REVIEW ARTICLE

Teaching clinical pharmacology and therapeutics with an emphasis on the therapeutic reasoning of undergraduate medical students

Milan C. Richir · Jelle Tichelaar · Eric C. T. Geijteman · Theo P. G. M. de Vries

Abstract

Background The rational prescribing of drugs is an essential skill of medical doctors. Clinical pharmacologists play an important role in the development of these skills by teaching clinical pharmacology and therapeutics (CP&T) to undergraduate medical students. Although the approaches to teaching CP&T have undergone many changes over the last decennia, it is essential that the actual teaching of CP&T continues to be a major part of the undergraduate medical curriculum.

Objectives The learning objectives of CP&T teaching in terms of developing the therapeutic competencies of undergraduate medical students are described, with an emphasis on therapeutic decision-making. On the basis of current theories of cognitive psychology and medical education, context-learning is presented as an effective approach by which to achieve therapeutic competencies. An example of a CP&T curriculum is presented.

Keywords Clinical pharmacology & therapeutics · Education · Pharmacotherapy · Teaching · Undergraduate

Introduction

The field of modern clinical pharmacology began to develop in the second half of the 19th century when physicians began to realise that agents such as heavy metals and plant extracts, then in use, more often made diseases worse instead of better [1]. In 1969, a study group on clinical pharmacology was convened by the World Health Organisation (WHO) in order to demarcate the scope of this relatively new discipline [2]. They concluded that the tasks of the clinical pharmacologist include: (1) research into the action of drugs in humans, (2) services such as providing information on drugs and (3) teaching clinical pharmacology and therapeutics (CP&T) to medical students, hospital staff and physicians [2]. While both research and services are important areas of clinical pharmacology, it is in their roles as teachers of CP&T to medical students that clinical pharmacologists have an extremely important effect on the development of rational prescribing by medical doctors. However, despite this importance, the undergraduate teaching of CP&T has not, in contrast to the two other functions of the clinical pharmacologist, achieved an international level of recognition [3, 4]. The lesser attention given to teaching CP&T is also reflected in the small number of scientific publications. For example, only about 20 articles on teaching CP&T were published in the *European Journal of Clinical Pharmacology* between 1980 and 2000.

In many medical schools, undergraduate students learn little about the therapeutic use of drugs and even after graduation, some doctors read little on the subject and rely too much on the promotional efforts and information from the pharmaceutical industry. As indicated by a survey conducted under the auspices of the WHO in 1989, in European medical schools, an average of only 28 h was devoted to teaching clinical pharmacology, even though over 100 h were devoted to pharmacology [5, 6]. However, the number of hours spent teaching CP&T is probably underestimated since clinical pharmacology and particularly therapeutics are taught implicitly during the clinical clerkships.

M. C. Richir · J. Tichelaar · E. C. T. Geijteman · T. P. G. M. de Vries (✉)
Department of Clinical Pharmacology and Pharmacy, Section Pharmacotherapy,
VU University Medical Center (VUMC),
De Boelelaan 1117,
1081 HV Amsterdam, The Netherlands
e-mail: thpgm.devries@vumc.nl

The European Association of Clinical Pharmacology and Therapeutics (EACPT) was founded in 1993 to promote the field of CP&T. One of the important objectives of the EACPT was to develop CP&T in Europe by improving and harmonising the teaching of the rational use of drugs at the undergraduate and postgraduate levels. An Education Subcommittee of the EACPT was subsequently established in 1997 to increase the amount of attention given to as well as the quality of teaching CP&T. The first task of this subcommittee was to identify the educational requirements of medical students in terms of CP&T. A positive consequence of the expanded attention for the teaching of CP&T has been the substantial increase of scientific publications on teaching CP&T during the past decade: there have been about 32 articles published between 2000 and 2007 in the *European Journal of Clinical Pharmacology*, which is twice as many as during the preceding two decades.

Unfortunately, despite the increasing amount of attention being given to the teaching of CP&T, CP&T educational programmes are still not optimal in many medical schools [7]. Nowadays, many graduates still feel insufficiently prepared to assume prescription responsibilities after graduation [7]. Therefore, it is important to improve the undergraduate teaching in CP&T.

In this review, we shall endeavour to indicate the essential aspects of teaching CP&T to undergraduate medical students. To this end, we first describe what is known about the general learning objectives in CP&T that medical students should master before graduation. Subsequently, we focus on an essential (in our opinion) core learning objective: 'therapeutic decision-making'. We go on to describe how medical students and physicians arrive at a therapeutic decision and discuss the possibilities of teaching medical students rational pharmacotherapy. Finally, we recommend approaches for organising, presenting and assessing CP&T in the undergraduate medical curriculum.

From core learning objectives to competencies

In many curricula, the teaching in clinical disciplines is centred on symptoms and diagnosis, and little or no time is given to the principles of drug treatment. In the past, CP&T was only taught as short courses in medical schools in which information was presented in the form of dogmatic indications of which drug to use and when. In some medical schools, however, clinical pharmacologists participated in basic pharmacology courses, usually given early in the clinical part of the curriculum [4]. Notwithstanding, much of the postgraduate and continuing education of the practicing physician has been left to the persuasive methods of the pharmaceutical industry [1].

It was only in 1989 that the Council for Medical Student Education in Clinical Pharmacology and Therapeutics stressed the importance of defining a core curriculum for clinical pharmacology in the medical curriculum. One year later, Nierenberg developed a core curriculum for medical students in CP&T [9]. Based on consensus between 40 clinical pharmacology teachers, Nierenberg formulated a list of core knowledge, skills and attitudes that every medical student should master before graduation in order to be able to prescribe effectively and safely [8, 9].

Core knowledge in clinical pharmacology deals with the facts that are necessary to make rational and optimal therapeutic plans; it includes the principles needed to organise these facts into useful information and to recognise when essential facts are missing [5, 8]. Core skills are in many ways similar to core knowledge because knowledge must be learned and used as the medical student develops skill in practicing rational therapeutics. Core attitudes include attitudes about what constitutes valid information, what kind of information is likely to be in error and what new information must be continuously acquired from reliable sources.

Based on the learning objectives as formulated by Nierenberg, a questionnaire on core learning objectives was subsequently developed in the United Kingdom by Walley [10]. Senior academic clinical pharmacologists who were active in teaching CP&T in the UK or Ireland assessed the relative importance of each learning objective as an element of a core curriculum. This resulted in a list of core knowledge, skills and attitudes [11] that largely matched the learning objectives as formulated by Nierenberg [8].

In addition to the approach of Nierenberg and Walley to defining the core curriculum in CP&T, Orme described two other approaches to developing a core curriculum for CP&T [12]. First, based on the WHO concept of an 'essential drug list', he developed two lists of drugs; one list consisted of approximately 120 essential drugs that students would be expected to know in detail, and a shorter list consisted of drugs that students would be expected to be familiar with but were not required to know in any detail. This list of essential drugs was then examined by the Education Subcommittee of the EACPT. The second approach to defining a core curriculum for CP&T was the disease-based approach. Three types of disease process were defined: (1) 67 diseases that were common and that the student must know how to manage; (2) 158 diseases that were less common but that students must be able to diagnose, after which the appropriate therapy could be found in the literature; (3) 36 diseases that were rare but that students should be aware of.

Defining a core curriculum for CP&T as presented by Nierenberg, Walley and Orme is important to defining the shape and boundary of the discipline and may be helpful as

part of a medical student's examination. However, in addition to knowledge, physicians must also have prescribing skills in order to prescribe rationally.

Therefore, the WHO Action Programme on Essential Drugs has developed, in collaboration with the University of Groningen, a manual for undergraduate medical students on the principles of rational prescribing, the so-called Guide to Good Prescribing (GGP). This manual provides a normative model for therapeutic reasoning and prescribing and provides a six-step guide to the process of rational prescribing that will be necessary throughout the clinical career of the medical student (Table 1). All six steps are based on the core learning objectives, knowledge, skills and attitudes as formulated by Nierenberg and Walley and on positive experience in the Netherlands [13, 14].

In addition, the content is based on an observational study among general practitioners and clinicians in the Netherlands and on 10 years of experience with pharmacotherapy courses for medical students in Dutch medical faculties and abroad. The GGP has also been reviewed and examined by a large body of international experts in the teaching of pharmacotherapy. As reported by De Vries et al., a short interactive training course in pharmacotherapy, using the GGP, was evaluated in a controlled study among 219 undergraduate international medical students [15]. This study indicated that undergraduate students who used the GGP performed significantly better than students who did not used the GGP. In addition, students not only remembered how to solve old problems, but they could also apply their skills to new problems, a so-called transfer effect.

A new framework for the innovation of medical curricula has been recently introduced, called the CanMEDS. The CanMEDS framework describes aspects of competence related to seven roles of a clinical specialist: the role of Medical Expert, Communicator, Health Advocate, Collaborator, Manager, Scholar and Professional [16]. Despite the fact that many doctors agree with the importance of these aspects of competence and that many countries have already adopted the CanMEDS roles in their curricula, there is limited information on how these roles can be applied in an international context and in different

Table 1 World Health Organisation six-step model of rational prescribing [18]

Steps	Description
Step 1	Define the patient's problem
Step 2	Specify the therapeutic objective
Step 3a	Choose your standard treatment (P-drug)
Step 3b	Verify the suitability of your treatment (P-drug)
Step 4	Start the treatment
Step 5	Give information, instructions and warnings
Step 6	Monitor (and stop?) treatment

specialities, such as CP&T. Therefore, before clinical pharmacology as a discipline can adopt the CanMEDS competencies, the core learning objectives as determined in the last decades will have to be translated into the CanMEDS competencies.

In conclusion, in order to improve the competency of future doctors to prescribe effectively and safely, several clinical pharmacologists have attempted to determine what every medical student should master before graduation. A common feature of all of the competencies formulated is that all students must acquire a knowledge of the clinical pharmacology of essential drugs and diseases and must master prescribing skills in order to become competent in the rational prescription of drugs.

Therapeutic decision-making

Although, as described previously, there are many essential therapeutic skills, the final choice of a (drug) treatment for a patient can be looked upon as a core skill in therapeutics. In order to find effective ways to teach our future doctors, it is important to explore how expert doctors arrive at this final therapeutic decision.

Therapeutic decision-making or therapeutic reasoning is, together with diagnostic reasoning, an important part of the process of clinical reasoning. Therapeutic reasoning can be defined as the step in clinical reasoning that pertains to the choice of therapy [17]. However, in contrast to the process of diagnostic reasoning, which has been investigated extensively, little is known about the process of therapeutic reasoning. To our knowledge, the first attempt to investigate therapeutic reasoning in real practice was a small observational study carried out in 1984 in the Netherlands. The results of this unpublished study constituted the basis for the development of the WHO six-step model [18]. Over 500 patient consultations by 25 general practitioners and 25 clinical specialists were observed and recorded. In addition, all doctors were interviewed about their therapeutic reasoning. Based on this study, it became evident that doctors generally based their choice of (drug) treatment on two steps: (1) doctors initially used treatment guidelines or drug formularies as a starting point; (2) this was followed by a verification of the suitability of this treatment for the individual patient and a modification of the choice of treatment if necessary (for example, in case of co-morbidity or co-medication). Moreover, it was also observed that the more experienced physicians knew more standard treatments by heart compared to less experienced physicians.

The first study that described the process of how therapeutic decisions are made in practice in greater detail was performed by Denig [19]. By interviewing 169 different general practitioners and 72 hospital physicians,

she studied how doctors arrive at a choice of drug and what factors influence this drug choice [19, 20]. This study indicated that when a doctor is confronted with a diagnosis – for example, a patient with both essential hypertension and a renal disorder – he or she immediately thinks of a number of pharmacotherapeutic possibilities, referred to as the 'evoked set'. Depending on the diagnosis, the 'evoked set' consists of 1.7–5 different pharmacotherapeutic options that are influenced by many factors, such as refresher courses, the literature, experience and advertisements from the pharmaceutical industry. The ultimate choice out of the 'evoked set' for an individual patient may be either 'unreasoned' (routine) or 'reasoned' (evaluation of the different options). However, how the final choice of treatment is made is still unknown.

In contrast to the scarcity of information available on therapeutic decision-making, much research has been done on diagnostic reasoning. When an experienced doctor is confronted with a patient with certain symptoms and signs, so-called illness scripts are called up from memory. Illness scripts contain clinically relevant information on diseases, their consequences, the context in which diseases develop, including the personal circumstances, and the experience of the doctor with previous patients. These scripts are generated by the frequent solving of diagnostic clinical problems [21, 22]. Based on recognition, experienced doctors are able to choose the right script for solving a specific diagnostic problem efficiently, particularly in routine cases [23].

In order to verify whether this is the right script for the individual patient, two types of diagnostic reasoning may be used – analytical and non-analytical. Analytical reasoning is characterised as a slow and relatively time-consuming process that is carried out consciously and systematically and, if possible, evidence-based. Less or inexperienced doctors, such as medical students, mostly use this type of reasoning, mainly because they do not possess the ability to call up so-called 'illness scripts'. In contrast to analytical reasoning, non-analytical reasoning is carried out rapidly and subconsciously and is based on experience and pattern recognition. This type of reasoning is used especially by experienced doctors. However, when an experienced doctor is confronted with a complex patient case, he or she will also use analytical reasoning.

Based on the similarities between therapeutic and diagnostic reasoning, it is possible to construct a hypothetical model of therapeutic reasoning (Fig. 1) [24]. When the diagnosis has been determined, one or more treatment scripts will be called up from the memory. In order to determine the right treatment, an analytical or non-analytical process, or a combination of both, will start. This process is similar to the process of diagnostic reasoning. The chosen treatment and its effect will

contribute to the modification of the existing treatment scripts or may result in a new treatment script.

However, in order to validate this hypothetical model, further research should be performed, particularly in terms of how experienced doctors arrive at their choice of treatment. In addition, we need to find out how these experienced doctors differ from less-experienced doctors, such as medical students and interns. The answers to these questions will provide more insight into how we should teach therapeutics to students although it can already be stated that early clinical practice will support the development of treatment scripts by undergraduate medical students.

How to teach and learn therapeutics

Gaining knowledge and at the same time applying this knowledge in practice is essential for learning in general and, presumably, also for the development of treatment scripts by medical students. This so-called context-learning seems to be more effective in many ways than sequential learning, in which learning and applying knowledge is separated [22, 25, 26]. The positive effect can be explained by theories from cognitive psychology and medical problem-solving [22, 26–28]. These theories suggest that the way in which knowledge is stored in the brain is essential for its recall and application. Therefore, storing pharmacotherapeutic knowledge in combination with the situation in which this knowledge will be applied benefits the speed and quality with which the information is recalled [21, 22, 29].

Context-learning is defined as learning in a setting that is similar to the setting of the future profession [30]. Context-learning is based on four basic principles: setting, repetition, feedback and responsibility [30]. The *setting* in which therapeutics is taught or learned should be the same as or as similar as possible to the setting of the future profession; for medical students, this is the clinical setting, such as in primary health care, hospitals or nursing homes. This clinical setting gives students the opportunity to gain experience the same way doctors do, allowing them to
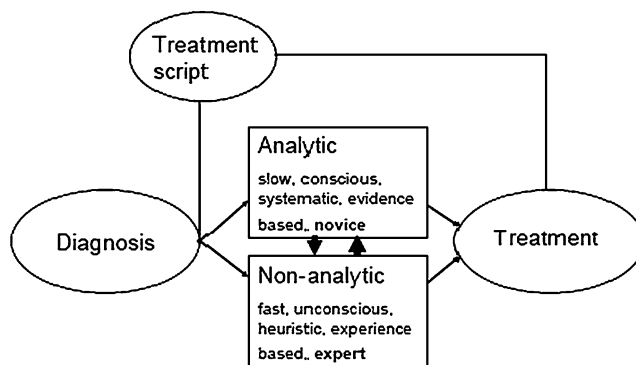
Fig. 1 Hypothetical model of therapeutic reasoning [24]

generate networks of organised knowledge in their memory and to develop illness and treatment scripts [31]. Subsequently, students should be given the opportunity to *repeat* the therapeutic problem-solving process as much as possible. Repetition allows students to generate networks of organised knowledge in the brain. Frequent exposure to patients and pharmacotherapeutic problems gradually condense these networks into readily accessible therapeutic scripts. Furthermore, students should also receive *feedback* immediately after their performance to assure the condensation of correct therapeutic scripts. Argumentation and motivational feedback may be a rapid way to reveal the process of therapeutic thinking and its possible errors. Finally, students should be *responsible* for their own learning. It is the student's own responsibility to repair any lack of knowledge or skills discovered during their clinical work and feedback sessions.

Apart from the most extreme form of context-learning, which is the clinical setting, different variations with lower levels of concreteness of the context are possible, varying from role-playing sessions with standardised patients in a simulated practice setting to the solution of written patient problems in small working groups and patient demonstrations during lectures. However, there are many ways to improve the setting, such as by using real case histories instead of written patient problems or through the use of video materials, laboratory test results or roentgenograms.

One possible approach to organising a context-learning programme in therapeutics is described by Vollebregt et al. [32]. These authors described a context-learning programme consisting of weekly-organized, role-playing sessions in the form of consulting hours. The role-playing sessions consist of three phases: consultation, argumentation and feedback. First, a 'student' doctor must carry out three therapeutic consultations of 10 min each. Before the start of a consultation, the doctors are given a written patient case. Subsequently, the 'student' patient and 'student' assessor enter the consultation room, and the doctor has to choose and prescribe the (drug) treatment interactively with the patient. The second phase (argumentation) starts immediately after the consultations. In this phase, the doctor has to substantiate the chosen therapy. Finally, during the third phase, all students sit together and discuss the various (drug) treatments and the performance of the doctors, guided by a clinical pharmacologist.

In addition to teaching therapeutics, assessing students' therapeutic knowledge and skills is an essential component of the medical curriculum. In 1990, Miller suggested a framework for clinical assessment (Fig. 2) [33]. According to this framework, students, residents or physicians must have *knowledge* in order to carry out the required professional functions effectively. Students must also *know how* to use the knowledge that they have accumulated. For example, they must develop the skill that is needed to acquire information from a variety of human and laboratory sources, to analyse and interpret data and, finally, to translate such findings into a rational diagnostic or therapeutic plan. When this quality is functionally adequate, it is defined as a competence. Furthermore, students must not only be able to demonstrate that they *know* and *know how*, but also to *show how* they do it when confronted with a patient, which is called *performance*. Finally, it is important what a graduate actually *does* when functioning independently in clinical practice. According to Miller, this *action* component of professional behaviour is the most difficult to measure.

The Objective Structured Clinical Examination (OSCE) and structured clinical examinations in general are well-known and approved methods for assessing competence and performance [34]. As far as the OSCE is concerned, this has also been shown to be useful for assessing therapeutic competence. Nevertheless, it is important that the manner in which the students are assessed is as similar as possible to the approach used in teaching them.

In conclusion, based on theories as to how physicians arrive at their therapeutic decisions, context-learning seems to be an effective way to teach CP&T to medical students. It is obvious that the ideal situation, i.e. real practice with real patients, is not always attainable, but various suboptimal forms of context-learning and assessment can be applied.

Conclusions and recommendations

In this document, the learning objectives of teaching CP&T to undergraduate medical students have been described, with an emphasis on therapeutic decision-making. Based on
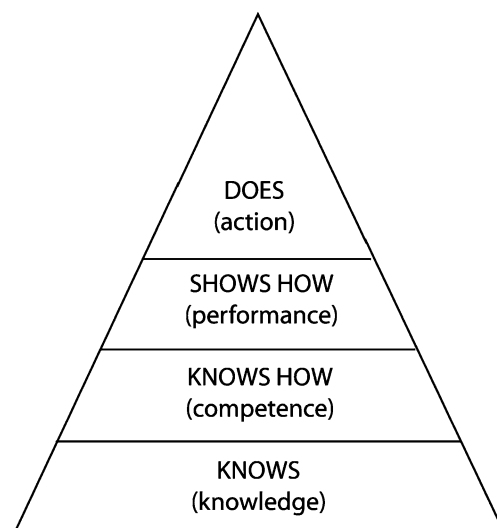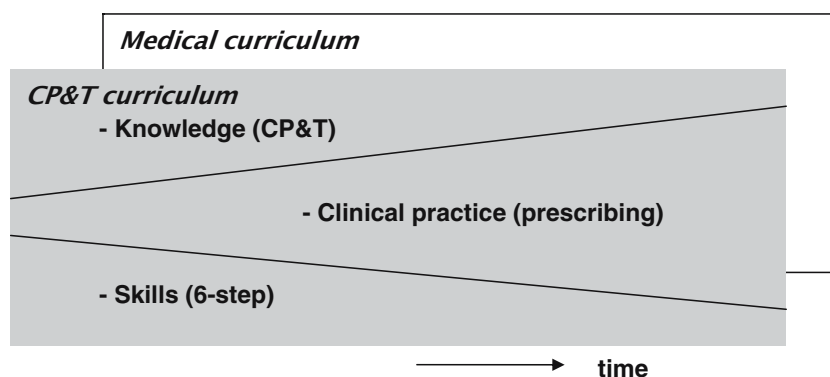

Fig. 2 'Pyramid' by Miller as an illustrative framework for discussing the assessment of clinical skills, competence and performance [33]

Fig. 3 A design of a clinical pharmacology and therapeutics (CP&T) context-learning curriculum (adapted from HJM van Rossum)

current theories of cognitive psychology and medical education, we have also discussed context-learning as an effective approach to teaching medical students how to prescribe rationally.

Until recently, there were only two groups of people who were permitted to prescribe drugs – registered medical practitioners and registered dental practitioners. Since 2006, some nurses, pharmacists and physician assistants have also been able to prescribe drugs for medical conditions within their area of competence [35]. Consequently, given this increasing number of registered prescribers with different qualifications, it has become increasingly important to train prescribers sufficiently in how to choose and prescribe drugs rationally. In addition, most curricula are changing from discipline- and subject-based *teaching* to competence and integrated or problem-based *learning*, resulting in less visibility of CP&T. The importance of teaching CP&T is further supported by the fact that many graduates still feel insufficiently prepared to assume prescribing responsibilities after graduation [7]. Furthermore, many hospital admissions and even deaths are caused by possibly avoidable medication errors [36].

Clinical pharmacologists should play an important role in the development of prescribing skills by teaching CP&T to undergraduate medical students. It is recommended that they formulate a CP&T context-learning curriculum within the medical curriculum – of course, in collaboration with physicians. This curriculum must be based on the final learning objectives of the CP&T education programme in which the required level of therapeutic competence of medical graduates has been determined. In addition, the curriculum must fulfil the criteria of context-learning, i.e. gaining knowledge and skills simultaneously in a (simulated) clinical practice setting. Furthermore, for the sake of clarity, it is stressed that the CP&T curriculum should be a visible part of the medical curriculum and that students must know, from the beginning, the required level of competence when they graduate. Current medical students often do not recognise the various CP&T teaching activities since they are scattered through the medical curriculum.

A draft of a CP&T context-learning curriculum is presented in Fig. 3. At the start of the curriculum, the emphasis lies on gaining CP&T *knowledge* and simultaneously learning to apply this knowledge by training *skills* in therapeutics. During this phase, little attention is given to the prescription of drugs in *clinical practice*. In the following study years, as CP&T knowledge and therapeutic skills increase, increased emphasis is given to prescribing in clinical practice, while the acquisition of knowledge and skills diminish. An example of a more specific CP&T curriculum is presented in Box 1.

In conclusion, effective undergraduate teaching of CP&T is essential to improve rational prescribing and will immunize students against factors that may induce irrational prescribing after graduation. Therefore, based on current knowledge about learning, cognitive psychology and research in therapeutic teaching, a CP&T curriculum should be a prominent part of the medical curriculum. The CP&T curriculum should also be linked to postgraduate and continuing education in order to maintain an optimal competence in rational prescribing after graduating. Finally, to achieve a CP&T curriculum, allies should be found because clinical pharmacologists can and should not work on this alone. Medical students are already allies; they are interested in clinical pharmacology and really want to learn how to prescribe drugs rationally. Physicians should also become allies, since they can provide the clinical context for teaching and can prevent students from copying the bad prescribing habits of some of the physicians that train medical students. Associate clinical pharmacologists must collectively determine the current state and perspectives of the undergraduate education of CP&T in Europe. To this end, a European research project, which is organised jointly by the EACPT and British Pharmacological Society, has recently been started.

Ultimately, clinical pharmacologists, students and physicians collectively may be able to convince the policy-makers, such as the faculty boards, of the need for a CP&T curriculum. Such a joint effort is truly necessary because, unfortunately, the following words, spoken by Miller in 1990, are, to a great extent, still valid: "*It will not be easy to convince conservative*

Fig. 4 Outline of a CP&T curriculum
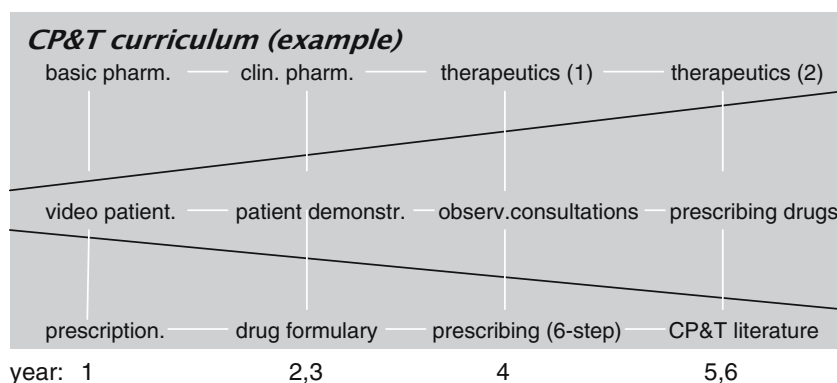
medical faculties, reasonably comfortable with the current conventions that allow clinical impressions to substitute for systematic accumulation of behavioural evidence, that change (in teaching, ed.) is in order".

Box 1. Illustration of a CP&T curriculum

Figure 4 shows the different learning activities and their mutual relations. The horizontal lines represent the three learning components: *knowledge* [upper line: basic pharmacology, clinical pharmacology, therapeutics (1) and therapeutics (2)], *clinical practice* (middle line: video patients, patient demonstrations, observation of consultations and prescribing drugs) and *skills* [lower line: prescription, drug formulary, prescribing (6-steps) and CP&T literature]. The vertical lines describe the simultaneous use of these three components in order to realise a context-learning curriculum.

Let us use the example of a clinical pharmacology department that provides a course of lectures in basic and clinical pharmacology during the first three years of a classical medical curriculum. The aim of the department is to expand its teaching activities and use the context-learning methodology as much as possible. Therefore, the lectures in basic and clinical pharmacology must be transformed according to the criteria of context-learning, i.e. by adding patient cases (clinical practice) and prescription writing (skills). For example, the lecture about 'P-450-dependent oxidation' is placed into the clinical context by presenting a video of a patient case illustrating a drug interaction as the result of a wrong drug choice (WHO step 3b). The lecture concludes by discussing the patient case according to the six-step approach, including how to write a new prescription [18]. The clinical pharmacology lectures in the second and third year can be transformed in a similar way by presenting real patients, followed by lectures on different classes of drugs. Simultaneously with the clinical pharmacology lectures, students must develop a personal drug formulary by, for example,

using an E-learning programme [3]. In the fourth year, students start on their clinical clerkships. In collaboration with their clinical colleagues, the clinical pharmacology department introduces a therapeutic assignment during these clerkships. Students must observe several consultations by clinicians in a structured way according to the WHO six-step approach and discuss these in small groups during therapeutic sessions with a clinical pharmacologist and/or physician. Concurrently, students must follow a skills training programme in order to learn how to prescribe rationally (six steps). During the clinical clerkships in the fifth and sixth years, prescriptions written by the students are evaluated by a clinical pharmacologist in collaboration with a physician and pharmacist during therapeutic sessions. Finally, students must attend a course on how to evaluate CP&T literature and how they must apply this knowledge in practice.

It is evident that in an integrated or problem-based medical curriculum it will be difficult to organise lectures. However, an advantage of this type of curriculum is that teaching is already centred on patient cases. As a result, clinical pharmacologists can introduce learning tasks with respect to basic and clinical pharmacology and therapeutics. In such a curriculum, it will probably be easier to train students in the six-step approach in small group-teaching sessions and practice prescribing in a clinical setting.

Obviously, there are various possibilities for context-learning teaching activities, and the above-mentioned are just a few examples of these. More detailed information on how to determine learning objectives for therapeutics and on methods for teaching and assessing therapeutics can be found in the WHO Teacher's Guide to Good Prescribing [37]. In addition, this guide also provides information on how to mobilise support for changing and implementing a CP&T curriculum and how to perform research in this field.

References

1. Wolff F (1970) Clinical Pharmacology Yesterday, Today, and Tomorrow. Chest 57(2):172–175
2. World Health Organisation (WHO) Study Group (1970) Clinical pharmacology scope, organization, training. World Health Organ Tech Rep Ser 446:5–21
3. Maxwell SR, McQueen DS, Ellaway R (2006) eDrug: a dynamic interactive electronic drug formulary for medical students. Br J Clin Pharmacol 62(6):673–681
4. Bircher J, Bogaert M, Dukes MN, Eichelbaum M, Gram LF, Huller H, Orme M, Sjoqvist F, Tognoni G (1988) Clinical pharmacology in Europe: an indispensable part of the health service. WHO Working Group on Clinical Pharmacology in Europe. Eur J Clin Pharmacol 33(6):535–539
5. Orme M, Reidenberg M (1989) The teaching of clinical-pharmacology in Europe and North-America. Trends Pharmacol Sci 10(6):224–226
6. Orme M, Sjoqvist F, Bircher J, Bogaert M, Dukes MN, Eichelbaum M, Gram LF, Huller H, Lunde I, Tognoni G; WHO Working Group on Clinical Pharmacology(1990) The teaching and organisation of clinical pharmacology in European medical schools. Eur J Clin Pharmacol 38(2):101–105
7. Han WH, Maxwell SR (2006) Are medical students adequately trained to prescribe at the point of graduation? Views of first year foundation doctors. Scott Med J 51(4):27–32
8. Nierenberg DW (1991) A core curriculum for medical-students in clinical-pharmacology and therapeutics. J Clin Pharmacol 31(4):307–311
9. Nierenberg DW (1990) A core curriculum for medical students in clinical pharmacology and therapeutics. The Council for Medical Student Education in Clinical Pharmacology and Therapeutics. Clin Pharmacol Ther 48(6):606–610
10. Walley T, Webb DJ (1997) Developing a core curriculum in clinical pharmacology and therapeutics: a Delphi study. Br J Clin Pharmacol 44(2):167–170
11. Walley T, Webb DJ (1997) Core content of a course in clinical pharmacology. Br J Clin Pharmacol 44(2):171–174
12. Orme M, Frolich J, Vrhovac B (2002) Towards a core curriculum in clinical pharmacology for undergraduate medical students in Europe. Eur J Clin Pharmacol 58(9):635–640
13. de Vries TP (1993) Presenting clinical pharmacology and therapeutics: the course in pharmacotherapeutics. Br J Clin Pharmacol 35(6):587–590
14. de Vries TP (1993) Presenting clinical pharmacology and therapeutics: evaluation of a problem based approach for choosing drug treatments. Br J Clin Pharmacol 35(6):591–597
15. de Vries TP, Henning RH, Hogerzeil HV, Bapna JS, Bero L, Kafle KK, Mabadeje A, Santoso B, Smith AJ (1995) Impact of a short course in pharmacotherapy for undergraduate medical students: an international randomised controlled study. Lancet 346 (8988):1454–1457
16. Frank JR, Langer B (2003) Collaboration, communication, management, and advocacy: Teaching surgeons new skills through the CanMEDS Project. World J Surg 27(8):972–978
17. Norman G (2005) Research in clinical reasoning: past history and current trends. Med Educ 39(4):418–427
18. de Vries TP, Henning RH, Hogerzeil HV, Fresle DA (1994) Guide to good prescribing. WHO, Geneva
19. Denig P, Haaijer-Ruskamp FM (1992) Therapeutic decision making of physicians. Pharm Weekbl Sci 14(1):9–15
20. Denig P (1994) Drug choice in medical practice. Ph.D. dissertation. University of Groningen, Groningen
21. Regehr G, Norman GR (1996) Issues in cognitive psychology: implications for professional education. Acad Med 71(9):988–1001
22. Schmidt HG, Norman GR, Boshuizen HP (1990) A cognitive perspective on medical expertise: theory and implication. Acad Med 65(10):611–621
23. Eva KW (2005) What every teacher needs to know about clinical reasoning. Med Educ 39(1):98–106
24. Geijteman ECT, Bissessur S, Aldulaimy M, Teunissen P, Richir MC, Arnold AER, de Vries TP (2007) A hypothetical model of therapeutic reasoning. Basic Clin Pharmacol Toxicol 101[Suppl 1]:53
25. Chastonay P, Brenner E, Peel S, Guilbert FF (1996) The need for more efficacy and relevance in medical education. Med Educ 30(4):235–238
26. Balla JI, Biggs JB, Gibson M, Chang AM (1990) The application of basic science concepts to clinical problem-solving. Med Educ 24(2):137–147
27. Charlin B, Tardif J, Boshuizen HP (2000) Scripts and medical diagnostic knowledge: theory and applications for clinical reasoning instruction and research. Acad Med 75(2):182–190
28. Norman GR, Schmidt HG (2000) Effectiveness of problem-based learning curricula: theory, practice and paper darts. Med Educ 34(9):721–728
29. Norman GR, Schmidt HG (1992) The psychological basis of problem-based learning: a review of the evidence. Acad Med 67(9):557–565
30. Coles C (1998) How students learn: the process of learning. In: Jolly B, Rees L (eds) Medical education in the millenium. Oxford University Press, Oxford, pp 63–82
31. Ashley EA (2000) Medical education – beyond tomorrow? The new doctor – Asclepiad or Logiatros? Med Educ 34(6):455–459
32. Vollebregt JA, van Oldenrijk J, Kox D, van Galen SR, Sturm B, Metz JC, Richir MC, de Haan M, Hugtenburg JG, de Vries TP (2006) Evaluation of a pharmacotherapy context-learning programme for preclinical medical students. Br J Clin Pharmacol 62(6):666–672
33. Miller GE (1990) The assessment of clinical skills/competence/performance. Acad Med 65[Suppl 9]:S63–S67
34. Harden RM, Gleeson FA (1979) Assessment of clinical competence using an objective structured clinical examination (OSCE). Med Educ 13(1):41–54
35. Avery AJ, James V (2007) Developing nurse prescribing in the UK. Br Med J 335(7615):316
36. Sheldon T (2006) Dutch doctors call for action on drug safety. Br Med J 333(7581):1238
37. Hogerzeil HV, Barnes KI, Henning RH, Kocabasoglu YE, Moller H, Smith AJ, Summers RS, de Vries TP (2001) Teacher's guide to good prescribing. WHO, Geneva