcaline 160 (43-200UI/L); bilirubine totale 77 (3,4-17 umol/L) conjuguée à 46; albumine à 23 (35-50 gr/L); INR à 1,4 (0,9-1,2); TTPa 36(23-32sec).

A7#2

Une femme de 70 ans consulte pour ictère d'apparition progressive

HMA : La patiente a noté l'apparition graduelle sur environ 1 mois d'une coloration jaune de sa peau. Elle se plaint également d'une perte d'appétit et de nausées post-prandiales sans douleur abdominale. Ses selles sont plus pâles, sans diarrhée ni constipation associées. Ses urines sont plus foncées. Elle dit avoir perdu 5 kg depuis le dernier mois. Elle n'a pas noté de fièvre, pas de frissons ni sudations nocturnes. Pas de changements des habitudes alimentaires. Pas de voyage récent à l'étranger.

Antécédents : Asthme léger de longue date et diabète type 2 depuis 1 an. Pneumonie en 2009. Thrombophlébite profonde membre inférieur gauche il y a 3 mois. Médicaments : Coumadin 5 mg die, Metformine 250 mg BID, salbutamol en inhalations prn.

Habitudes de vie : Infirmière à la retraite, vit à la maison avec son conjoint, ne fume pas et ne prend pas d'alcool.

Examen physique : patiente en bon état général, TA 115/75, pouls 72/min, afébrile, poids 55kg. Ictère franc au niveau de la peau. Aires ganglionnaires libres d'adénopathies. L'examen du cœur et des poumons est normal. À l'examen de l'abdomen, il n'y a pas de douleur à la palpation. Le foie et la rate semblent de volume normal et il n'y a pas de masse palpable. Le toucher rectal est normal. Les membres inférieurs sont sans œdème.

Bilan para clinique : FSC : hémoglobine 110 (130-180) VGM 86 (80-100) GB 7,2 (3,8-10,6) plaquettes 280 (130-400); les électrolytes, la créatinine sont normaux; la glycémie à jeûn à 6,7 (3,3-6,1); AST 55 (14-50 UI/L) , ALT 79 (21-72 UI/L), phosphatase alcaline 725 (43-200 UI/L), bilirubine totale 130 (3,4-17 umol/L); conjuguée 115; albumine 32 (35-50gr/L); INR et TTPa normaux. À l'analyse, l'urine est brune, fortement positive pour la bilirubine et négative pour l'urobilinogène.

A8#2

Un patient de 40 ans consulte pour ictère et fatigue

HMA : le patient rapporte une fatigue progressive depuis 3 mois et une coloration jaune de la peau depuis quelques jours. Son appétit et son poids sont stables. Il n'a pas noté de douleur abdominale, ni autres symptômes digestifs. Ses selles et son urine sont de coloration normale. Il se plaint de dyspnée nouvelle à la marche depuis 1 semaine. Pas de toux, d'expectorations ni douleur thoracique.

Antécédents : Cure d'hernie inguinale en bas âge, thyroïdite de Hashimoto avec hypothyroïdie secondaire. Pas d'antécédents familiaux particuliers. Médicaments : levothyroxine 0,112 mg die, acétaminophène prn, pas de produits naturels ou autres médicaments sans ordonnance

Habitudes de vie : le patient ne fume pas, ne prend pas de drogue ni alcool, n'a pas eu de relations sexuelles à risque élevé; professeur d'anglais au secondaire; pas de voyage récents

Examen physique : TA 140/80 pouls 110/min Température 37,7 ; eupnéique au repos ; saturation 99% air ambiant. Ictère de la peau et des sclérotiques. Pâleur des conjonctives. Aires ganglionnaires libres d'adénopathies. L'examen du cœur ne démontre pas de souffle et les bruits sont normaux. L'auscultation pulmonaire est normale. L'abdomen est souple et sans hépatomégalie ou masse. Rate palpable à 2 cm sous le rebord costal. Pas d'œdème périphérique.

Bilan para clinique : FSC : hémoglobine 66 (130-180), VGM 105 (80-100), GB 10 (3,6-10,6) plaquettes 390 (130-400); la créatinine, les électrolytes et la glycémie sont normaux; AST 28 (14-50UI/L), ALT 30 (21-72 UI/L), phosphatase alcaline 98 (43-200 UI/L), bilirubine totale 78 (3,4-17 umol/), conjuguée 8; INR et TTPa normaux; l'analyse d'urine est négative pour la bilirubine et fortement positive pour l'urobilinogène.

Cardiac failure cases : far transfer cases

B 1 #2

Une patiente de 72 ans consulte à l'urgence pour dyspnée exacerbée

HMA : La patiente présente depuis 3 à 4 semaines une dyspnée progressive qui est passée d'une classe fonctionnelle de II/IV à IV/IV. Elle a noté également une augmentation de la fréquence de ses douleurs angineuses mais sans épisode au repos ou prolongé. Depuis la dernière semaine, elle est dyspnéique la nuit et doit maintenant dormir avec 3 oreillers. Elle présente un œdème chronique mais stable aux membres inférieurs. Elle dit avoir pris 4 kg mais respecter sa limite liquidienne. Elle n'a pas ressenti de douleur thoracique ni de palpitations. Elle présente une toux chronique matinale avec expectorations blanchâtres et n'a pas fait de fièvre ni rhume récemment. Elle est incommodée depuis quelques mois par une douleur à l'épaule droite d'allure tendineuse

Antécédents : Diabète type 2 depuis 25 ans ; HTA; Dyslipidémie; 2005 : infarctus non Q, angioplasties sur l'artère circonflexe et descendante antérieure, fraction d'éjection évaluée à 35 % à l'échographie; MPOC modérée.
Médicaments : ASA 80 mg die, Lisinopril 10 mg die, Métoprolol 50 mg BID, Imdur 60 mg die, bronchodilatateurs, Naproxen 500 mg BID depuis 6 semaines.

Habitudes de vie : tabagisme 2 paquets/jour pendant 20 ans cessé depuis 2005, ne consomme pas d'alcool, peu active en général.

Examen physique : Bon état général TA 149/70 pouls 84/min régulier, RR 20/min, saturation à 91% air ambiant, température 36. L'examen du cou révèle des jugulaires légèrement distendues. Cœur : apex étalé et palpable sur la ligne axillaire antérieure, B1 B2 normaux, B3 présent, pas de souffle. Poumons : murmure vésiculaire diminué bilatéralement avec quelques crépitants aux bases. L'examen de l'abdomen est normal. Œdème léger prétibial bilatéral.

Bilan para clinique : Les électrolytes, la créatinine et la glycémie sont normaux. FSC : hémoglobine 80 ((130-180) VGM 74 (80-100) GB et plaquettes normaux. Troponines normales. L'ÉCG montre un rythme sinusal. La radiographie pulmonaire montre une hyperinflation avec une accentuation diffuse de la trame interstitielle et des épanchements pleuraux modérés plus marqués à droite.

B 2 #2

Une patiente de 84 ans consulte à l'urgence pour dyspnée.

HMA : Depuis 6 mois, la patiente a noté une nette diminution de sa capacité à l'effort avec une dyspnée et une fatigue à la marche. Elle n'est plus capable de passer l'aspirateur dans son appartement et de faire ses courses alors qu'elle était parfaitement autonome auparavant. Elle dort maintenant avec 2 oreillers sinon elle se sent essoufflée. Elle a également noté l'apparition d'œdème progressif des jambes depuis les 2 dernières semaines. Depuis également 2 semaines, elle présente une congestion nasale, de la toux avec expectorations jaunes-verdâtres sans fièvre ni frissons.

Antécédents : Diabète et hypertension depuis 10 ans bien contrôlés; Hypothyroidie; Notion de souffle au cœur depuis plusieurs années. Médicaments : Metformin 500 mg BID et Amlodipine 10 mg die, levothyroxine 0,05 mg die.

Examen physique : bon état général, TA est à 155/88, pouls 105/min, RR 20/min, saturation est à 91 à l'air ambiant. Afébrile Les veines jugulaires sont distendues. On note un soulèvement parasternal gauche et l'apex est étalé et déplacé vers la gauche. À l'auscultation, le rythme est régulier, B1 et B2 normaux, pas de B3, souffle holosystolique 4/6 maximal en parasternal gauche irradié vers l'aisselle. L'auscultation pulmonaire rapporte quelques crépitants aux deux bases et une matité à la base droite. L'abdomen est souple et sans viscéromégalie. On note un œdème à godet symétrique jusqu'aux genoux.

Bilan para clinique : FSC : Hb 110 (130-180gr/L); créatinine 120umol/L (Ccréat 40 cc/min) Analyse d'urine normale, les électrolytes et la glycémie sont normaux. La troponinémie est normale. À l'ECG on note un rythme régulier à 108 /min avec anomalies de l'onde T non spécifiques en latéral. La radiographie pulmonaire montre une cardiomégalie, et un épanchement pleural modéré à droite et léger à gauche. Pas d'infiltrat pneumonique

B 3 #2

Un patient de 54 ans consulte à l'urgence pour dyspnée

HMA : Le patient consulte pour un troisième épisode de dyspnée rapidement progressive en moins de 2 mois. Les deux fois précédentes, il avait rapidement répondu au furosémide intraveineux et avait insisté pour quitter l'hôpital le lendemain se disant revenu à sa normale. Depuis les 3 derniers jours, le patient se plaint d'essoufflement à l'effort léger. Son état s'est détérioré la nuit dernière avec une orthopnée et une dyspnée de repos. Il n'a pas présenté de douleur thoracique ni de palpitation, de syncope ou d'œdème des membres inférieurs. Il n'a pas fait de fièvre et nie tout autre symptôme respiratoire.

Antécédents : Hypertension depuis plusieurs années. Lors de ses visites récentes à l'urgence, sa tension artérielle à l'arrivée variait de 180-195/100-110. Dyslipidémie.
Médicaments: Ramipril 10 mg po die, Hydrochlorothiazide 12.5 mg po die.

Habitudes de vie : Il fume un paquet de cigarettes par jour depuis 30 ans, prend 5 à 7 consommations d'alcool par semaine. Il ne prend pas de drogues ou de produits naturels. Mécanicien.

Examen physique : TA 195/105 aux deux bras, pouls 104/minute régulier, respiration à 24/minute avec saturation à 89% à l'air ambiant. Le patient est dyspnéique dès qu'il se mobilise, température 36,3 . Les jugulaires ne sont pas distendues. Pas de souffle carotidien. L'auscultation cardiaque démontre un B1 et B2 normaux, la présence d'un B4 et l'absence de souffle; l'apex est non déplacé. À l'auscultation des poumons, on note des crépitants aux tiers inférieurs des deux plages pulmonaires avec quelques sibilances. L'examen abdominal est normal. Il n'y a pas d'œdème des membres inférieurs.

Bilan paraclinique : FSC normale. Créatinine 132 umol/L (clairance estimée à 55 ml/min), les électrolytes sont normaux. Les troponines sont normales. L'ÉCG montre une inversion des ondes T en latéral et des signes suggestifs d'hypertrophie ventriculaire gauche. À la radiographie pulmonaire, l'index cardio-pulmonaire est normal. On note une accentuation de la trame interstitielle et un flou péri hilaire.

B 4 #2

Un homme de 40 ans consulte pour dyspnée et œdème des membres inférieurs

HMA : Le patient se présente pour un œdème aux deux membres inférieurs évoluant depuis 3 semaines, uniquement vespéral la première semaine et constant par la suite. Une dyspnée s'est installée depuis la dernière semaine, surtout en position couchée et maintenant au repos. Il n'a pas présenté de douleur thoracique ni palpitations. Il dit avoir présenté de la congestion nasale, de la toux sèche et une légère fièvre auto résolutive pendant 3-4 semaines avant l'apparition de l'œdème. Il se dit fatigué mais son appétit et poids sont stables.

Antécédents : Déchirure ménisque genou droit en 2004. Deux frères ont subit des pontages coronariens dans la quarantaine avancée.

Habitudes de vie : Il ne fume pas, prend quelques bières la fin de semaine et ne consomme pas de drogues. Partenaire stable depuis 15 ans. Monteur de ligne chez Hydro-Québec. Actif physiquement avant les symptômes actuels. Médicaments : acétaminophène occasionnellement depuis 2004

Examen physique : Le patient est facilement dyspnéique TA 105/61, pouls 104/ min, RR 24/min saturation 90% air ambiant, afébrile. Absence de pouls paradoxal. Les jugulaires sont distendues; pas de souffle carotidien. Cœur : rythme cardiaque régulier, B1et B2 normaux. Présence d'un B3, souffle systolique 1/6 au foyer mitral. Le choc de pointe est étalé et déplacé sur la ligne axillaire antérieure. L'auscultation pulmonaire démontre une diminution du murmure vésiculaire aux deux bases et des crépitants aux tiers inférieurs bilatéralement de même que des sibilances expiratoires. L'abdomen est globuleux sans hépatosplénomégalie. Aux membres inférieurs, on note un œdème à godet bilatéralement jusqu'aux genoux.

Bilan paraclinique : FSC hémoglobine 128 (130-180) VGM 94, GB et plaquettes normaux. La créatinine et les électrolytes sont normaux. Le bilan hépatique est normal. Les troponines sont normales. La vitesse de sédimentation est à 40, la crp à 84. L'ÉCG montre un rythme sinusal à 100/min. La radiographie pulmonaire montre une cardiomégalie, un flou périhilaire, un infiltrat interstitiel aux 2 bases.

Filler cases

C 1 #2

Une femme de 62 ans est amenée à l'urgence par les ambulanciers pour syncope

HMA : La patiente attendait en ligne à la banque quand elle a senti qu'elle allait «s'évanouir». Elle s'est accrochée à sa voisine mais celle-ci n'a pu l'empêcher de tomber sans connaissance. Une fois à terre, elle a presque immédiatement ouvert les yeux mais est restée très faible, avec une pâleur au visage et aux mains. Elle est nauséeuse, a vomi une fois durant le transport. Les ambulanciers décrivent le vomit, abondant, comme ressemblant à du marc de café. Elle n'a pas eu de mouvements tonico-cloniques, d'incontinence ni de période de confusion après sa perte de conscience. À la revue des systèmes, on note que depuis 3 jours, ses selles sont pâteuses, plutôt noires et avec occasionnellement un filet rougeâtre . Épigastralgies fréquentes de longues dates soulagées par prise d'antiacides, légèrement empirées depuis un mois.

Antécédents : HTA depuis 5 ans. Médicaments : ASA 80 mg die, Métoprolol 12,5 mg BID, Ramipril 5 mg die, Suppléments de calcium et de vitamine D, pas de médicaments sans ordonnance.

Habitudes de vie : 1-2 consommations d'alcool par jour, avec quelques «excès» le week end, partenaire stable depuis 2 ans.

Examen physique : TA 100/60, pouls 90/min, température buccale 37,2 Pâleur des conjonctives et des plis palmaires. Examen cardio-pulmonaire normal, abdomen souple, avec une sensibilité épigastrique à la palpation profonde. Pas d'hépato-splénomégalie. Membres inférieurs sans œdème.

Bilan para clinique : FSC : hb 68 (130-180), VGM 100 (80-100), GB normaux, plaquettes 110 (130-140) électrolytes, glycémie, créatinine normaux; ALT 80, AST ,Phosphatase alcaline normale, Bilirubine totale 20 (3,4-17umol/L) Albumine 32 (35-50gr/L), INR 1,20

C 2 #2

Un homme de 69 ans consulte à l'urgence pour une fièvre de 39,5C.

HMA : Le patient a noté l'apparition de frilosité aujourd'hui, avec une température qui a augmenté en soirée. Il a depuis 3 jours une douleur à la miction au niveau de l'urètre et au méat. Il urine fréquemment et en petites quantités et sent que sa vessie ne se vide pas complètement. Il sent un inconfort profond au niveau du rectum, exacerbé avec chaque miction. Pas de lombalgie. Urines nauséabondes depuis cinq jours. Pas de toux. Il se plaint également d'une asthénie ce soir, avec une difficulté à se lever du lit. Il est par ailleurs constipé de longue date. Depuis un an, il remarque qu'il souffre de miction incomplète, de nycturie (jusqu'à trois fois par nuit), de fréquence urinaire augmentée, d'urgence mictionnelle occasionnelle mais sans incontinence. Il n'a pas noté d'hématurie. Son poids est stable

Antécédents : HTA essentielle depuis 25 ans, obésité, diabète traité par diète seulement. Médicaments : Aténolol 50 mg die, Amlodipine 5 mg die.

Habitudes de vie : Ancien fumeur de 40 paquets-années. Il prend 1 verre de vin par jour, ne prend pas de drogues ou de produits naturels. Il est électricien et vit avec sa conjointe depuis 35 ans.

Examen physique : TA 146/98, pouls 80/min, T 38,5C buccal. L'examen du cou, du cœur et des poumons est normal. Il n'y a pas d'adénopathies. L'abdomen est normal, le foie est percuté sur 8 cm en mid claviculaire et la rate n'est pas palpable. Il n'y a pas de sensibilité à la percussion des loges rénales. Au toucher rectal, la prostate est très sensible à la palpation. Pas d'œdème des membres inférieurs.

Bilan para clinique : FSC : hémoglobine à 130 (130-180gr/l), VGM 87, GB 14,2 (3,8-10,6), plaquettes 147 (130-400); la créatinine, les électrolytes sont normaux, la glycémie est à 7 (3,3-6,1 mmol/L); profil hépatique normal, Analyse d'urine nitrites+, 20 GB/champ, hématies 10-20/champ, bactéries+.

C 3 #2

Une patiente de 50 ans consulte à l'urgence pour douleur au membre inférieur droit.

HMA : La patiente présente une douleur progressive de la jambe droite depuis 3-4 jours avec œdème. Il n'y a pas de notion de traumatisme. Pas de fièvre ni frisson. Elle dit aussi être plus asthénique depuis 2-3 mois, période durant laquelle est aurait perdu une quinzaine de livres et noté une baisse d'appétit. Elle nie tout autre symptôme digestif hormis du reflux de longue date inchangé.

Antécédents : Reflux gastro-œsophagien sous Esomeprazole 40 mg die. Pseudo goutte aux deux genoux. Pas d'autres médicaments ni produits naturels.

Habitudes de vie : Elle fume 1 paquet/j depuis 50 ans. Ne prend pas d'alcool et n'a jamais utilisé de drogues intraveineuses. Elle est retraitée.

Examen physique : TA 120/60, pouls 60 /min, température buccale 37,8. La patiente est amaigrie (IMC 18). Les muqueuses sont normales. L'examen cardio-pulmonaire est sans particularité. À l'examen de l'abdomen, le péristaltisme est normal, le foie est sensible à la palpation et percuté sur 15 cm en mid claviculaire. Il n'y a pas de splénomégalie. Elle présente une masse palpable de 7 cm au quadrant inférieur droit de l'abdomen. Le membre inférieur droit présente un œdème avec chaleur de la cuisse et du mollet, avec une différence de 4 cm 10 cm sous la rotule entre les 2 jambes. La palpation du mollet droit est légèrement douloureuse. L'examen locomoteur est normal.

Bilan para clinique : La formule sanguine démontre une hémoglobine à 111 g/L (120-160 g/L), un VGM à 74 fL (80-100 fL), les leucocytes et les plaquettes sont normaux. Les électrolytes, la créatinine et le glucose sont normaux. L'albumine est à 33 (35-50 gr/L), AST à 80 (14-50 UI/L), ALT 155 (21-72 UI/L), phosphatase alcaline à 75 (43-200UI/L). INR et PTT normaux. L'analyse d'urine est normale.

C 4 #2

Un patient de 21 ans est référé de l'urgence pour hématurie et insuffisance rénale.

HMA : Le patient consulte car il présente depuis 24 heures une hématurie macroscopique. Il se plaint aussi d'œdème progressif bilatéral aux membres inférieurs depuis 2-3 jours et d'asthénie. Il a présenté un mal de gorge il y a une dizaine de jours avec fièvre légère, mais n'a pas consulté car il préparait ses examens, et ce tableau s'est résolu depuis 4 jours avec prise d'Ibuprofène. Il n'a pas de douleur abdominale ou pollakiurie, dysurie ou autre symptôme infectieux en ce moment. Il s'agit du premier épisode du genre.

Antécédents : Appendicectomie à l'âge de 10 ans. Asthme sous Salbutamol au besoin (1-2 fois/semaines). Pas d'autres médicaments ni produits naturels. Histoire de lithiase rénale chez le père et de polyarthrite rhumatoïde chez la mère.

Habitudes de vie : Il ne fume pas et ne prend pas d'alcool; n'a jamais utilisé de drogues intraveineuses. Il est étudiant. Il a une conjointe stable depuis 2 ans.

Examen physique : TA 170/104, pouls 75 /min, température buccale 37,3. Les muqueuses sont normales. Pas de rash. Les aires ganglionnaires sont normales. Il n'y a pas de distension des veines jugulaires. L'examen cardio-pulmonaire est sans particularité. L'examen de l'abdomen est normal. Les membres inférieurs présentent de l'œdème 2+ bilatéralement. Pas de synovite.

Bilan para clinique : La formule sanguine, les électrolytes et la glycémie sont normaux. La créatinine est à 260 (60-120 µmol/L), l'urée à 15 (2-8 mmol/L). L'albumine est à 25 (35-50 gr/L), AST, ALT, phosphatase alcaline normales; INR 1,0 (0,9-1,2) TTPa 24 (23-32sec). L'analyse d'urine montre une protéinurie 3+ et une hématurie 3+ avec des cylindres de globules rouges.

Appendix 2

Example of a standardised procedure used for the training phase for students using self-explanation

Auto-explication : Étude 1, session 1

Bienvenue et merci d'avoir accepté de participer au projet de recherche. Mon nom est ___ et je serai responsable du déroulement de la rencontre d'aujourd'hui. Cette rencontre sera d'une durée approximative de 2h30.

Avant toute chose, je vous précise que je lirai les consignes pour standardiser le processus. Maintenant, nous allons commencer par le formulaire de consentement:

Lire et signer le formulaire de consentement

Voici le formulaire de consentement. Nous allons le lire attentivement ensemble. Si vous avez des questions, n'hésitez pas à me les poser.

L'assistant de recherche lit lentement et à voix haute le formulaire de consentement.

Accent sur le titre du projet, le nom de la responsable et les coordonnées du comité d'éthique. *Pour la suite de la rencontre, nous allons parler d'auto-explication au lieu d'autoréflexion explicative pour faciliter les échanges.*

Remise d'une copie aux participants.

L'assistant de recherche doit préciser :

Bien sûr, il s'agit d'un projet de recherche, alors tout ce qui sera fait et mentionné au cours de notre rencontre doit rester totalement CONFIDENTIEL, c'est-à-dire que vous n'en parlez à personne. La rigueur du projet de recherche en dépend. Lorsque le projet sera terminé, il est certain que la responsable du projet, Dre Martine Chamberland, se fera un plaisir de divulguer à toutes et à tous le contenu et les résultats de ce projet. Voici plus précisément ce que nous vous invitons à faire aujourd'hui. Nous allons vous initier à une stratégie d'apprentissage que l'on nomme « l'auto-explication ». Ensuite, nous allons écouter une bande audio illustrant un exemple d'une personne qui fait de l'auto-explication. Puis, vous aurez à mettre en pratique cette stratégie pour résoudre 12 vignettes cliniques. Vous disposerez de 10 minutes pour effectuer chaque vignette. Il y aura une pause muffin et jus à la fin de la 6^e^ vignette pour vous permettre de vous dégourdir un peu.

Initiation au concept de l'auto-explication

Pour commencer, nous allons voir ensemble ce qu'est l'auto-explication. Voici la définition [l'assistante de recherche lit lentement et à voix haute la définition] *:*
L'auto-explication est une <u>stratégie d'apprentissage</u>. Cette stratégie nécessite que l'apprenant génère <u>ses propres explications</u> afin <u>d'approfondir des connaissances</u> qui seront utilisées lors de contextes de résolutions de problèmes. De plus, <u>l'apprenant doit gérer activement et efficacement l'évolution et de sa compréhension</u>. Les mécanismes cognitifs associés à cette stratégie sont :

- *établir des liens entre des éléments de l'objet d'étude;*
- *établir des liens entre des éléments de l'objet d'étude et des connaissances antérieures;*
- *générer des inférences (hypothèses) pour approfondir la compréhension de l'objet d'étude;*
- *monitorer et corriger les connaissances erronées à propos de l'objet d'étude.*

Ainsi, si je résume dans mes propres mots, l'auto-explication est une <u>stratégie d'apprentissage</u> où vous devrez vous <u>expliquer à vous-même</u> la vignette clinique sur papier. Cette explication devrait vous aider à <u>approfondir vos connaissances</u> et <u>résoudre cette vignette</u>.

Pour votre part, votre rôle pendant l'activité est de mettre en pratique l'auto-explication. Concrètement, cela signifie que – À VOIX HAUTE – vous allez :

- *identifier les signes et les symptômes qui vous sont familiers et ceux qui vous sont moins familiers;*
- *vous expliquer les signes et les symptômes à partir de vos connaissances antérieures;*
- *émettre des hypothèses diagnostiques probables et vous les expliquer en fonction des signes et des symptômes présents dans la vignette;*

Pendant l'activité, mon rôle sera de vous rappeler que vous devez continuellement vous auto-expliquer à voix haute la vignette. De plus, tel que mentionné dans le formulaire de consentement, votre auto-explication sera enregistrée sur bande audio. Je vais également gérer les 10 minutes accordées pour résoudre chaque vignette.

Écoute d'une bande audio illustrant l'auto-explication
Voici un exemple d'auto-explication. Vous pouvez suivre sur papier en même temps que vous écoutez la bande audio.

Remise de la vignette papier à l'étudiant. PLAY

Vous venez d'entendre un exemple d'auto-explication, mais <u>vous pouvez adapter cet exemple à votre façon.</u> Par exemple, vous pourriez lire à voix haute d'un trait la vignette puis ensuite vous expliquer les signes et symptômes ainsi que les liens entre eux OU encore, vous pourriez lire lentement, surligner les concepts qui vous semblent pertinents et vous les expliquer au fur et à mesure. L'important dans cette stratégie est que vous preniez le temps de réfléchir à voix haute à ce que vous connaissez, ce que vous connaissez moins. Établissez des liens entre les deux afin de

vous expliquer à voix haute quels sont les éléments qui ont guidés votre hypothèse diagnostique principale ainsi que les hypothèses alternatives ».
Avez-vous des questions sur l'auto-explication?

Familiarisation avec les questions à répondre
Voici les questions qui vous seront posées pour chaque vignette, ainsi qu'un exemple de réponse. C'est ce type de réponse que nous recherchons.

1- Quel est le diagnostic le plus probable pour expliquer la douleur et gonflement du genou, incluant l'étiologie spécifique?
Il faut donner à la fois la catégorie et l'étiologie spécifique.

2- Quels sont vos deux arguments principaux qui supportent cette étiologie?
3- Nommez 2 alternatives diagnostiques plausibles

4- Indiquer votre niveau de confiance par rapport à votre diagnostic en utilisant l'échelle suivante : *sur une échelle de 1 (peu confiant) à 10 (totalement confiant)*

Ces réponses nous permettront de capturer l'essence de votre approche diagnostique.
Avez-vous des questions?

Résoudre 12 vignettes cliniques présentées sous forme papier
Je vous rappelle que mon rôle est de vous inviter à continuellement vous auto-expliquer à voix haute la vignette. Après 8 minutes ½, je vous indiquerai qu'il vous reste une minute ½ pour répondre par écrit – EN SILENCE – aux questions. À ce moment vous cessez votre auto-explication à voix haute et vous rédigez vos réponses. À la 10e minute, je vous demanderai de tourner la page et de commencer à résoudre la prochaine vignette.

De votre côté, votre rôle est de mettre en pratique l'auto-explication. Vous parlez le plus naturellement possible, Surtout, vous ne vous adressez pas à moi ni à l'enregistreuse. Vous vous parlez à vous-même, comme si vous étiez seul.

Avez-vous des questions?

EXERCICE
Notes pour les assistantes de recherche :

Consignes
1er cas : le participant peut prendre jusqu'à 20 sec pour lire en silence, après 20 secondes il faut dire :

Auto-expliquez-vous à voix haute

Après le premier 20 sec. **ET** pour tous les autres cas, **TOUTES** périodes de 10 sec de silence seront interrompues par :

Auto-expliquez-vous à voix haute

Après 7 minutes, si le participant arrête de s'auto-expliquer, il faut lui dire :

Il vous reste X minutes et XX secondes, continuez à vous auto-expliquer à voix haute

Évaluation

La qualité de l'auto-explication sera évaluée sur une échelle de 0-3.

	Descriptif	# de prompts
0	Le participant ne parvient pas à effectuer de l'auto-explication même avec plusieurs prompts. Par exemple, le participant explique à l'assistante de recherche, il refuse de parler à voix haute, etc.	
2	Le participant fait un minimum d'auto-explication mais nécessite plusieurs prompts pour y parvenir. Le participant fait de l'auto-explication mais semble distrait, ne semble pas prendre la tâche au sérieux.	
2	Le participant fait naturellement de l'auto-explication.	

Pause

Je vous demande de prendre la pause dans la salle.

À la fin de l'exercice

Je vous remercie beaucoup pour votre participation à ce projet de recherche. Je vous rappelle que nous nous rencontrerons le 24 avril prochain à 13h30 au local XX. Un courriel de rappel vous sera acheminé quelques jours avant. Je vous rappelle aussi que vous vous êtes engagé à respecter la confidentialité du projet. Pour assurer la rigueur de l'étude, nous vous demandons de ne pas en discuter avec vos collègues avant que le projet soit terminé.

Acknowledgments

First of all, I would like to express my gratitude to Professor Henk Schmidt, who made this all possible. It all started some years ago when he proposed a collaboration with our School to support local research initiatives. His friendship, openness, vision, and expert mentorship provided impetus to initiate interinstitutional collaboration, which later lead to me taking my first steps on this doctoral journey. Through his expert knowledge, tremendous scholarship, and guidance, he enabled me to transpose into research what has fascinated me for the last 20 years as an internist and as a teacher: helping students develop effective clinical reasoning. It was more than a privilege over these last few years to have had the opportunity of discussing, exchanging, and working with Henk, who is a giant in medical education research, a generous colleague, and a respectful teacher and facilitator.

I would also like to thank Professor Silvia Mamede for her continuous and supportive coaching throughout the successive studies underlying this thesis. Her expert advice on clinical reasoning, methods, and data analysis clearly contributed to making this thesis a scholarly work. During each of the studies, she patiently and repeatedly provided constructive feedback and guidance in revising what was supposedly the “last” version of the manuscript! Thank you so much, Silvia, for your endless encouragement throughout the whole process.

Through his active participation to the initial interinstitutional collaboration, Professsor Remy Rikers significantly contributed to the first part of this thesis. His remarkable expertise in research and psychology initially allowed me to illuminate my practical experience with the light of relevant theoretical frameworks. In the first study, he “saw the music in the data” and recognized the value of a work in progress. Through his friendly support, confidence, and frank discussions, he convinced me to pursue a doctorate and I will always be grateful for that.

I am also indebted to my colleague and friend, Christina St-Onge, who engaged herself and has invested time and energy into research development in Sherbrooke in recent years. Her collaboration ranged from sharing her expertise in education and assessment to helping in the organizational and practical aspects of conducting research. I am genuinely thankful for all she did and look forward to having her valuable collaboration in the future.

Over the course from the first study to the last, I progressively got to know a new fellow internist and dedicated teacher, Jean Setrakian. His enthusiasm, creativity, thoroughness, and efficient contribution helped me persevere, even when things were not moving as I expected. Thank you, Jean, for your continuous and active contributions and I anticipate many new projects in collaboration with you in the years to come.

Many other colleagues contributed to this thesis along the way. In particular, I want to express my gratitude to Linda Bergeron for her sustained collaboration on many aspects of the work from the outset; to Luc Lanthier for his support as Head of Division of Internal medicine and for his contribution to the material development for the first two studies; to Marc-Antoine Rivard, who devoted time and effort to data collection and coding for the second study; and to Annie Lévesque for her technical support for the second study. I also thank the residents and other clinicians played roles in developing materials for the third and fourth studies. In addition, I want to acknowledge the support and interest of my friends and colleagues in the Division of Internal Medicine in Sherbrooke, who, at different strategic moments, agreed to take on some extra clinical or teaching activities so that the work could move ahead.

I want to acknowledge the unswerving support of Diane Clavet, Vice Dean of Educational and Professional Development and Director of the Centre de Pédagogie des Sciences de la Santé (Health-Sciences Education Center), who believed in this project as a way to build local capacity and promote research. She provided continuous support and optimal conditions, enabling me to conduct the studies and to complete the thesis.

I also want to thank the medical students in four successive cohorts, who graciously gave their time either in pilot-testing materials or in participating in one of the studies.

Last but not least, I am extremely grateful to and thankful for my husband, Claude, and my two daughters, Frédérique and Gabrielle. They lovingly and patiently accepted the many extra hours of work at home. Without their continuous support, I would not be writing this last sentence in my thesis.

Curriculum Vitae

A native of Sherbrooke, Quebec (Canada), Martine Chamberland earned her medical degree in 1984 and completed her postdoctoral training in internal medicine in 1988 at the Université de Sherbrooke. Stimulated by the major educational reform underway then in the School of Medicine, with the large-scale implementation of problem-based learning (PBL), she got involved in medical education and pursued her training at the University of Southern California, where she earned a master's degree in education in 1989 working on learning activities applied to clinical reasoning in the clerkship that would extend the PBL approach. The next 25 years of her professional life in Sherbrooke combined clinical practice in internal medicine at the academic medical center and active involvement in medical education at various levels. Martine Chamberland has been a professor of medicine since 2005, teaching both at the undergraduate and postgraduate levels. She has also been deeply involved in educational innovation and faculty development. In 2002, she completed a "diplôme de 3^{ième} cycle en pédagogie universitaire" (graduate diploma between the master's and doctoral degrees) at the Université de Sherbrooke's School of Education focusing on faculty development for clinical teachers and role modeling. Martine Chamberland served as the director of the Centre de Pédagogie des Sciences de la Santé (Health-Sciences Education Center) at the Sherbrooke School of Medicine from 2000 to 2008. From 2008 to 2011, she headed up interinstitutional collaboration with Erasmus University to support the development of research in health science education at Sherbrooke. Martine Chamberland's research interests and work have focused on the themes of clinical reasoning, clinical teaching, problem-based learning, role modeling, and faculty development.

Author's publications

Chamberland M, Mamede S, Self-explanation, an instructional strategy to foster clinical reasoning in medical students. Submitted for publication.

Chamberland M, Mamede S, St-Onge C, Setrakian J, Bergeron L, Schmidt HG. Self-explanation in learning clinical reasoning: the added value of examples and prompts. Med. Educ. (in press)

Chamberland M, Mamede S, St-Onge C, Setrakian J, Schmidt HG. Does medical students' diagnostic performance improve by observing examples of self-explanation provided by peers or experts? Submitted for publication

St-Onge C, Chamberland M, Lévesque A, Varpio L.Characterizing Raters' Role in Performance-Based Assessment: Identifying indicators of excellent raters. The Clinical Teacher 2014; 11:209-13.

Chamberland M, St-Onge C. Back to basics: keeping students active cognitively between the classroom and the exam. Invited commentary. Med Educ 2013. 47:641-48.

Chamberland M, Mamede S, St-Onge C, Rivard MA, Setrakian J, Lévesque A, Lanthier L, Schmidt HG, Rikers RMJP. Students' self-explanations during clinical reasoning: the role of biomedical knowledge. Med Educ 2013. 47:1109-13.

Faucher C, Tardif J, Chamberland M. Optometrists' clinical reasoning made explicit: A qualitative study. Optometry and Vision Science 2012;89(12) :1774-1784.

Chamberland M. Comment exploiter les résultats de la recherche pour améliorer nos activités d'enseignement et d'apprentissage du raisonnement clinique? Using research findings to improve our teaching and learning activities on clinical reasoning. Éditorial. Pédagogie Médicale 2005;6(4) :197-99.

Chamberland M, Hivon R. Les compétences de l'enseignant clinicien et le modèle de rôle en formation clinique. Pédagogie Médicale 2005;6(2) :98-111.

Côté DJ, Bellavance C, Chamberland M, Graillon A. Un programme pour aider les étudiants en médecine à développer leurs stratégies d'apprentissage. Pédagogie Médicale 2004; 5 : 95-102.

Charlin B, Chamberland M, Desmarchais JE. Chapter 7. Reforming the clerkship: The challenge of clinical learning. In: Learning to become a physician at Sherbrooke: A full switch to a student-centered MD program. JE Desmarchais and collaborators. Network Publications. Maastricht 2001. pp. 209-32.

Chamberland M, Hivon R, Tardif J, Bédard D. Évolution du raisonnement clinique au cours d'un stage d'externat : une étude exploratoire. Pédagogie médicale 2001; 2 : 9-17.

Desmarchais JE, Chamberland M. Faculty development for new roles in health profession education. Chapitre 14. Dans : H. Schmidt, M. Magzoub, G. Feletti, Z. Nooman, P. Vluggen. Handbook of community-based education: theory and practices. Network Publications, Maastrich, The Netherlands, 2000.

Chamberland M. Les séances d'apprentissage du raisonnement clinique (ARC): un exemple d'activité pédagogique contextualisée adaptée aux stages cliniques en médecine. Ann Med Interne 1998:149(8), 479-84.

Charlin B, Chamberland M, Desmarchais JE. Chapitre 7: La réforme de l'externat : Le défi de l'apprentissage clinique. Dans: Apprendre à devenir médecin: Bilan d'un changement pédagogique centré sur l'étudiant. JE Desmarchais et collaborateurs, Université de Sherbrooke 1996, 418 pages.

Chamberland M, Desmarchais JE. Adapting the Clerkship to PBL Preclinical Curriculum: Is it necessary and possible? Answers from the Sherbrooke experience. Bulletin de l'ACEM 1994; 6(2):1-4.

Chamberland M, Desmarchais JE, Charlin B. Carrying PBL into the Clerkship: A Second Reform in the Sherbrooke Curriculum. Annals of Community - Oriented Education., 1992; 5: 235-47.

Chamberland M, Boulé R. Les résidents et l'enseignement : Revue de la littérature. Can Med Assoc J 1990:143(8):725-30.