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CHAPTER 1

General introduction
1.1 Introduction

In medical education the notion of ‘integration’ has flourished during the past decade. The wish to improve integration has been at the basis of many curriculum reforms (Dahle, Brynhildsen, Behrbohm Fallsberg, Rundquist, & Hammar, 2002; Wilkerson, Stevens, & Krasne, 2009). This integration may concern integration of theory and skills by implementing patient encounters in preclinical programs (Yardley et al., 2010); integration of clinical disciplines, the so-called horizontal integration (Dahle et al., 2002; Eva, 2005); and integration of clinical and basic sciences, called vertical integration (Dahle et al., 2002; Wilkerson et al., 2009).

This thesis focuses on vertical integration. While medical teachers -clinicians as well as basic scientists- generally agree that educational programs should help students to integrate clinical and basic science (Koens, Custers, & Ten Cate, 2006), their lectures, assignments and clinical programs still do not always underline the importance of that integration, which results in recommendations for improvements (Irby, Cooke, & O’Brien, 2010). When it comes to an explication of the relations between clinical and basic science concepts, both tutors and students fall short, even when clinical patient cases are the starting point of the literature study as in a problem-based learning environment (Prince & Boshuizen, 2004). Obviously, it is not so easy explicitly to relate clinical and basic science concepts, neither for students nor for teachers.

Medical schools in the Netherlands are accommodated in academic hospitals. Faculty members of these hospitals can be characterized as highly experienced specialists in their domains. They are experts with extensive specialized knowledge and often researchers with an international reputation. Although interdisciplinary cooperation between clinicians and basic scientists in patient care and research projects occurs more and more, the two groups seem to speak different languages (Magnani, 1997). Explication of clinical and basic science viewpoints might help to bridge that gap, and hence contribute to vertical integration in medical education (Kinchin, Cabot, & Hay, 2008). By making their viewpoints explicit, clinicians and basic scientists can explore which concepts from their disciplines are related and how the meanings of these concepts are affected by these relations (Feltovich, Spiro, & Coulson, 1993). This might enable them to develop programs that help students to build up a knowledge base in which clinical and basic science knowledge are intertwined. By ‘clinical disciplines’ we mean disciplines such as internal medicine, gynaecology and surgery. Specialists in these disciplines have direct patient encounters. ‘Basic science’ refers to disciplines such as histology, anatomy, physiology, biochemistry, and pathology – these have in common that working in these disciplines does not entail patient encounters on a regular basis.
As a vehicle to explicate knowledge, the use of concept maps has been suggested (Coffey, Hoffman, Canas, & Ford, 2002; Hoffman & Lintern, 2006; Novak, 1998). For this research project, we have therefore chosen concept maps as an instrument to explicate disciplinary points of view. Concept maps aim to capture the complexity and elaborateness of subject-related knowledge (Novak, 1998) and thus relate disciplinary viewpoints on a subject. As an educational instrument they reflect the idea that a sound organization of knowledge is fundamental (Norman, Eva, Brooks, & Hamstra, 2006). In the studies described in this thesis, concept maps can have a variety of forms. However, they are always schematic overviews and have in common that they include concepts, clusters of concepts, hierarchical structures, and links between concepts.

The objective of this thesis is to unravel what integration of clinical and basic sciences entails, and to evaluate the role that concept maps can play in the explication of this integration. Investigating integration in concept maps requires a framework of features to describe it. Such a framework might help to understand what integration of clinical and basic sciences constitutes on the level of clinical problems. If medical teachers are to construct concept maps that visualize integration of clinical and basic sciences, specific instructions that focus on integration might help. It raises the question how and to what extent clinicians and basic scientists of different expertise levels can articulate integration in concept maps if they use such instructions. This information is useful for curriculum development because it underpins expectations about how and to what extent integration might be achieved.

The purpose of this chapter is to introduce the theoretical framework and to give an overview of this thesis. Because all studies presented in this thesis revolve around medical knowledge, we will first elaborate on the role of knowledge in clinical reasoning, and argue that current insights about this role should be transferred to medical education and hence to concept mapping instructions. We then describe the rationale of the use of concept maps in medical education, and the way in which knowledge is visualized in concept maps. Drawing on recommendations to transfer cognitive psychological insights to educational contexts (Regehr & Norman, 1996), we then review existing research on the knowledge base of clinicians and from that derive implications for the development of concept maps. Current insights into clinicians’ knowledge base inspired us to design concept mapping instructions which might help constructors to articulate integration in concept maps. We conclude this chapter with the research questions we formulated for our project, and outline how the four studies contributed to the answers.
1.2 Knowledge

1.2.1 Crucial role of knowledge

Medical preclinical programs aim to efficiently equip students with the knowledge and skills required to adequately handle patient problems during their clerkships (Boshuizen, 2004; Prince & Boshuizen, 2004; Wilkerson et al., 2009). The role of knowledge in this equipment of medical students has not always been evident (Norman et al., 2006). The studies by Elstein and colleagues revealed that knowledge is the most important component of clinical reasoning performance. In experienced clinicians, clinical reasoning performance could not be explained mainly by general problem solving skills, as was assumed at the time (Elstein, Shulman, & Sprafka, 1978). However, the assumption that general, content free heuristics plays a major role in clinical reasoning persevered among researchers. They focused on the reasoning strategies that were supposed to distinguish experienced clinicians from novices. According to Patel and Groen, the clinical reasoning of experienced clinicians relies principally on forward reasoning, i.e., assembling data about the patient while seeking for a pattern, whereas novices apply mainly backward reasoning, i.e., distilling hypotheses from patient data and checking these with more patient data (Patel & Groen, 1986). More recent studies show that novices and experienced clinicians can not be distinguished by the use of certain heuristics, and point to the flexible use of heuristics that distinguishes experienced clinicians from novices (Charlin, Tardif, & Boshuizen, 2000; Eva, Brooks, & Norman, 2002). Moreover, knowledge and a solid knowledge organization determine to a great extent success in clinical reasoning (Boshuizen & Schmidt, 2000; Elstein & Schwarz, 2002; Norman et al., 2006). This is in concordance with studies in other domains of expertise that show that a solid knowledge base is a major determinant for becoming an expert (Ericsson & Charness, 1994). Since then, the questions of what constitutes a solid knowledge base and how to develop it have dominated the research agenda (Boshuizen, 2004; Eva, Brooks, et al., 2002; Norman et al., 2006), and are relevant from the perspective of student learning.

The knowledge base of experienced clinicians is noted for its elaborate network in which clinical and basic science knowledge are integrated. It is this integration that makes it possible to solve clinical problems adequately and efficiently (Boshuizen & Schmidt, 2000). The task of medical education is to help students to develop such an integrated knowledge base (Boshuizen & Schmidt, 2000; Charlin et al., 2000) with the particular challenge to both students and teachers being the integration of clinical and basic sciences.
1.2.2 Transferring cognitive psychological research findings to medical education

Research on knowledge development in the medical field brought us many insights into the changes in medical knowledge organization when clinicians acquire expertise (Norman et al., 2006). Yet, it makes sense to explore whether and how these insights into the knowledge base of clinicians can be used for educational purposes (Norman, 2005a; Vosniadou, 1996).

The findings of cognitive psychological research on knowledge development and organization have indeed found their way into medical education, and have led to various more or less radical innovations that have proved fruitful for student learning. A first example is the trend to include patient problems and real patient encounters early in medical curricula. A rationale for this trend lies in learning theories, such as situated learning. Situated learning takes into account the organization of the long-term memory along semantic networks, i.e., mental networks in which abstract concepts and students’ own experiences are related (Custers, 1995; Regehr & Norman, 1996). Results of other studies in which the knowledge base of experienced clinicians and clinicians on lower expertise levels were compared also justify the adoption of early clinical experiences in medical curricula. Patient encounters account for the integration of clinical and basic science knowledge of residents and might thus enable students to link their basic science knowledge with clinical knowledge (Boshuizen, 2004). Research on the effectiveness of early patient encounters unequivocally shows benefits for motivation, performance and professional roles (Charlin et al., 2000; Yardley et al., 2010). A second example is teaching students to analyse patient problems by categorizing the symptoms, complaints and the data from lab research (De Vries, Custers, & Ten Cate, 2006). This approach goes back to insights about knowledge organization in illness scripts, which are knowledge networks of symptoms, complaints and other findings centred around a patient problem (Charlin et al., 2000; Custers, 1995). The categories of symptoms, complaints and lab data are supposed to coincide with these illness scripts, and they help students with their clinical reasoning tasks. A third example of cognitive psychological research being used in medical education addresses general problem solving skills. Research findings indicate that problem solving is domain specific (Elstein et al., 1978), implying that it relies mainly on domain knowledge. Thus, positive learning effects of problem-based learning curricula do not stem from the development of general problem solving skills, as was previously assumed. Its success in learning effects might be found in contextual learning, which fosters motivation and integration of clinical and basic sciences (Norman & Schmidt, 1992). Evidently, applying cognitive psychological insights
furthers the effectiveness of medical education and the understanding of students’ learning processes.

Notwithstanding these innovations in medical education, clerks still perceive their knowledge as insufficient, and feel their knowledge is structured in a way which does not fit their needs (Prince & Boshuizen, 2004). However, the amount of time spent on knowledge acquisition in the preclinical years seems to be substantial and cannot be expanded drastically. A solid knowledge base not only comprises a great deal of knowledge, it is also structured in such a way as to be accessible, so that new information can be understood (Anderson, 2005). Hence, it appears worthwhile to explore instruments that may help students to organize their knowledge rather than merely expand it, and help teachers to make their knowledge organization explicit.

In our studies we explored concept maps as an instrument to make integrated knowledge explicit. In this way, we wanted to take up the cognitive psychological insights mentioned above, in order to investigate teachers’ cognitions and behaviour regarding the integration of clinical and basic sciences. We transferred these insights in three different ways. The first insights we took on board were the domain specificity of clinical reasoning (Elstein et al., 1978; McGaghie, Boerger, McRimmom, & Ravitch, 1994) and the mental organization of domain specific knowledge (Custers, 1995; Norman et al., 2006; Van de Wiel, Boshuizen, Schmidt, & Schaper, 1999). Domain specific knowledge consists of both clinical and basic science knowledge (Norman et al., 2006) and is organized along semantic networks. By visualizing these semantic networks in concept maps, the constructors in our studies, i.e., groups of medical teachers focused on the domain specific component of clinical reasoning and were stimulated to relate relevant clinical and basic science disciplines. Moreover, the contribution of various disciplines in concept maps for educational purposes seemed pivotal. Teaching a clinical problem such as ‘pain on the chest’ from just a single discipline gives students a narrow view on the problem, which implies that educational concept maps should be constructed by teachers of different disciplinary backgrounds in cooperation. Second, we reasoned what were the implications of insights about the knowledge base of clinicians (Boshuizen, Bromme, & Gruber, 2004) for concept mapping instructions intended to improve the articulation of integration in these concept maps. Such instructions should help medical teachers to articulate the integration of clinical and basic sciences. Third, our point of departure for the construction of the concept maps were patient problems by which illness scripts of clinicians were activated (Custers, 1995) and subsequently explained in cooperation with basic scientists.
1.3 Concept maps

1.3.1 Explication of knowledge organization in concept maps

Schematizations such as concept maps, knowledge maps, and graphic organizers are used as educational tools (Nesbit & Adesope, 2006). What concept maps and knowledge maps have in common is that they provide an overview of all relevant concepts and their relations, in which concepts in concept maps are visualized in a hierarchic way. They support text processing by offering a scaffold that helps to interpret new information, they serve as communication tools for sharing knowledge (O’Donnell, Dansereau, & Hall, 2002), and are put forward as a knowledge elicitation technique (Hoffman & Lintern, 2006). Overall, the reported positive effects concern better recall of information, but vary depending on students’ ability level and instructional conditions (Nesbit & Adesope, 2006). The underlying mechanism that is supposed to account for the effectiveness of concept maps is that of meaningful learning. The activity of concept mapping actively engage students in searching for relations between their prior knowledge and new information (Novak, 2003). It is the explicitness of concept maps by articulating the knowledge of the constructors, whether students or teachers, that makes knowledge communicable.

It is not only the activity of concept mapping that contributes to positive learning effects, but the use of preconstructed concept maps is also reported to have positive learning effects (Nesbit & Adesope, 2006; Rendas, Fonseca, & Pinto, 2006). Preconstructed concept maps scaffold student learning by giving an overview of the relevant concepts and their relations, which students can use while studying literature. By explicating relations and providing an organizational framework of concepts, concept maps enrich and accelerate the learning process of medical students (Cutrer, Castro, Roy, & Turner, 2011; Rendas et al., 2006).

Concept maps also turn out to be valuable for curriculum development (Amundsen, Weston, & McAlpine, 2008; Harden, 2001; Weiss & Levison, 2000). They support teachers by displaying the concepts that should be adopted in a module, and so provoke discussions about what a student needs to know about a certain subject. Concept maps are a vehicle for sharing relevant knowledge between colleagues (Novak, 1998). Because of the overview they offer about a subject, concept maps have proved especially valuable for the development of integrated learning programs (Amundsen et al., 2008; Weiss & Levison, 2000).

1.3.2 Complexity of concept maps

If concept maps are constructed along the instructions as put forward by Novak, the founder of concept mapping (Novak, 1998), they become more elaborate as expertise
develops and are therefore a means to inform us about their constructors’ knowledge base (Kassab & Hussain, 2010; Novak, 2003). Experienced clinicians articulate more concepts, relations and hierarchical layers in the concept map than less experienced colleagues and students (Kassab & Hussain, 2010; Rendas et al., 2006; West, Pomeroy, Park, Gerstenberger, & Sandoval, 2000). Some factors have been identified that might influence the appearance of concept maps. A self-evident one is the instructions for constructing the concept map. These instructions influence how and what knowledge is evoked (Feltovich, Prietula, & Ericsson, 2006), affecting the concepts, their relations, and the way the concept map is structured (Ruiz-Primo & Shavelson, 1996; H. J. Schmidt, 2006). Schmidt (H. J. Schmidt, 2006) also mentions the influence of context on the appearance of concept maps, such as the kind of patient problems the constructors are used to handling in their own clinical discipline. Hence, as with any other instrument for eliciting knowledge, unequivocal conclusions about a constructor’s precise knowledge organization can not be distilled from concept maps. Concept maps inform us about the knowledge and the knowledge organization constructors are able to make explicit.

1.3.3 Concept maps and other schematizations

Concept maps should be distinguished from schematization formats such as flow charts and decision trees. In the field of medical education flow charts and decision trees are not unknown (Norman, 2005b). These schematizations visualize algorithms that help users to make decisions leading to a solution. However, they are of limited use when it comes to building a sound knowledge base. Visualized algorithms in a decision tree require clear-cut, well-defined problems (Eysenck & Keane, 2005), but most medical problems are rather diffuse; this hampers the choice of the right algorithm and blurs the pattern of successive phases in the decision tree (Feltovich et al., 2006). Whereas an algorithm leads step by step to the solution to a problem, medical problems are often too complicated to have just one, replicable solution. Every patient and every case is different; one can seldom claim that there is just one approach to handle the patient problem. Moreover, whether a problem is well-defined depends on the level of expertise of the problem solver. A problem might be very well defined to an experienced clinician who recognizes underlying patterns, but can still be ill-defined in the eyes of a novice (Koedinger & Anderson, 1990). Finally, the use of algorithms does not seem a characteristic of expert behaviour. Expert behaviour seems to be dictated by informal heuristics instead of fixed rules (Hoffman & Lintern, 2006). Flow charts and decision trees therefore seem of little help for the integration of clinical and basic sciences in the case of student learning.
Another schematization format that is used in medical education are the schemes as proposed by Mandin (Mandin, Jones, Woloschuk, & Harasym, 1997). These are claimed to represent the medical expert’s mental categorizations of knowledge. They do not guide decision taking step by step, as is the case with decision trees, but are supposed to represent expert knowledge organization by visualizing diagnostic categories (Woloschuk, Harasym, Mandin, & Jones, 2000). They are intended to serve as scaffolds and role models for students’ learning and clinical reasoning. The point of departure for constructing the schemes are diagnoses. Medical experts are requested to sort diagnoses along underlying -mostly basic science- principles (McLaughlin, Coderre, Mortis, Fick, & Mandin, 2007). As a consequence, the schemes as proposed by Mandin and colleagues visualize the categorizations of possible diagnoses that go with a clinical problem (Mandin et al., 1997); clinical concepts that concern history, physical examination, lab research and interventions are generally not included. Therefore, the integration of clinical and basic sciences remains mainly limited to relations between diagnostic categories and the underlying basic science categorization (McLaughlin et al., 2007). This is in contrast with concept maps, which aim to provide an overview. For medical knowledge, this overview entails clinical and basic science knowledge that clinicians deem relevant for understanding a clinical problem, including history, physical examination, lab research and interventions.

Hence, for the purpose of articulating relevant knowledge for understanding a clinical problem, including the integration of clinical and basic science knowledge, concept maps seem promising (Kinchin et al., 2008). As an elicitation technique (Hoffman & Lintern, 2006) they do not only elicit procedural and declarative knowledge (Feltovich et al., 2006) which make them suitable for gathering clinical knowledge such as history, physical examination, lab research and interventions. They can also elicit tacit knowledge, which is -as we will explain in 1.4- often basic science knowledge (Kinchin et al., 2008). Moreover, as an instrument for sharing knowledge (Nesbit & Adesope, 2006; Novak, 1998), they might be helpful when teachers develop educational programs. It seems therefore worthwhile to explore the value of concept maps for the improvement of integration in medical education.

1.4 Concept mapping instructions derived from clinicians’ knowledge base

What should be the content and structure of the concept maps that are supposed to support integration of clinical and basic sciences in educational programs? In this section, we will discuss research that has provided insights into the knowledge base of
clinicians, and the implications for the construction of concept maps for medical education.

1.4.1 Which concepts?

If we intend to use concept maps for student learning and curriculum development, we need to ascertain that the relevant knowledge is covered. Three kinds of knowledge figure in research on the knowledge base of clinicians: clinical knowledge, basic science knowledge, and experiential knowledge (Boshuizen et al., 2004; Norman, 2005a; Norman et al., 2006).

**Clinical knowledge**

In the diagnostic process that experienced physicians go through, clinical knowledge is crucial, and hence, this kind of information should be covered in concept maps. A patient who is coughing, has brown fingers and difficulty breathing immediately leads the clinician to the conclusion that this patient could suffer of lung carcinoma. For a lung specialist a few typical signs, symptoms and complaints, that is a minimum of clinical information are sufficient to take this diagnosis into account, without causal connections being considered.

Clinical knowledge comprises the whole network of signs, symptoms, complaints, results of lab research, and the accompanying diseases. This knowledge is time-based (Custers, 1995): data assembled by history taking limit the perspective on the information which will be collected during the physical examination and lab research. Part of the knowledge base of clinicians is the awareness of the bias that history taking introduces in the interpretation of data that have been gathered in the other phases of the clinical reasoning process. For the more experienced clinician, clinical knowledge is almost synonymous with the medical nomenclature that describes diagnostic categories used to communicate with other physicians (Norman, 2005a). Furthermore, knowledge about the course of diseases and how this course might be manipulated by interventions enables clinicians to intervene in the disease process (Custers, 1995).

Concept maps should reflect this wide extent of clinical knowledge, but a clinician’s knowledge is not just a bunch of data. Experienced clinicians know that certain patient data are more critical with respect to a particular disease than others, which symptoms and signs often co-occur, the extent to which these are typical of a disease, and the probabilities of diseases (Elstein & Schwarz, 2002). These clinicians use their knowledge flexibly, tuning it to the case under consideration, whereby some patient data outweigh others and justify a conclusion about the disease class, even if usual data are missing. Concept mapping instructions should therefore generate concept maps that prioritize, cluster and categorize clinical concepts.
A way of categorizing clinical concepts is to use semantic analogies and distinctions, a characteristic of clinical reasoning by experienced clinicians (Lemieux & Bordage, 1992). These so-called semantic qualifiers are organized along bipolar axes (e.g., time: acute versus chronic, sudden versus gradual; location: peripheral versus central, unilateral versus bilateral). An instruction to relate clinical concepts along these semantic qualifiers might help clinicians to complement and organize the clinical concepts in the concept map.

**Basic science knowledge**

That the knowledge base of clinicians includes basic science knowledge goes without saying. Whatever the philosophy of the curriculum, students are obliged to study basic sciences. It is therefore not surprising that years after graduation clinicians can still rely on their basic science knowledge base (Custers & Ten Cate, 2005).

Basic science knowledge is beneficial for the understanding and memorizing of signs and symptoms in patient cases (Feltovich et al., 1993; Pawlina, 2009; Woods, Brooks, & Norman, 2007; Woods, Brooks, & Norman, 2005), as it addresses the causal mechanisms of these clinical phenomena (Woods et al., 2005). Basic science concepts glue signs and symptoms into a coherent framework and enable the clinician to categorize these patient data (McLaughlin et al., 2007; Murphy & Medin, 1985). If the relations between clinical concepts and basic science concepts are articulated in the concept maps, students may see the cohesion between clinical data and this might help their understanding.

Yet, exactly what basic science knowledge is necessary for understanding clinical cases is not so obvious (Koens et al., 2006). Clinicians and basic scientists often agree about the need for knowledge of broad basic science concepts, but disagree about the level to which these concepts have to be acquired: organs, cells or molecules (Koens et al., 2006). Not surprisingly, basic scientists favour a more detailed level than clinicians do. It is tempting to argue that the level indicated by clinicians should settle the matter, because they know the context in which the basic science concepts need to be applied. However, this view fails to take into account that much of the basic science knowledge of experienced clinicians is tacit, and that clinicians therefore may not be aware of the wide extent of their basic science knowledge base (Boshuizen et al., 2004; Van de Wiel, 1997). They appear to use mainly clinical knowledge while solving routine problems. However, when experienced clinicians are confronted with non-routine patient cases, they revert to basic science explanations (Rikers, 1999). Thus, basic science knowledge appears to be relevant knowledge, but remains tacit in situations when pattern recognition suffices. It seems therefore wise to construct concept maps in the context of multi-disciplinary groups of professionals in the medical field: clinicians, anatomists, pathophysiologists and the like, so that
clinical and basic science viewpoints can be taken into account. Moreover, because complex patient cases evoke tacit basic science concepts, it is these cases that could be used during the construction of the concept map.

**Experiential knowledge**

Clinicians rely on their clinical and basic science knowledge for an analytic approach to patient cases. Besides this, experienced clinicians also use their experiential knowledge, that is their database of exemplars. Each exemplar addresses a patient case and its accompanying signs and symptoms, which enables clinicians to process new patient cases on the basis of similarity with these exemplars (Kulatunga-Moruzi, Brooks, & Norman, 2001). Students seem to profit from both approaches, which has led several authors to plead for an educational program that fosters both analytical and similarity-based approaches to clinical reasoning (Ark, Brooks, & Eva, 2006; Eva, 2005). For similarity-based reasoning students should build their own database of exemplars. If concept maps are constructed by teachers—either for curriculum development or for scaffolding student learning—teachers’ experiential knowledge is of little use to students, because their database of exemplars does not belong to the students’ experience. For the use of concept maps, this implies that students should add their own exemplars of patient cases.

1.4.2 Which relations? Integration of clinical and basic sciences

Thus, concept maps constructed by teachers with the purpose to support student learning should cover both clinical and basic science concepts. But how are clinical and basic science knowledge connected in the knowledge base of clinicians? Insights into these connections enable us to make decisions about how the two domains should be linked in concept maps.

Basic science and clinical knowledge have been considered distinctive mental representations, both with their own taxonomies (Patel & Groen, 1986). With its focus on organs, micro-organisms and cells, basic science consists of general principles and unsituated concepts; clinical knowledge, on the other hand, is based on taxonomies linking symptoms to diseases. Its concepts are situated (i.e., belong to a certain patient) and revolve around attributes of people (Magnani, 1997). Patel and Groen argued that the value of basic science knowledge for clinical reasoning is very limited and mainly shows up when clinicians are prompted to explain clinical findings (Patel & Groen, 1986).

This view on the relation between clinical and basic science knowledge has changed. In several studies the group of Boshuizen and Schmidt has demonstrated that experienced clinicians abbreviate their thought chains when analysing patient cases: in the online protocols they were much more concise and used fewer basic
Clinicians on lower expertise levels were much more elaborate in their analyses of patient cases and mentioned more basic science concepts (Boshuizen & Schmidt, 1992; Van de Wiel, 1997). In the long run, basic science knowledge becomes subsumed by clinical concepts and hence tacit, a process that seems to start with practical experiences during the clerkships. Integrating clinical and basic science knowledge takes time and is achieved after a process called ‘knowledge encapsulation’: basic science knowledge becomes encapsulated under higher order, clinical concepts. This accounts for the above mentioned finding that clinicians appear to use little basic science knowledge when analysing routine patient cases, and seem to rely mainly on higher order clinical concepts such as diagnostic categories (Boshuizen & Schmidt, 1992; Van de Wiel, 1997).

Although not all studies on the theory of knowledge encapsulation substantiated the theory (Van de Wiel, 1997), many did. In medical educational programs, it seems to be worthwhile to allocate time and attention to stimulating students to integrate the framework of basic science concepts with that of clinical concepts (Eva, 2005). Making clinical problems a point of departure of the concept maps, and subsequently explain them with the help of both clinicians and basic scientists, could facilitate the integration of basic science and clinical concepts. Moreover, links between clinical and basic science concepts that are articulated in concept maps could indicate the hierarchies via which higher order clinical concepts encapsulate basic science concepts.

Another view on the organization of the concept maps can be derived from studies on the use of causal relationships by experts (Cheng & Holyoak, 1985; Ericsson & Lehmann, 1996). There, the importance of causal relationships is construed into characteristic behaviour of experienced problem solvers who do not linger on the surface features of a problem, as novices tend to do, but restructure the problem along the lines of theoretical principles (Ericsson & Lehmann, 1996) and abstractions (Cheng & Holyoak, 1985). As stated above, basic science concepts provide a coherent framework which guides the interpretation of clinical concepts (Woods et al., 2007; Woods et al., 2005) as they indicate causal relationships between clinical concepts (Murphy & Medin, 1985). Although novices, such as clerks, usually do have knowledge of basic sciences and hence the underlying theoretical principles, they are still familiarizing themselves with a basic science concept in all its meanings, which often results in them not being able to easily use the concept for the analysis of patient cases. This causes erroneous clinical reasoning, as Feltovich and colleagues show via citations of think-aloud protocols of students’ medical problem analysing (Feltovich et al., 1993). Hence, novices experience difficulties with restructuring information from patient cases to causal basic science principles. Medical educational programs that
aim at strengthening the relations between basic science concepts and clinical concepts seem to be beneficial to student learning (Dahle et al., 2002; Wilkerson et al., 2009; Yardley et al., 2010). Basic science concepts could provide a framework for the organization of the clinical concepts in the concept maps, and hence contribute to the understanding of both basic science and clinical concepts.

1.5 Problem definition and research questions

1.5.1 Problem definition

The integration of clinical and basic sciences is a challenge in medical education. Internationally, medical schools are exploring ways to improve this integration in their curricula (Dahle et al., 2002; Harden, 2000). Integration of clinical and basic sciences fosters meaningful learning: basic science knowledge helps to understand clinical data (Woods et al., 2005), and vice versa: basic science concepts obtain meaning when they are linked to clinical contexts (Feltovich et al., 1993). However, the literature fails to offer insights into what integration of clinical and basic sciences entails on the level of clinical problems in educational contexts, and how it can be articulated. Therefore, a conceptual framework on the level of clinical problem does not exist. Describing the integration of clinical and basic sciences in concept maps is a first step in the development of such a conceptual framework.

From the viewpoint of integration, concept maps are supposed to be valuable (Kinchin et al., 2008; Weiss & Levison, 2000) for both curriculum development and student learning, in particular because concept maps articulate relevant knowledge. So far, concept mapping studies did not address the question how and to which extent integration of clinical and basic sciences could be articulated in concept maps. The explicit character of concept maps goes without saying, but it is an empirical question whether clinicians and basic scientists are able to articulate their shared knowledge and the relations between their knowledge domains. In this thesis we endeavoured to remedy these omissions.

Concept mapping is a technique that can be used in all kinds of domains (Novak, 1998). The general concept mapping instructions as proposed by Novak are therefore content-independent. Given the content specificity of clinical reasoning it seems legitimate to broaden the repertoire of instructions for concept mapping, and to add instructions inferred from research about knowledge organization and knowledge development in the medical domain. We therefore formulated concept mapping instructions that are in line with the characteristics of the knowledge base of clinicians and were derived from cognitive psychological research in the medical field,
with the intention to support the articulation of the integration of clinical and basic sciences.

Integration requires communication and cooperation between clinicians and basic scientists. In the literature about curriculum innovation the need for communication and cooperation between clinicians and basic scientists is acknowledged (Wilkerson et al., 2009) and the extent of communication is used as an indicator of the extent of integration in a curriculum (Harden, 2000). For the construction of concept maps that articulate the integration of clinical and basic sciences we assume communication and cooperation of clinicians and basic scientists to be a prerequisite. The activity of concept mapping in a multidisciplinary group actually is an act of communication and cooperation. Examining the process of concept mapping and the factors that stimulate or hinder cooperation in the group of constructors can help to clarify the integration that is visualized in the concept maps.

An additional aim of the analysis of the concept mapping process is for the process itself to inform us about the usefulness of the concept mapping instructions that we designed to facilitate the articulation of integration. The process might provide clues for improving them. This approach can be characterized as Design-Based Research. The concept mapping instructions we designed were grounded in cognitive psychological theory, put into practice in a semi-natural research environment, evaluated and refined. By using the instructions we also aimed to improve our theoretical insights into the integration of clinical and basic sciences (Barab & Squire, 2004).

1.5.2 Focus on teachers

The four studies in this thesis revolve around the medical teachers’ points of view on the development and use of concept maps. Successful implementation of educational innovations requires acceptance by teachers (Verloop, Van Driel, & Meijer, 2001). When teachers lack knowledge about an innovation, or the innovation does not harmonize with their beliefs about teaching and learning, it is not very likely that it will be successfully implemented (Janssen, Westbroek, Doyle, & Van Driel, 2013). The use of concept maps as a vehicle for enhancing integration is still in its infancy, and hence research in this domain is explorative. This exploration concerns the question whether teachers in the medical domain are able to articulate integration in concept maps, and teachers’ points of view on the use of concept maps that articulate the integration of clinical and basic sciences.

Teachers’ attitudes toward concept maps articulating the integration of clinical and basic sciences also concern their views on the importance of integration in medical education. It is difficult to imagine a curriculum that shows a high degree of
integration of clinical and basic sciences with clinical and basic science teachers teaching solely their own discipline. While teachers do adhere to integration on curriculum level (Dahle et al., 2002; Wilkerson et al., 2009), integration on the level of modules and clinical problems is harder to achieve (Koens et al., 2006; Prince & Boshuizen, 2004). Medical teachers are either clinicians or basic scientists. A first step towards teaching behaviour that facilitates integration is for clinical teachers and basic science teachers to communicate their knowledge and to explore the knowledge that is shared, i.e., the knowledge they agreed on (Harden, 2000; Wilkerson et al., 2009). Constructing concept maps is expected to contribute to knowledge sharing (Novak, 1998) and subsequently to the integration of clinical and basic sciences (Kinchin et al., 2008; Weiss & Levison, 2000). This research project combined both aspects: concept maps as an instrument to foster teachers’ articulation of integration, and as an instrument to enhance communication between clinical and basic science teachers. All studies included here focused on concept maps constructed by teachers, or potential teachers such as residents, and aimed to serve as a vehicle for curriculum development or student learning.

### 1.5.3 Research questions

In the four studies presented in this thesis we investigated the use of concept maps for the integration of clinical and basic sciences, by exploring this issue from four different angles: the way in which and extent to which integration is articulated in concept maps, expertise differences affecting the articulation of integration, the process of concept mapping in multidisciplinary groups, and the extent to which medical teachers perceived concept maps that articulate integration of clinical and basic sciences useful for medical education. We addressed these angles via the following research questions:

1. A. Can integration of clinical and basic sciences be articulated in concept maps, and to what extent, if instructions intended to support the articulation of integration are used?
2. B. What features describe integration in concept maps?
3. What consistent variations are found in concept maps constructed by groups of experts, and by groups of constructors at resident level?
4. Which factors affect the learning process of interdisciplinary groups of clinicians and basic scientists at different expertise levels if they jointly construct concept maps guided by instructions focusing on the articulation of integration of clinical and basic sciences?
5. Is the perceived usefulness of preconstructed concept maps, constructed collaboratively by groups of clinicians and basic scientists, affected by factors
such as teachers’ participation in the construction, the degree to which non-
constructing teachers share the content of the concept map, teachers’ prior
experience with schematizing or concept mapping, teachers’ need for change
to improve integration in their teaching practice, or the degree of articulated
integration in the concept maps?

1.5.4 Design of the research project and outline of this thesis

Between 2008 and 2010 ten groups of clinical and basic science specialists (experts)
and seven groups of clinical residents and basic scientists in training constructed
concept maps about a clinical problem within their domain of expertise. Each group
consisted of clinicians and basic scientists; the composition of the expert and resident
groups and the clinical problems of the concept map were equivalent. All groups of
participants were instructed to make a concept map in cooperation, following
instructions explicitly aimed at supporting the articulation of integration. All groups
met at least twice: in the first meeting the instructions were carried out and this
resulted in a draft concept map; in the second session, the concept map was refined
and corrected.

We assembled information about the resulting concept maps and the articulated
integration, the process of concept mapping, and the perceived usefulness of the
concept maps, by collecting both quantitative and qualitative data.

- The draft and the revised concept maps were analysed by means of an
  interpretation framework, to assemble information about the integration
  articulated in the concept map.
- A questionnaire was used to collect the experiences of the constructors
during the first session of concept mapping.
- The groups were videotaped and field notes were taken.
- All participants completed a questionnaire about their views on the
  usefulness of the final version of the concept maps for medical education.
- The same questionnaire about perceived usefulness, with additional
  questions, was sent to expert medical clinicians and basic scientists that are
  involved in medical undergraduate education in all eight medical schools in
  the Netherlands, one school in Belgium, and some teaching hospitals.

We expected this variety of data sources to contribute to an improved understanding
of the role of concept maps with respect to integration of clinical and basic sciences.

The theoretical considerations as described in this introduction were the
basis for the studies described in Chapters 2 and 3. In Chapter 2 the first research
question is addressed. The concept mapping instructions derived from the literature
on the knowledge base of clinicians are described. For this study, we investigated
whether groups of expert clinicians and basic scientists were able to use these instructions to construct concept maps that visualize integration of clinical and basic science. We conducted a descriptive study in which seven teams of three experts (clinicians and basic scientists) constructed a concept map about a clinical problem. Analysis of these concept maps resulted in a framework of features that portrayed integration in concept maps.

Chapter 3 deals with the second research question. Seven groups on resident level, whose composition was equivalent to that of the expert groups of Chapter 2, constructed concept maps by using the same set of instructions. Our hypotheses about consistent variations between expert and resident concept maps were derived from literature on the knowledge base of clinicians and of experts in general. Using the framework of features from Chapter 2, we were able to map out consistent differences between expert and resident concept maps.

Chapter 4 turns to the process of concept mapping, and here we tried to answer the third research question that aims to clarify the articulated integration. We investigated what were the enabling and disabling factors affecting groups of clinicians and basic scientists when they constructed concept maps. The concept mapping sessions described in Chapters 2 and 3 and of three additional expert teams were investigated further. By triangulation of three data sources we aimed to gain a comprehensive understanding of the process of concept mapping in multidisciplinary groups. We then applied the framework of features to the concept maps of the first and the second sessions, in order to examine whether medical teachers’ articulation of integration had changed over time. Videotapes of the sessions were analysed by means of a checklist matrix, with the focus on communication and cooperation between the participants. Moreover, the participants completed a questionnaire about the process of concept mapping.

In Chapter 5, the focus moves from the construction of concept maps to their perceived usefulness for medical education (research question 4). Both the constructors and clinicians and basic scientists who had not been involved in the construction of the concept maps completed a questionnaire, intended to measure the perceived usefulness of the concept maps for medical education and to investigate the factors that might affect teachers’ views on this usefulness.

In Chapter 6 we discuss the main findings and conclusions of the studies and the way they hang together. We evaluate the insights that we gained about concept mapping with respect to the articulation of clinical and basic sciences, and the instructions for constructing such concept maps, taking into account theoretical underpinnings and the limitations of the studies. Chapter 6 concludes with implications for education, and suggestions for further research directions. Figure 1.1 shows a schematic overview of the thesis.
Figure 1.1 Overview of the studies
References


Chapter 1


