Chapter 1
Introduction

Olle ten Cate

Clinical reasoning is a professional skill that experts agree is difficult and takes time to acquire, and, once you have the skill, it is difficult to explain what you actually do when you apply it—clinical reasoning then sometimes even feels as an easy process. The input, a clinical problem or a presenting patient, and the outcome, a diagnosis and/or a plan for action, are pretty clear, but what happens in the doctor's mind in the meantime is quite obscure. It can be a very short process, happening in seconds, but it can also take days or months. It can require deliberate, painstaking thinking, consultation of written sources, and colleague opinions, or it may just seem to happen effortless. And "reasoning" is such a nicely sounding word that doctors would agree captures what they do, but is it always reasoning? Reasoning sounds like building a chain of thoughts, with causes and consequences, while doctors sometimes jump at a conclusion, sometimes before they even realize they are clinically reasoning. Is that medical magic? No, it's not. Laypeople do the same. Any adult witnessing a motorcycle accident and seeing a victim on the street showing a lower limb in a strange angle will instantly "reason" the diagnosis is a fracture. Other medical conditions are less obvious and require deep thinking or investigations or literature study. Whatever presentation, doctors need to have the requisite skills to tackle the medical problems of patients that are entrusted to their care. No matter how obscure clinical reasoning is, students need to acquire that ability. So how does a student begin to learn clinical reasoning? How must teachers organize the training of students?

Case-based clinical reasoning (CBCR) education is a design of training of preclinical medical students, in small groups, in the art of coping with clinical problems as they are encountered in practice. As will be apparent from the description

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later in this chapter, CBCR is not identical to problem-based learning (Barrows and Tamblyn 1980), although some features (small groups, no traditional teacher role) show resemblance. While PBL is intended as a method to arrive at personal educational objectives and subsequently acquire new knowledge (Schmidt 1983), CBCR has a focus on training in the application of systematically acquired prior knowledge, but now in a clinical manner. It aims at building illness scripts—mental representations of diseases—while at the same time supports the acquisition of a diagnostic thinking habit. CBCR is not an algorithm or a heuristic to be used in clinical practice to efficiently solve a new medical problem. CBCR is no more and no less than *educational method* to acquire clinical reasoning skill. That is what this book is about.

The elaboration of the method (Part II and III of the book) is preceded in Part I by chapters on the general background of clinical reasoning and its teaching.

What Is Clinical Reasoning?

Clinical reasoning is usually defined in a very general sense as “The thinking and decision -making processes associated with clinical practice” (Higgs and Jones 2000) or simply “diagnostic problem solving” (Elstein 1995).

For the purpose of this book, we define clinical reasoning as the mental process that happens when a doctor encounters a patient and is expected to draw a conclusion about (a) the nature and possible causes of complaints or abnormal conditions of the patient, (b) a likely diagnosis, and (c) patient management actions to be taken. Clinical reasoning is targeted at making decisions on gathering diagnostic information and recommending or initiating treatment. The mental reasoning process is interrupted to collect information and resumed when this information has arrived.

It is well established that clinicians have a range of mental approaches to apply. Somewhat simplified, they are categorized in two thinking systems, sometimes subsumed under the name *dual-process theory* (Eva 2005; Kassirer 2010; Croskerry 2009; Pelaccia et al. 2011). Based in the work of Croskerry (2009) and the Institute of Medicine (Balogh et al. 2015), Fig. 1.1 shows a model of how clinical reasoning and the use of System 1 and 2 thinking can be conceptualized graphically.

The first thinking approach is rapid and requires little mental effort. This mode has been called *System 1 thinking* or *pattern recognition*, sometimes referred to as non-analytical thinking. Pattern recognition happens in various domains of expertise. Based on studies in chess, it is estimated that grand master players have over 50,000 patterns available in their memory, from games played and games studied (Kahneman and Klein 2009). These mental patterns allow for the rapid comparison of a pattern in a current game with patterns stored in memory and for a quick decision which move to make next. This huge mental library of patterns may be compared with the mental repository of *illness scripts* that an experienced clinician has and that allows for the rapid recognition of a pattern of signs and symptoms in a

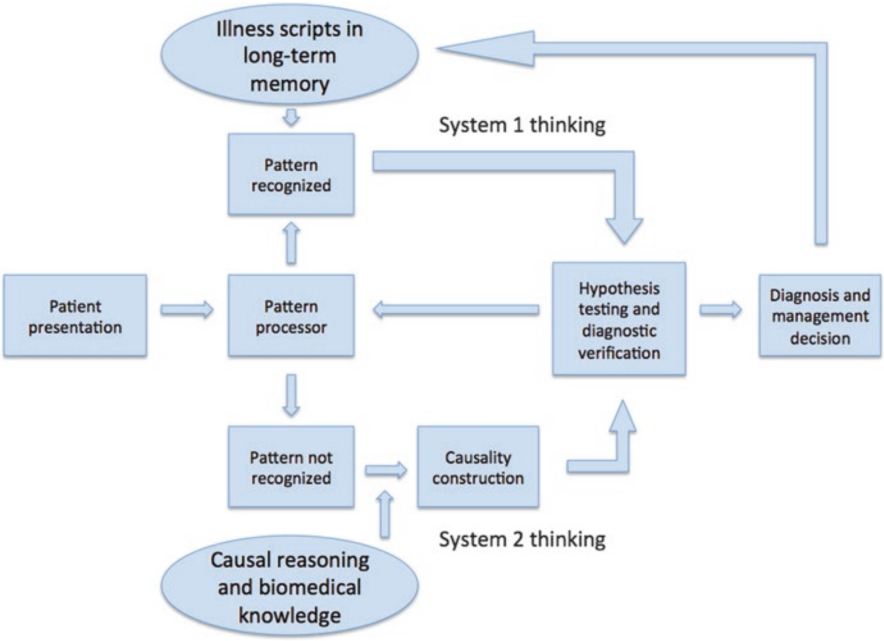

Fig. 1.1 A model of clinical reasoning (Adapted from Croskerry 2009)

Box 1.1 Illness Script
An illness script is a general representation in the physician's mind of an illness. An illness script includes details on typical causal or associated preceding features ("enabling conditions"); the actual pathology ("fault"); the resulting signs, symptoms, and expected diagnostic findings ("consequences"); and, added to the original illness script definition (Feltovich and Barrows 1984), the most likely course and prognosis with suitable management options ("management"). An illness script may be stored as one comprehensive unit in the long-term memory of the physician. It can be triggered to be retrieved during new clinical encounters, to facilitate comparison and contrast, in order to generate a diagnostic hypothesis.

patient with patients encountered in the past (Feltovich and Barrows 1984; Custers et al. 1998). See Box 1.1.

A mental matching process can lead to an instant recognition and generation of a hypothesis, if sufficient features of the current patient resemble features of a stored illness script.

Next to this rapid mental process, clinicians use *System 2 thinking:* the *analytical thinking mode of presumed causes-and-effects reasoning* that is slow and takes effort and is used when a System 1 process does not lead to an acceptable proposition to act. Analytic, often pathophysiological, thinking is typically the approach that textbooks of medicine use to explain signs and symptoms related to pathophysiological conditions in the human body. Both approaches are needed in clinical health care, to arrive at decisions and actions and to retrospectively justify actions taken. The two thinking modes can be viewed on a cognitive continuum between instant recognition and a reasoning process that may take a long time (Kassirer et al. 2010; Custers 2013). In routine medical practice, the rapid *System 1* thinking prevails. This thinking often leads to correct decisions but is not infallible. However, the admonition to slow down the thinking when System 1 thinking fails and move to System 2 thinking may not lead to more accurate decisions (Norman et al. 2014). In fact, emerging fMRI studies seem to indicate that in complex cases, inexperienced learners search for rule-based reasoning solutions (System 2), while experienced clinicians keep searching for cases from memory (System 1) (Hruska et al. 2015).

How to Teach Clinical Reasoning to Junior Students?

It is not exactly clear how medical students acquire clinical reasoning skills (Boshuizen and Schmidt 2000), but they eventually do, whether they had a targeted training in their curriculum or not. Williams et al. found a large difference in reasoning skill between years of clinical experience and across different schools (Williams et al. 2011). Even if reasoning skill would develop naturally across the years of medical training, it does not mean that educational programs cannot improve.

One way to approach the training of students in clinical reasoning is to focus on things that can go wrong in the practice of clinical reasoning and on threats to effective

Box 1.2 Summary of Prevalent Causes of Errors and Cognitive Biases
Errors (Graber et al. 2005; Kassirer et al. 2010)

– Lack or faulty knowledge
– Omission of, or faulty, data gathering and processing
– Faulty estimation of disease prevalence
– Faulty test result interpretation
– Lack of diagnostic verification

Biases (Balogh et al. 2015)

– Anchoring bias and premature closure (stop search after early explanation)
– Affective bias (emotion-based deviance from rational judgment)
– Availability bias (dominant recall of recent or common cases)
– Context bias (contextual factors that mislead)

thinking in clinical care. Box 1.2 shows the most prevalent errors and cognitive biases in clinical reasoning (Graber et al. 2005; Kassirer et al. 2010). See also Chap. 3.

In general, diagnostic errors are considered to occur too often in practice (McGlynn et al. 2015; Balogh et al. 2015), and it is important that student preparation for clinical encounters be improved (Lee et al. 2010). In a qualitative study, Audétat et al. observed five prototypical clinical reasoning difficulties among residents: generating hypotheses to guide data gathering, premature closure, prioritizing problems, painting an overall picture of the clinical situation, and elaborating a management plan (Audétat et al. 2013), not unlike the prevalent errors in clinical practice as summarized in Box 1.2. Errors in clinical reasoning pertain to both System 1 and System 2 thinking and cognitive biases causing errors are not easily amenable to teaching strategies. An inadequate knowledge base appears the most consistent reason for error (Norman et al. 2017). A number of authors have recommended tailored teaching strategies for clinical reasoning (Rencic 2011; Guerrasio and Aagaard 2014; Posel et al. 2014). Most approaches pertain to education in the clinical workplace. Box 1.3 gives a condensed overview.

One dominant approach that clinical educators use when teaching students to solve medical problems is ask them to analyze pathophysiologically, in other words to use System 2 thinking. While this seems the only option with students who do not

Box 1.3 Summary of Recommended Approaches to Teaching Clinical Reasoning (Guerrasio and Aagaard 2014; Rencic 2011; Posel et al. 2014; Chamberland et al. 2015; Balslev et al. 2015; Bowen 2006)

Let students

- Maximize learning by remembering many patient encounters.
- Recall similar cases as they increase experience.
- Build a framework for differential diagnosis using anatomy, pathology, and organ systems combined with semantic qualifiers: age, gender, ethnicity, and main complaint.
- Differentiate between likely and less likely but important diagnoses.
- Contrast diagnoses by listing necessary history questions and physical exam maneuvers in a tabular format and indicating what supports or does not support the respective diagnoses.
- Utilize epidemiology, evidence, and Bayesian reasoning.
- Practice deliberately; request and reflect on feedback; and practice mentally.
- Generate self-explanations during clinical problem solving.
- Talk in buzz groups at morning reports with oral and written patient data.
- Listen to clinical teachers reasoning out loud.
- Summarize clinical cases often using semantic qualifiers and create problem representations.

possess a mental library of illness scripts to facilitate System 1 thinking, those teachers teach something they usually do not do themselves when solving clinical problems This teaching resembles the "do as I say, not as I do" approach, in part because they simply cannot express "how they do" when they engaged in clinical reasoning.

In a recent review of approaches to the teaching of clinical reasoning, Schmidt and Mamede identified two groups of approaches: a predominant serial-cue approach (teachers provide bits of patient information to students and ask them to reason step by step) and a rare whole-task (or whole-case) approach in which all information is presented at once. They conclude that there is little evidence for the serial-cue approach, favored by most teachers and recommend a switch to whole-case approaches (Schmidt and Mamede 2015). While cognitive theory does support whole-task instructional techniques (Vandewaetere et al. 2014), the description of a whole-case in clinical education is not well elaborated. Evidently a whole-case cannot include a diagnosis and must at least be partly serial. But even if all the information that clinicians in practice face is provided to students all at once, the clinical reasoning process that follows has a serial nature, even if it happens quickly. Schmidt and Mamede's proposal to first develop causal explanations, second to encapsulate pathophysiological knowledge, and third to develop illness scripts (Schmidt and Mamede 2015) runs the risk of separating biomedical knowledge acquisition from clinical training and regressing to a Flexnerian curriculum. Flexner advocated a strong biomedical background before students start dealing with patients (Flexner 1910). This separation is currently not considered the most useful approach to clinical reasoning education (Woods 2007; Chamberland et al. 2013).

Training students in the skill of clinical reasoning is evidently a difficult task, and Schuwirth rightly once posed the question "Can clinical reasoning be taught or can it only be learned?" (Schuwirth 2002). Since the work of Elstein and colleagues, we know that clinical reasoning is not a skill that is trainable independent of a large knowledge base (Elstein et al. 1978). There simply is not an effective and teachable algorithm of clinical problem solving that can be trained and learned, if there is no medical knowledge base. The actual reasoning techniques used in clinical problem solving can be explained rather briefly and may not be very different from those of a car mechanic. Listen to the patient (or the car owner), examine the patient (or the car), draw conclusions, and identify what it takes to solve the problem. There is not much more to it. In difficult cases, medical decision-making can require knowledge of Bayesian probability calculations, understanding of sensitivity and specificity of tests (Kassirer et al. 2010), but clinicians seldom use these advanced techniques explicitly at the bedside.

These recommendations are of no avail if students do not have background knowledge, both about anatomical structures and pathophysiological processes and about patterns of signs and symptoms related to illness scripts. When training medical students to think like doctors, we face the problem that we cannot just look how clinicians think and just ask students to mimic that technique. That is for two reasons: one is that clinicians often cannot express well how they think, and the second is simply that the huge knowledge base required to think like an experienced clinician is simply not present in students.

As System 1 pattern recognition is so overwhelmingly dominant in the clinician's thinking (Norman et al. 2007), the lack of a knowledge base prohibits junior students to think like a doctor. It is clear that students cannot "recognize" a pattern if they do not have a similar pattern in their knowledge base. It is unavoidable that much effort and extensive experience are needed before a reasonable repository of illness scripts is built that can serve as the internal mirror of patterns seen in clinical practice. Ericsson's work suggests that it may take up to 10,000 hours of deliberate practice to acquire expertise in any domain, although there is some debate about this volume (Ericsson et al. 1993; Macnamara et al. 2014). Clearly, students must see and experience many, many cases and construct and remember illness scripts. What a curriculum can try to offer is just that, i.e., many clinical encounters, in clinical settings or in a simulated environment. Clinical context is likely to enhance clinical knowledge, specifically if students feel a sense of responsibility or commitment (Koens et al. 2005; Koens 2005). This sense of commitment in practice relates to the patient, but it can also be a commitment to teach peers.

System 2 analytic reasoning is clearly a skill that *can* be trained early in a curriculum (Ploger 1988). Causal reasoning, usually starting with pathology (a viral infection of the liver) and a subsequent effect (preventing the draining of red blood cell waste products) and ending with resulting symptoms (yellow stains in the blood, visible in the sclerae of the eyes and in the skin, known as jaundice or icterus), can be understood and remembered, and the reasoning can include deeper biochemical or microbiological explanations (How does it operate the chemical degradation of hemoglobin? Which viruses cause hepatitis? How was the patient infected?). This basically is a systems-based reasoning process. The clinician however must reason in the opposite direction, a skill that is not simply the reverse of this chain of thought, as there may be very different causes of the same signs and symptoms (a normal liver, but an obstruction in the bile duct, or a normal liver and bile duct, but a profuse destruction of red blood cells after an immune reaction). So analytic reasoning is trainable, and generating hypotheses of what may have caused the symptoms requires a knowledge base of possible physiopathology mechanisms. That can be acquired step by step, and many answers to analytic problems can be found in the literature. But clearly, System 2 reasoning too requires prior knowledge. So both a basic science knowledge base and a mental illness script repository must be available.

The case-based clinical reasoning training method acknowledges this difficulty and therefore focuses on two simultaneous approaches (1) building illness scripts from early on in the curriculum, beginning with simple cases and gradually building more complex scripts to remember, and (2) conveying a systematic, analytic reasoning habit starting with patient presentation vignettes and ending with a conclusion about the diagnosis, the disease mechanism, and the patient management actions to be taken.

Summary of the CBCR Method

When applying these principles to preclinical classroom teaching, a case-based approach is considered superior to other methods (Kim et al. 2006; Postma and White 2015). Case-based clinical reasoning was designed at the Academic Medical Center of University of Amsterdam in 1992, when a new undergraduate medical curriculum was introduced (ten Cate and Schadé 1993; ten Cate 1994, 1995). This integrated medical curriculum with multidisciplinary block modules of 6–8 weeks had existed since 10 years, but was found to lack a proper preparation of students to think like a doctor before entering clinical clerkships. Notably, while all block modules stressed the knowledge acquisition structured in a systematic way, usually based on organ systems and resulting in a systems knowledge base, a longitudinal thread of small group teaching was created to focus on patient-oriented thinking, with application of acquired knowledge (ten Cate and Schadé 1993). This CBCR training was implemented in curriculum years 2, 3, and 4, at both medical schools of the University of Amsterdam and the Free University of Amsterdam, which had been collaborating on curriculum development since the late 1980s. After an explanation of the method in national publications (ten Cate 1994, 1995), medical schools at Leiden and Rotterdam universities adopted variants of it. In 1997 CBCR was introduced at the medical school of Utrecht University with minor modifications and continued with only little adaptations throughout major undergraduate medical curriculum changes in 1999, 2006, and 2015 until the current day (2017).

CBCR can be summarized as the practicing of clinical reasoning in small groups. A CBCR course consists of a series of group sessions over a prolonged time span. This may be a semester, a year, or usually, a number of years. Students regularly meet in a fixed group of 10–12, usually every 3–4 weeks, but this may be more frequent. The course is independent of concurrent courses or blocks. The rationale for this is that CBCR stresses the application of previously acquired knowledge and should not be programmed as an “illustration” of clinical or basic science theory. More importantly, when the case starts, students must not be cued in specific directions or diagnoses, which would be the case if a session were integrated in, say, a cardiovascular block. A patient with shortness of breath would then trigger too easily toward a cardiac problem.

CBCR cases, always titled with age, sex, and main complaint or symptom, consist of an introductory case vignette reflecting the way a patient presents at the clinician’s office. Alternatively, two cases with similar presentations but different diagnoses may be worked through in one session, usually later in the curriculum when the thinking process can be speeded up. The context of the case may be at a general practitioner’s office, at an emergency department, at an outpatient clinic, or at admission to a hospital ward. The case vignette continues with questions and assignments (e.g., *What would be first hypotheses based on the information so far? What diagnostic tests should be ordered? Draw a table mapping signs and symptoms against likelihood of hypotheses*), at fixed moments interrupted with the provision of new findings about the patient from investigations (more extensive history, additional physical examination, or new results of diagnostic tests), distributed or read out loud by a facilitator during the session at the appropriate moment. A full case includes the complete course of a problem from the initial presentation to follow-up after treatment, but cases often concentrate on key stages of this course. Case descriptions should refer to relevant pathophysiological backgrounds and basic sciences (such as anatomy, biochemistry, cell biology, physiology) during the case.

The sessions are led by three (sometimes two) students of the group. They are called *peer teachers* and take turns in this role over the whole course. Every student must act as a peer teacher at multiple sessions across the year. Peer teachers have more information in advance about the patient and disclose this information at the appropriate time during the session, in accordance with instructions they receive in advance. In addition, a clinician is present. Given the elaborated format and case description, this teacher only acts as a consultant, when guidance is requested or helpful, and indeed is called "consultant" throughout all CBCR education.

Study materials include a general study guide with explanations of the rules, courses of action, assessment procedures, etc. (see Chap. 10): a "student version" of the written CBCR case material per session, a "peer teacher version" of the CBCR case per session with extra information and hints to guide the group, and a full "consultant version" of the CBCR case per session. Short handouts are also available for all students, covering new clinical information when needed in the course of the diagnostic process. Optionally, homemade handouts can be prepared by peer teachers. The full consultant version of the CBCR case includes all answers to all questions in detail, sufficient to enable guidance by a clinician who is not familiar with the case or discipline, all suggestions and hints for peer teachers, and all patient information that should be disclosed during the session. Examples are shown in Appendices of this book.

Students are assessed at the end of the course on their knowledge of all illnesses and to a small extent on their active participation as a student and a peer teacher (see Chap. 7).

Essential Features of CBCR Education

While a summary is given above, and a detailed procedural description is given in Part II, it may be helpful to provide some principles to help understand some of the rationale behind the CBCR method.

Switching Between System-Oriented Thinking and Patient-Oriented Thinking

It is our belief that preclinical students must learn to acquire both system-oriented knowledge and patient-oriented knowledge and that they need to practice switching between both modes of thinking (Eva et al. 2007). In that sense, our approach not only differs from traditional curricula with no training in clinical reasoning but also from curricula in which all education is derived from clinical presentations (Mandin et al. 1995, 1997).

By scheduling CBCR sessions spread over the year, with each session requiring the clinical application of system knowledge of previous system courses, this practice of switching is stimulated. It is important to prepare and schedule CBCR cases carefully to enable this knowledge application. It is inevitable, because of differential diagnostic thinking, that cases draw upon knowledge from different courses and sometimes knowledge that may not have been taught. In that case, additional information may be provided during the case discussion. Peer teachers often have an assignment to summarize relevant system information between case questions in a brief presentation (maximum 10 min), to enable further progression.

Managing Cognitive Load and the Development of Illness Scripts

Illness scripts are mental representations of disease entities combining three elements in a script (Custers et al. 1998; Charlin et al. 2007): (1) factors causing or preceding a disease, (2) the actual pathology, and (3) the effect of the pathology showing as signs, symptoms, and expected diagnostic findings. While some authors, including us, add (4) course and management as the fourth element (de Vries et al. 2006), originally the first three, "enabling conditions," "fault," and "consequences," were proposed to constitute the illness script (Feltovich and Barrows 1984). Illness scripts are stored as units in the long-term memory that are simultaneously activated and subsequently instantiated (i.e., recalled instantly) when a pattern recognition process occurs based on a patient seen by a doctor. This process is usually not deliberately executed, but occurs spontaneously. Illness scripts have a temporal nature like a film script, because of their cause and effect features, which enables clinicians to quickly take a next step, suggested by the script, in managing the patient. "Course and management" can therefore naturally be considered part of the script.

A shared explanation why illness scripts "work" in clinical reasoning is that the human working memory is very limited and does not allow to process much more than seven units or *chunks* of information at a time (Miller 1956) and likely less than that. Clinicians cannot process all separate signs and symptoms, history, and physical examination information simultaneously—that would overload their working memory capacity, but try to use one label to combine many bits of information in one unit (e.g., the illness script "diabetes type II" combines its enabling factors, pathology, signs and symptoms, disease course, and standard treatment in one chunk). If necessary, those units can be unpacked in elements (Figs. 1.1 and 1.2).

To create illness scripts stored in the long-term memory, students must learn to see illnesses as a unit of information. In case-based clinical reasoning education,

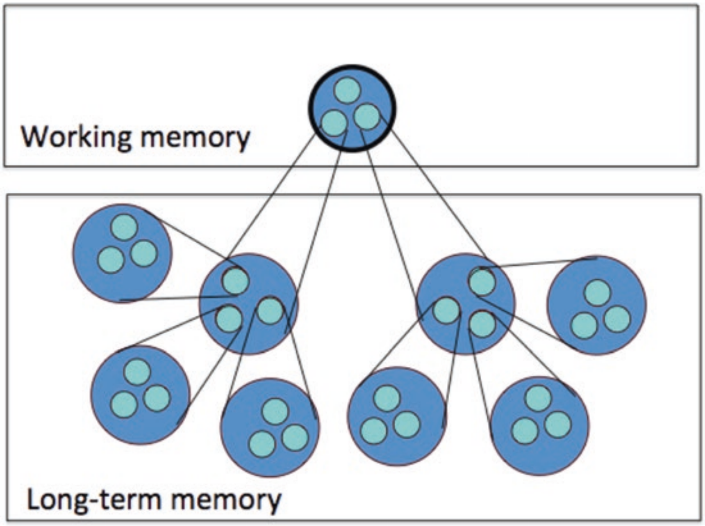

Fig. 1.2 One information chunk in the working memory may be decomposed in smaller chunks in the long-term memory (Young et al. 2014)

students face complete patient scripts, i.e., with enabling conditions (often derived from history taking) to consequences (as presenting signs and symptoms). Although illness scripts have an implicit chronology, from a clinical reasoning perspective, there is an adapted chronology of (a) consequences → (b) enabling conditions → (c) fault and diagnosis → (d) course and management, as the physician starts out observing the signs and symptoms, then takes a history, performs a physical examination, and orders tests if necessary before arriving at a conclusion about the "fault." To enable building illness script units in the long-term memory, students must start out with simple, prototype cases that can be easily remembered. CBCR aims to develop in second year medical students stable but still somewhat limited illness scripts. This still limited repository should be sufficient to quickly recognize the causes, symptoms, and management of a limited series of common illnesses, and handle prototypical patient problems in practice if they would encounter these, resonating with Bordage's prototype approach (Bordage and Zacks 1984; Bordage 2007). See Chap. 3. The assessment of student knowledge at the end of a CBCR course focuses on the exact cases discussed, including, of course, the differential diagnostic considerations that are activated with the illness script, all to reinforce the same carefully chosen illness scripts. The aim is to provide a foundation that enables the addition in later years of variations to the prototypical cases learned, to enrich further illness script formation and from there add new illness scripts. We believe that working with whole, but not too complex, cases in an early phase in the medical curriculum serves to help students in an early phase in the medical curriculum to learn to recognize common patterns.

Educational Philosophies: Active Reasoning by Oral Communication and Peer Teaching

A CBCR education in the format elaborated in this book reflects the philosophy that learning clinical reasoning is enhanced by reasoning aloud. The small group arrangement, limited to no more than about 12 students, guarantees that every student actively contributes to the discussion. Even when listening, this group size precludes from hiding as would be a risk in a lecture setting.

Students act as peer teachers for their fellow students. Peer teaching is an accepted educational method with a theoretical foundation (ten Cate and Durning 2007; Topping 1996). It is well known that taking the role of teacher for peers stimulates knowledge acquisition in a different and often more productive way than studying for an exam (Bargh and Schul 1980). Social and cognitive congruence concepts explain why students benefit from communicating with peers or near-peers and should understand each other better than when students communicate with expert teachers (Lockspeiser et al. 2008). The peer teaching format used in CBCR is an excellent way to achieve active participation of all students during small group education. An additional benefit of using peer teachers is that they are instrumental in the provision of just-in-time information about the clinical case for their peers in the CBCR group, e.g., as a result of a diagnostic test that was proposed to be ordered.

Case-based clinical reasoning has most of the features that are recommended by Kassirer et al.: "First, clinical data are presented, analyzed and discussed in the same chronological sequence in which they were obtained in the course of the encounter between the physician and the patient. Second, instead of providing all available data completely synthesized in one cohesive story, as is in the practice of the traditional case presentation, data are provided and considered on a little at a time. Third, any cases presented should consist of real, unabridged patient material. Simulated cases or modified actual cases should be avoided because they may fail to reflect the true inconsistencies, false leads, inappropriate cues, and fuzzy data inherent in actual patient material. Finally, the careful selection of examples of problem solving ensures that a reasonable set of cognitive concepts will be covered" (Kassirer et al. 2010). While we agree with the third condition for advanced students, i.e., in clerkship years, for pre-clerkship medical students, a prototypical illness script is considered more appropriate and effective (Bordage 2007). The CBCR method also matches well with most recommendations on clinical reasoning education (see Box 1.3).

Chapter 4 of this book describes six prerequisites for clinical reasoning by medical students in the clinical context: having clinical vocabulary, experience with problem representation, an illness script mental repository, a contrastive learning approach, hypothesis-driven inquiry skill, and a habit of diagnostic verification. The CBCR approach helps to prepare students with most of these prerequisites.

Indications for the Effectiveness of the CBCR Method

The CBCR method finds its roots in part in problem-based learning (PBL) and other small group active learning approaches. Since the 1970s, various small group approaches have been recommended for medical education, notably PBL (Barrows and Tamblyn 1980) and team-based learning (TBL) (Michaelsen et al. 2008). In particular PBL has gained huge interest in the 1980s onward, due to the developmental work done by its founder Howard Barrows from McMaster University in Canada and from Maastricht University in the Netherlands, which institution derived its entire identity to a large part from problem-based learning. Despite significant research efforts to establish the superiority of PBL curricula, the general outcomes have been somewhat less than expected (Dolmans and Gijbels 2013). However, many studies on a more detailed level have shown that components of PBL are effective. In a recent overviews of PBL studies, Dolmans and Wilkerson conclude that "a clearly formulated problem, an especially socially congruent tutor, a cognitive congruent tutor with expertise, and a focused group discussion have a strong influence on students' learning and achievement" (Dolmans and Wilkerson 2011). These are components that are included in the CBCR method.

While there has not been a controlled study to establish the effect of a CBCR course per se, compared to an alternative approach to clinical reasoning training, there is some indirect support for its validity, apart from the favorable reception of the teaching model among clinicians and students over the course of 20 years and different schools. A recent publication by Krupat and colleagues showed that a "case-based collaborative learning" format, including small group work on patient cases with sequential provision of patient information, led to higher scores of a physiology exam and high appreciation among students, compared with education using a problem-based learning format (Krupat et al. 2016). A more indirect indication of its effectiveness is shown in a comparative study among three schools in the Netherlands two decades ago (Schmidt et al. 1996). One of the schools, the University of Amsterdam medical school, had used the CBCR training among second and third year students at that time (ten Cate 1994). While the study does not specifically report on the effects of clinical reasoning education, Schmidt et al. show how students of the second and third year in this curriculum outperform students in both other curricula in diagnostic competence.

CBCR as an Approach to Ignite Curriculum Modernization

Since 2005, the method of CBCR has been used as leverage for undergraduate medical curriculum reform in Moldova, Georgia, Ukraine, and Azerbaijan (ten Cate et al. 2014). It has proven to be useful in medical education contexts with heavily lecture-based curricula—likely because the method can be applied within an existing curriculum, causing little disruption, while also being exemplary for recommended modern medical education (Harden et al. 1984). It stimulates integration, and the method is highly student-centered and problem-based. While observing CBCR in practice, a school can consider how these features can also be applied more generally in preclinical courses. This volume provides a detailed description that allows a school to pilot CBCR for this purpose.

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