BRITISH JOURNAL OF HOSPITAL MEDICINE

EDUCATION AND TRAINING UPDATE

Clinical reasoning: exploring its characteristics and enhancing its learning

Mark Gruppetta[1,2]

Maria Mallia[1,3]

Author details can be found at the end of this article

Correspondence to:
Mark Gruppetta;
markgruppetta@gmail.com

Abstract

Clinical reasoning is an extensive and intricate field, dealing with the process of thinking and decision making in practice. Its study can be quite challenging because it is context and task dependent. Educational frameworks such as the conscious competence model and the dual process reasoning model have been developed to help its understanding. To enhance the learning of clinical reasoning, there are significant areas that can be targeted through learning processes. These include knowledge adequacy; ability to gather appropriate patient data; use of proper reasoning strategies to address specific clinical questions; and the ability to reflect and evaluate on decisions taken, together with the role of the wider practice community and the activity of professional socialisation. This article explores the characteristics of clinical reasoning and delves deeper into the various strategies that prove useful for learning.

Key words: Characteristics; Clinical reasoning; Learning strategies; Knowledge adequacy; Learning

Submitted: 10 May 2020; accepted following double-blind peer review: 27 July 2020

Introduction

The concept of clinical reasoning is defined as 'a context-dependant (sic) way of thinking and decision making in professional practice to guide practice actions. It involves the construction of narratives to make sense of the multiple factors and interests pertaining to the current reasoning task.' (Higgs and Jones, 2008). Clinical reasoning exhibits itself as a multifaceted and intricate field, dependent on both the task at hand and its clinical context (Smith et al, 2007). Clinical reasoning relies on knowledge and the process of knowledge building. A heightened awareness of clinical reasoning, specifically focusing on its impact, possible pitfalls and potential for biases, can improve and enrich clinical practice (Smith et al, 2007; Elstein, 2009).

This article focuses on better understanding the main characteristics of clinical reasoning, as well as exploring the cited techniques and processes that are considered to have an effect on the learning of clinical reasoning. It provides a holistic and comprehensive account of the relevant concepts, to provide a useful scheme for practice.

Clinical reasoning characteristics

There is general consensus that studying and exploring clinical reasoning is challenging. (Croskerry, 2009a; Cutrer et al, 2013; Durning et al, 2013). Frameworks and models have been developed in an attempt to explain clinical reasoning and provide a scheme of how it can be learned and improved. These include the conscious competence model (Cutrer et al, 2013) and the dual process reasoning model (Croskerry, 2009a) (Figure 1).

Conscious competence model

This framework describes four stages that a learner goes through progressively (Cutrer et al, 2013; Chapman, 2020). The first stage, known as unconscious incompetence, is where the learner is unaware of what is not known or the skills they are deficient in. Gaining those insights and information is essential to progress to the next stage, that of conscious incompetence. In this stage, the learner becomes aware of their lack of skill or knowledge. At this point the learner gains understanding that improving their knowledge or skill in the relevant area will improve their overall effectiveness. With adequate teaching, training

How to cite this article:
Gruppetta M, Mallia M. Clinical reasoning: exploring its characteristics and enhancing its learning. Br J Hosp Med. 2020. https://doi.org/10.12968/hmed.2020.0227

and encouragement the learner moves to the third stage of conscious competence. At this stage the learner can function well and independently after having gained the right skills and knowledge. At this stage, the learner, while performing competently, will need to concentrate and focus to perform the task at hand. With repeated practice, the learner progresses to the fourth stage of unconscious competence where the learned skill becomes second nature. At this stage practices become much more instinctive, with less need for deliberate concentration (Cutrer et al, 2013; Chapman, 2020).

Dual process reasoning model

This model attempts to explain clinical reasoning and provide a scheme on which decision making can be analysed (Eva, 2005; Croskerry, 2009a; Norman et al, 2017). It integrates the two main groups of approaches to thinking, reasoning and decision making: the intuitive and analytical approaches.

The intuitive approach makes use of reasoning that is based on inductive logic and relies heavily on the individual's experience. In this approach, the decision maker uses pattern recognition to make overall sense of the scenario or problem presented. Heuristics, or mental shortcuts, are typically used and this reasoning is usually fast, economical and effortless as it bases itself on instinctive first impressions. For most clinical situations the intuitive approach proves effective (Croskerry, 2009a). However, this approach is highly dependent on the context and there is huge risk of the learner being influenced by their surrounding environments. At times this system fails, and on occasions, it does so miserably (Croskerry, 2009a; Mamede et al, 2008; Norman et al, 2017). Taking the example of a 28-year-old woman presenting with tachypnoea and chest discomfort, who had recently undergone a period of severe psychological stress. Given this context, use of the intuitive approach can lead to the presumptive diagnosis of generalised anxiety disorder, overlooking important factors in the history that might be neglected. This could be the fact that the patient had recently been started on the oral contraceptive pill, which might lead to a missed diagnosis of pulmonary embolism.

On the other hand, the analytical approach is a slower, more meticulous and focused one. Through its use of deductive reasoning, it approaches normative reasoning and rationality. This approach uses critical thinking and is usually more reliable. It is resource intensive, requires high effort from the decision maker and is single channelled. This system improves with learning and is further refined as an individual perfects their logical reasoning skills through training and education (Croskerry, 2000; 2009a; 2009b).

The dual process model attempts to integrate these two systems together (Croskerry, 2009a; 2009b). When a patient's set of symptoms or a clinical question are presented, the clinician will react in a way that if features are recognised, system one (intuitive approach) processes are triggered. This pattern recognition system is largely unconscious and automatic. On the other hand, if the symptoms or question are not straightforward or are not immediately recognised, system two (analytical approach) processes are triggered. This system is a linear one, dealing with one input at a time in a deductive logical manner. While it is often slower, it is potentially less liable to error (Mamede et al, 2008; Croskerry, 2009a; 2009b). However, some reports suggest that both reasoning approaches are similarly prone to errors. In system one, errors can arise from cognitive biases resulting from the associative nature of memory. In system two, errors can arise from the limited capacity of one's own working memory, with gaps in diverse areas of knowledge being key contributors. This limitation thereby affects the rational processes (Sherbino et al, 2012; Lambe et al, 2016; Norman et al, 2017).

In practice, system one and two processes can interact with each other in accordance with the dual process model. It may happen that in a particular situation system one processes are triggered initially. The monitoring that is constantly applied by the system two analytical approach then leads to the forcing of a rational override, with system two taking over. Some states, such as fatigue and distraction, can lead to diminished system two monitoring, with a greater freedom for system one processes to be pursued unchallenged. On the other hand, system one processes can override an otherwise sound system two analytical approach in other situations, such as when individual clinicians think they know best and can do better autonomously than by following well established guidelines (Croskerry, 2009a).

Although this dual process reasoning model presents a logical analysis of clinical reasoning approaches and is considered to be quite robust, this model may oversimplify

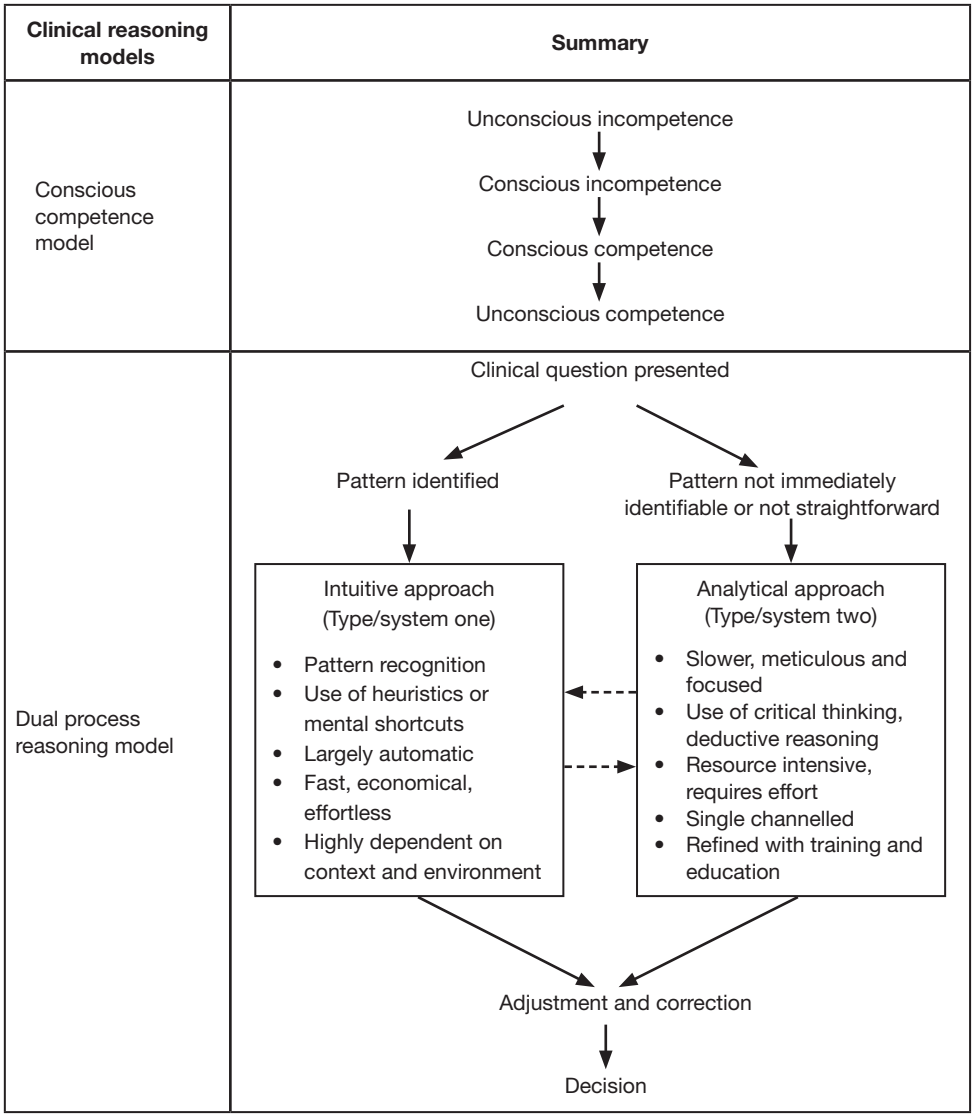

Figure 1. Summary of clinical reasoning models. Adapted from Croskerry (2009a; 2009b); Cutrer et al (2013); Chapman (2020).

very intricate and complex processes. Furthermore, at times it is difficult to accommodate the different characteristics specifically to systems one (intuitive) or two (analytical), making it difficult to categorise a process to a particular system (Figure 1) (Evans, 2008).

Learning clinical reasoning

In order to achieve effective clinical reasoning, various processes are involved. Different learning strategies and methods can be used to acquire and master these crucial skills. The main themes identified and targeted through learning processes are knowledge adequacy; ability to gather appropriate patient data; use of proper reasoning strategies to address specific clinical questions; and the ability to reflect and evaluate on decisions taken (Graber et al, 2002; Bowen, 2006; Kassirer, 2010; Cutrer et al, 2013; Audétat et al, 2017a). These points, together with the role of the practice community and professional socialisation, will be explored further (Table 1) (Ajjawi and Higgs, 2008).

Improving knowledge

A strong knowledge base is essential for effective clinical reasoning (Eva, 2005; Norman, 2005). An important consideration is that, apart from the depth of knowledge, the way in which knowledge is organised and made available for reasoning processes is also very significant (Graber et al, 2012; Audétat et al, 2017b; Norman et al, 2017). When clinical

Table 1. Recommended techniques to help foster effective clinical reasoning

Clinical reasoning learning interventions	Technique or process
Improving knowledge	■ Promoting reading that facilitates reasoning and conceptualisation ■ Enhanced use of illness scripts ■ Scaffolding ■ Queries, suggestions and real-time feedback ■ Discussion of contrasting cases ■ Focusing learning activities on clinical problems rather than diagnoses ■ Reasoning aloud and self-explanation by experienced physicians
Improving data gathering skills	■ Enhancing ability to formulate and ask questions ■ Physical examination and communication skills ■ Use of templates, schemes or checklists ■ Opportunities for repeated practice with feedback ■ Simulations ■ Ability to identify key features and link them to clinical context
Improving data processing	■ Ability to summarise accurately and succinctly ■ Reporter, interpreter, manager, educator (RIME) framework ■ Summarise, narrow, analyse, probe, plan, select (SNAPPS) method ■ Enhanced and effective use of semantic qualifiers ■ Slowing down to encourage reasoning ■ Gauging importance of contextual factors
Improving metacognition and reflection	■ Reflection in action ■ Reflection on action ■ Feedback ■ Consider alternatives; consider the opposite; think like an outsider ■ Insight into cognitive biases ■ Diagnostic timeouts ■ Reflection on mistakes and discussion of errors
Professional socialisation and role of practice community	■ Recounting cases and discussing ■ Critiquing and formulating opinions in a practice community

knowledge is organised adequately, it will allow for proper recall and use of notions and facts needed during clinical reasoning (Custers et al, 1996). Promoting reading that facilitates clinical reasoning and conceptualisation as opposed to simple memorising of facts is an important strategy, together with an emphasis on self-directed learning and the provision of opportunities to share learning experiences (Bowen, 2006). The use of illness scripts can be a useful approach. Scripts are cognitive ways in which humans understand and interpret real-life scenarios. Illness scripts can be used by clinicians to make sense of new clinical situations that arise to assess, compare or contrast features of different conditions or to help interpret new information with the use of known facts or prior experiences. Using congestive heart failure as an example, an illness script would contain a number of slots that correspond to different aspects of the disease including symptoms, predisposing features and clinical sequelae. The default value for each slot for a particular illness script will be the one most likely to occur. In this example, orthopnoea and paroxysmal nocturnal dyspnoea would form part of the slot for symptoms. Over the years one would build a repertoire of patients presenting with heart failure and thus broaden the depth of the illness script (Charlin et al, 2007). As the clinician progresses through their years of training and gains experience, these illness scripts become more comprehensive and thorough (Schmidt and Rikers, 2007; Cutrer et al, 2013). Another strategy that can be useful in aiding clinical reasoning is the concept of scaffolding. Through this process, a teacher can assist a learner in making clinical decisions that would be out of their reach if it were not for the appropriate support. Through a series of queries and suggestions, the

learner is invited to re-organise their knowledge; this process relies heavily on real-time feedback (Cutrer et al, 2013; Feyzi-Behnagh et al, 2014). Another effective way of using scaffolding is in the discussion of contrasting cases, whereby a learner can enhance their ability to differentiate the characteristics of a particular condition or a particular decision-making process (Bowen, 2006; Fleming et al, 2012). Focusing the learning activities around clinical problems rather than the diagnoses is another method of improving knowledge (Eva, 2005). Having experienced physicians verbally articulate a specific case and reason aloud about their hypothesis formulation and analytical thinking can help trainees strengthen their reasoning skills and knowledge retrieval systems (Bowen, 2006; Audétat et al, 2017a).

Improving data-gathering skills

The next crucial step is the ability to gather data from a patient's history, clinical examination, results and other records in order to acquire the necessary prerequisites for apt clinical reasoning. Techniques to be developed for this include formulating and asking questions; using templates or schemes to perform a comprehensive yet relevant and specific history taking; physical examination skills and communication skills to present the findings (Cutrer et al, 2013). Another technique that has been advocated is the use of checklists. Different types have been identified, including generalised checklists that promote best practice in this field. Others relate to differential diagnoses and there are checklists to avoid pitfalls and biases (Ely et al, 2011; Sibbald et al, 2013; Graber et al, 2014). Furthermore, providing opportunities for repeated practice with real-time feedback is vital for the learning process of these skills (Graber et al, 2012). One such development is the use of simulations involving clinical scenarios and simulated patients. The question remains as to how many simulations are required to mitigate the need for real clinical experience (Bond et al, 2008; Graber et al, 2012). The learning process related to clinical reasoning needs to instill in clinicians the ability to identify key features (both positive and negative) so that relevant data can be collected and separated from the unnecessary information. Ultimately, the data collected need to stimulate clinicians to ask important questions, in terms of what the diagnosis is or which management approaches will need to be taken. Hence the association required between clinical findings and the clinical context is a priority in the learning process (Eva, 2005; Cutrer et al, 2013; Audétat et al, 2017a).

Improving data processing

Another crucial aspect of clinical reasoning that is extensively dealt with in the literature is data processing capabilities. Certain frameworks or schemes have been suggested to help in this regard (Cutrer et al, 2013). One such framework is the reporter, interpreter, manager, educator (RIME) framework with four designated levels for progression (Table 2). This framework can be used to track the trainees' progress at various levels and guide feedback to help them reach the next level (Pangaro, 1999). Another scheme that can be used is the summarise, narrow, analyse, probe, plan and select (SNAPPS) method where the clinician follows the six steps highlighted in the acronym. Such an approach could be suggested at the beginning of a placement with students or trainees, to be used as a format when presenting cases throughout their rotation (Wolpaw et al, 2003).

Table 2. Reporter, interpreter, manager, educator (RIME) framework

No.	Designated levels in framework	Description
1	Reporter	This level deals with data gathering capabilities and the ability to report findings accurately
2	Interpreter	At this level the trainee is able to prioritise and analyse different clinical problems and come up with a differential diagnosis
3	Manager	This level involves reasoning about best treatment options and what plan of action needs to be adopted, factoring in patients' individual situations and preferences
4	Educator	At this level the clinician will be able to share skills and knowledge with others and go beyond the basics, they will also have the aptitude for research

A clinician's ability to summarise a clinical problem accurately and comprehensibly is directly related to the efficacy of their clinical reasoning skills (Bordage, 2007). In this regard, the use of semantic qualifiers using paired opposing words (acute vs chronic; severe vs mild) significantly helps the characterisation of a clinical scenario and the streamlinining of subsequent clinical reasoning processes (Bordage, 2007). Another significant consideration for the enhancement of clinical reasoning is acknowledging that effective reasoning requires time. Encouraging learners to slow down in their clinical reasoning is an effective strategy to reduce errors, although evidence supporting this has not been consistent (Trowbridge, 2008; Coderre et al, 2010; Norman et al, 2017). It is important to acknowledge the effect that context has on clinical reasoning itself. This context is made up of both the specific circumstances (for example clinical setting, cases encountered, physical set up) and the clinician's individual factors (for example training, experience, opinions, character traits, values, prejudices, stress levels, interests, sensitivity) (Eva, 2005; Mamede et al, 2008; Audétat et al, 2017a; McBee et al, 2018). One method by which clinical reasoning may be improved is by working on the 'context' factor; by making sure that a trainee is exposed to a wide array of clinical cases that span the breadth of a particular specialty (Eva, 2005; Graber, 2009; Kassirer, 2010).

Improving metacognition and reflection

Reflecting on the thinking and reasoning process is a key step to enhancing clinical reasoning (Croskerry, 2000; Mamede and Schmidt, 2004; Graber, 2009; Cutrer et al, 2013). Enhancing reflective practices is crucial to improving clinical reasoning and there are aids for reflective practice that need to be emphasised. There are two types of reflection: reflection in action and reflection on action. Reflection in action refers to a process where a clinician, when faced with an uncertain scenario or clinical problem, uses reflective processes that determine their response to the specific situation. Reflection on action refers to the type of reflection that is done after the reasoning process has been completed (Schön, 2017). This provides an excellent opportunity to assess and understand what went well and what could be improved or approached differently. In this area the importance of feedback is obvious. Feedback ideally has to be objective, intensive, focused, instructive and constructive. Aside from immediate one-to-one feedback provided by peers, there are other occasions through which feedback can be conveyed, including morbidity and mortality meetings, web-based settings, audits and peer reviews (Schiff, 2008; Graber et al, 2012). Another educational strategy is to gain an insight into cognitive bias that may be at play at various stages in the clinical reasoning process. Learners can then develop precautionary methods to avoid biases (Mamede et al, 2010; Graber et al, 2012; Audétat et al, 2017a). More than 30 different types of cognitive bias have been described (Croskerry, 2000; 2002) (Table 3). A review article by Norman et al (2017) analysed relevant studies and concluded, rather controversially, that the evidence does not support the notion that existing strategies for recognising biases can reduce errors in clinical reasoning. However, this conclusion was drawn after considering only 15 studies that specifically examined the role of cognitive biases and subsequent diagnostic errors, as these were the only ones deemed relevant to the subject matter.

Table 3. Some of the most prevalent types of cognitive bias

Type of bias	Description
Anchoring	The tendency to lock on to particular features early on in the diagnostic process and give them undue importance. This may lead to the neglect of other factors that become available later on in the process
Availability	The tendency to think about particular diagnoses more or for perceived increases in frequency, as a result of factors such as recent exposure to said diagnosis
Search satisfying	The tendency to stop looking for new findings or explanations once something is found
Premature closure	The tendency for a particular diagnosis or explanation to be accepted as a fact before it has been sufficiently proven
Overconfidence	The tendency to think that one knows more than is actually known, for example by relying excessively on gut feeling, incomplete information or personal opinions

From Croskerry (2002), Mamede et al (2010; 2014)

A suggested technique for avoiding the aforementioned forms of cognitive bias and the subsequent errors that may result involves taking a diagnostic timeout. This will enable the clinician to stop, reflect and tackle the clinical scenario with a more systematic approach, allowing the diagnosis to be reconstructed from its basic principles. Efforts need to be made for the particular case not to be framed within the working diagnosis that will have been considered as the most probable (Trowbridge, 2008; Ely et al, 2011; Gay et al, 2013). A fundamental element of this exercise would be to consider alternative diagnoses and modify the workup, to be able to exclude these alternatives rather than just confirming what has been deemed to be most likely (Graber et al, 2012). Another strategy that aids clinical reasoning is admitting to mistakes, in terms of reflecting, evaluating and discussing errors. This can help to develop self-evaluation skills and improve clinical reasoning. However, finding the appropriate environment to accomplish such an exercise can be challenging as there can be sensitive issues that might need to be addressed (Eva, 2005; Trowbridge, 2008).

Enhancing clinical reasoning through professional socialisation and the role of the practice community

Various attempts at defining professional socialisation have been made, but broadly speaking it refers to a complex process involving a series of situational social interactions, through which knowledge, values, attitudes and norms are acquired by individuals seeking to form part of a profession, leading to the attainment of professional identity and a commitment towards responsible professional practice. Clinical reasoning is one of the factors that will be affected by this continuous process (Richardson, 1999; Ajjawi and Higgs, 2008). In this regard the community of practice and belonging to such a community assumes an important role in clinical reasoning. Such a community includes educational supervisors, mentors, role models, peers, juniors, associated healthcare professionals and patients. Recounting cases, discussing, receiving feedback, critiquing and formulating opinions in the community of practice have all been noted to be powerful tools in the learning and perfecting of clinical reasoning skills (Ajjawi and Higgs, 2008; Audétat et al, 2017a; 2017b). Interactions among these communities of practice can happen in various settings and can be both formal and informal. This process also serves to bring an enhanced awareness of less explicit or subconscious clinical reasoning processes that may occur (Ajjawi and Higgs, 2008).

Conclusions

Clinical reasoning proves to be an essential component of a clinician's professional practice. Attempts have been made to create a scheme or framework in order to comprehend this complex, multifaceted and intricate process. A number of different strategies, practices and considerations that affect the teaching of clinical reasoning have been explored and discussed. It is evident that an improvement of clinical outcomes for patients is the ultimate benefit to be achieved from enhancing clinical reasoning skills and abilities.

Author details

[1]Department of Medicine, Faculty of Medicine and Surgery, University of Malta, Mater Dei Hospital, Msida, Malta

[2]Department of Medicine, Mater Dei Hospital, Msida, Malta

[3]Department of Neuroscience, Mater Dei Hospital, Msida, Malta

Conflicts of interest

The authors declare no conflicts of interest.

References

Ajjawi R, Higgs J. Learning to reason: a journey of professional socialisation. Adv Health Sci Educ Theory Pract. 2008;13(2):133–150. https://doi.org/10.1007/s10459-006-9032-4

Audétat MC, Laurin S, Dory V, Charlin B, Nendaz MR. Diagnosis and management of clinical reasoning difficulties: Part II. Clinical reasoning difficulties: Management and remediation strategies. Med Teach. 2017a;39(8):797–801. https://doi.org/10.1080/0142159X.2017.1331034

Key points

- Clinical reasoning guides clinical practice, through context- and task-dependent methods for thinking and decision making.
- Studying and exploring clinical reasoning is challenging but there are some frameworks that can provide a useful schema.
- Enhancement of knowledge adequacy; improvement of data gathering techniques; use of appropriate reasoning strategies, reflection and evaluation all serve to enhance learning of clinical reasoning.
- Some of the strategies discussed include the organisation of knowledge; use of illness scripts; scaffolding, thinking aloud by teachers; use of checklists, simulations, use of frameworks enhancing data processing capabilities; appreciation of contextual factors, feedback, reflection and evaluation practices including insights into cognitive bias.
- Professional socialisation is another activity that influences the learning of clinical reasoning and the practice community has an integral effect on the promotion of clinical reasoning strategies.

Audétat MC, Laurin S, Dory V, Charlin B, Nendaz MR. Diagnosis and management of clinical reasoning difficulties: Part I. Clinical reasoning supervision and educational diagnosis. Med Teach. 2017b;39(8):792–796. https://doi.org/10.1080/0142159X.2017.1331033

Bond W, Kuhn G, Binstadt E et al. The use of simulation in the development of individual cognitive expertise in emergency medicine. Acad Emerg Med. 2008;15(11):1037–1045. https://doi.org/10.1111/j.1553-2712.2008.00229.x

Bordage G. Prototypes and semantic qualifiers: from past to present. Med Educ. 2007;41(12):1117–1121. https://doi.org/10.1111/j.1365-2923.2007.02919.x

Bowen JL. Educational strategies to promote clinical diagnostic reasoning. N Engl J Med. 2006;355(21):2217–2225. https://doi.org/10.1056/NEJMra054782

Chapman A. Conscious competence learning model. Businessball.com. 2020. http://www.businessballs.com/consciouscompetencelearningmodel.htm (accessed 5 August 2020)

Charlin B, Boshuizen HP, Custers EJ, Feltovich PJ. Scripts and clinical reasoning. Med Educ. 2007;41(12):1178–1184. https://doi.org/10.1111/j.1365-2923.2007.02924.x

Coderre S, Wright B, McLaughlin K. To think is good: querying an initial hypothesis reduces diagnostic error in medical students. Acad Med. 2010;85(7):1125–1129. https://doi.org/10.1097/ACM.0b013e3181e1b229

Croskerry P. The cognitive imperative thinking about how we think. Acad Emerg Med. 2000;7(11):1223–1231. https://doi.org/10.1111/j.1553-2712.2000.tb00467.x

Croskerry P. Achieving quality in clinical decision making: cognitive strategies and detection of bias. Acad Emerg Med. 2002;9(11):1184–1204. https://doi.org/10.1197/aemj.9.11.1184

Croskerry P. A universal model of diagnostic reasoning. Acad Med. 2009a;84(8):1022–1028. https://doi.org/10.1097/ACM.0b013e3181ace703

Croskerry P. Clinical cognition and diagnostic error: applications of a dual process model of reasoning. Adv Health Sci Educ Theory Pract. 2009b;14(S1):27–35. https://doi.org/10.1007/s10459-009-9182-2

Custers EJ, Regehr G, Norman GR. Mental representations of medical diagnostic knowledge: a review. Acad Med. 1996;71(10):S55–S61. https://doi.org/10.1097/00001888-199610000-00044

Cutrer WB, Sullivan WM, Fleming AE. Educational strategies for improving clinical reasoning. Curr Probl Pediatr Adolesc Health Care. 2013;43(9):248–257. https://doi.org/10.1016/j.cppeds.2013.07.005

Durning SJ, Artino Jr AR, Schuwirth L et al. Clarifying assumptions to enhance our understanding and assessment of clinical reasoning. Acad Med. 2013;88(4):442–448. https://doi.org/10.1097/ACM.0b013e3182851b5b

Elstein AS. Thinking about diagnostic thinking: a 30-year perspective. Adv Health Sci Educ Theory Pract. 2009;14(S1):7–18. https://doi.org/10.1007/s10459-009-9184-0

Ely JW, Graber ML, Croskerry P. Checklists to reduce diagnostic errors. Acad Med. 2011;86(3):307–313. https://doi.org/10.1097/ACM.0b013e31820824cd

Eva KW. What every teacher needs to know about clinical reasoning. Med Educ. 2005;39(1):98–106. https://doi.org/10.1111/j.1365-2929.2004.01972.x

Evans JSB. Dual-processing accounts of reasoning, judgment, and social cognition. Annu Rev Psychol. 2008;59(1):255–278. https://doi.org/10.1146/annurev.psych.59.103006.093629

Feyzi-Behnagh R, Azevedo R, Legowski E et al. Metacognitive scaffolds improve self-judgments of accuracy in a medical intelligent tutoring system. Instr Sci. 2014;42(2):159–181. https://doi.org/10.1007/s11251-013-9275-4

Fleming A, Cutrer W, Reimschisel T, Gigante J. You too can teach clinical reasoning! Pediatrics. 2012;130(5):795–797. https://doi.org/10.1542/peds.2012-2410

Gay S, Bartlett M, McKinley R. Teaching clinical reasoning to medical students. Clin Teach. 2013;10(5):308–312. https://doi.org/10.1111/tct.12043

Graber ML. Educational strategies to reduce diagnostic error: can you teach this stuff? Adv Health Sci Educ Theory Pract. 2009;14(S1):63–69. https://doi.org/10.1007/s10459-009-9178-y

Graber M, Gordon R, Franklin N. Reducing diagnostic errors in medicine: what's the goal? Acad Med. 2002;77(10):981–992. https://doi.org/10.1097/00001888-200210000-00009

Graber ML, Kissam S, Payne VL et al. Cognitive interventions to reduce diagnostic error: a narrative review. BMJ Qual Saf. 2012;21(7):535–557. https://doi.org/10.1136/bmjqs-2011-000149

Graber ML, Sorensen AV, Biswas J et al. Developing checklists to prevent diagnostic error in emergency room settings. Diagnosis. 2014;1(3):223–231. https://doi.org/10.1515/dx-2014-0019

Higgs J, Jones MA. Clinical decision making and multiple problem spaces. In: Higgs J (ed). Clinical reasoning in the health professions. 3rd edn. Amsterdam: Elsevier; 2008:3–18

Kassirer JP. Teaching clinical reasoning: case-based and coached. Acad Med. 2010;85(7):1118–1124. https://doi.org/10.1097/acm.0b013e3181d5dd0d

Lambe KA, O'Reilly G, Kelly BD et al. Dual-process cognitive interventions to enhance diagnostic reasoning: a systematic review. BMJ Qual Saf. 2016;25(10):808–820. https://doi.org/10.1136/bmjqs-2015-004417

Mamede S, Schmidt HG. The structure of reflective practice in medicine. Med Educ. 2004;38(12):1302–1308. https://doi.org/10.1111/j.1365-2929.2004.01917.x

Mamede S, Schmidt HG, Rikers RM et al. Influence of perceived difficulty of cases on physicians' diagnostic reasoning. Acad Med. 2008;83(12):1210–1216. https://doi.org/10.1097/ACM.0b013e31818c71d7

Mamede S, van Gog T, van den Berge K et al. Effect of availability bias and reflective reasoning on diagnostic accuracy among internal medicine residents. JAMA. 2010;304(11):1198–1203. https://doi.org/10.1001/jama.2010.1276

Mamede S, Van Gog T, Van Den Berge K, Van Saase JL, Schmidt HG. Why do doctors make mistakes? A study of the role of salient distracting clinical features. Acad Med. 2014;89(1):114–120. https://doi.org/10.1097/ACM.0000000000000077

McBee E, Ratcliffe T, Schuwirth L et al. Context and clinical reasoning: understanding the medical student perspective. Perspect Med Educ. 2018;7(4):256–263. https://doi.org/10.1007/s40037-018-0417-x

Norman G. Research in clinical reasoning: past history and current trends. Med Educ. 2005;39(4):418–427. https://doi.org/10.1111/j.1365-2929.2005.02127.x

Norman GR, Monteiro SD, Sherbino J et al. The causes of errors in clinical reasoning: cognitive biases, knowledge deficits, and dual process thinking. Acad Med. 2017;92(1):23–30. https://doi.org/10.1097/ACM.0000000000001421

Pangaro L. A new vocabulary and other innovations for improving descriptive in-training evaluations. Acad Med. 1999;74(11):1203–1207. https://doi.org/10.1097/00001888-199911000-00012

Richardson B. Professional development: 1. Professional socialisation and professionalisation. Physiotherapy. 1999;85(9):461–467. https://doi.org/10.1016/S0031-9406(05)65470-3

Schiff GD. Minimizing diagnostic error: the importance of follow-up and feedback. Am J Med. 2008;121(5):S38–S42. https://doi.org/10.1016/j.amjmed.2008.02.004

Schmidt HG, Rikers RM. How expertise develops in medicine: knowledge encapsulation and illness script formation. Med Educ. 2007;41(12):1133–1139. https://doi.org/10.1111/j.1365-2923.2007.02915.x

Schön DA. The reflective practitioner: how professionals think in action. New York: Routledge; 2017

Sherbino J, Dore KL, Wood TJ et al. The relationship between response time and diagnostic accuracy. Acad Med. 2012;87(6):785–791. https://doi.org/10.1097/ACM.0b013e318253acbd

Sibbald M, de Bruin AB, van Merrienboer JJ. Checklists improve experts' diagnostic decisions. Med Educ. 2013;47(3):301–308. https://doi.org/10.1111/medu.12080

Smith M, Higgs J, Ellis E. Physiotherapy decision making in acute cardiorespiratory care is influenced by factors related to physiotherapist and the nature and context of the decision: a qualitative study. Aust J Physiother. 2007;53(4):261–267. https://doi.org/10.1016/S0004-9514(07)70007-7

Trowbridge RL. Twelve tips for teaching avoidance of diagnostic errors. Med Teach. 2008;30(5):496–500. https://doi.org/10.1080/01421590801965137

Wolpaw TM, Wolpaw DR, Papp KK. SNAPPS: a learner-centered model for outpatient education. Acad Med. 2003;78(9):893–898. https://doi.org/10.1097/00001888-200309000-00010