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Mapping for meaning

**Using concept maps to integrate clinical and
basic sciences in medical education**

Sylvia Vink



ICLON, Leiden University Graduate School of Teaching

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Mapping for meaning

Using concept maps to integrate clinical and basic sciences in medical education

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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

further 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, McCrimmon, & 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

science concepts than in their pathophysiological explanations. 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?
3. 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?
4. 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.

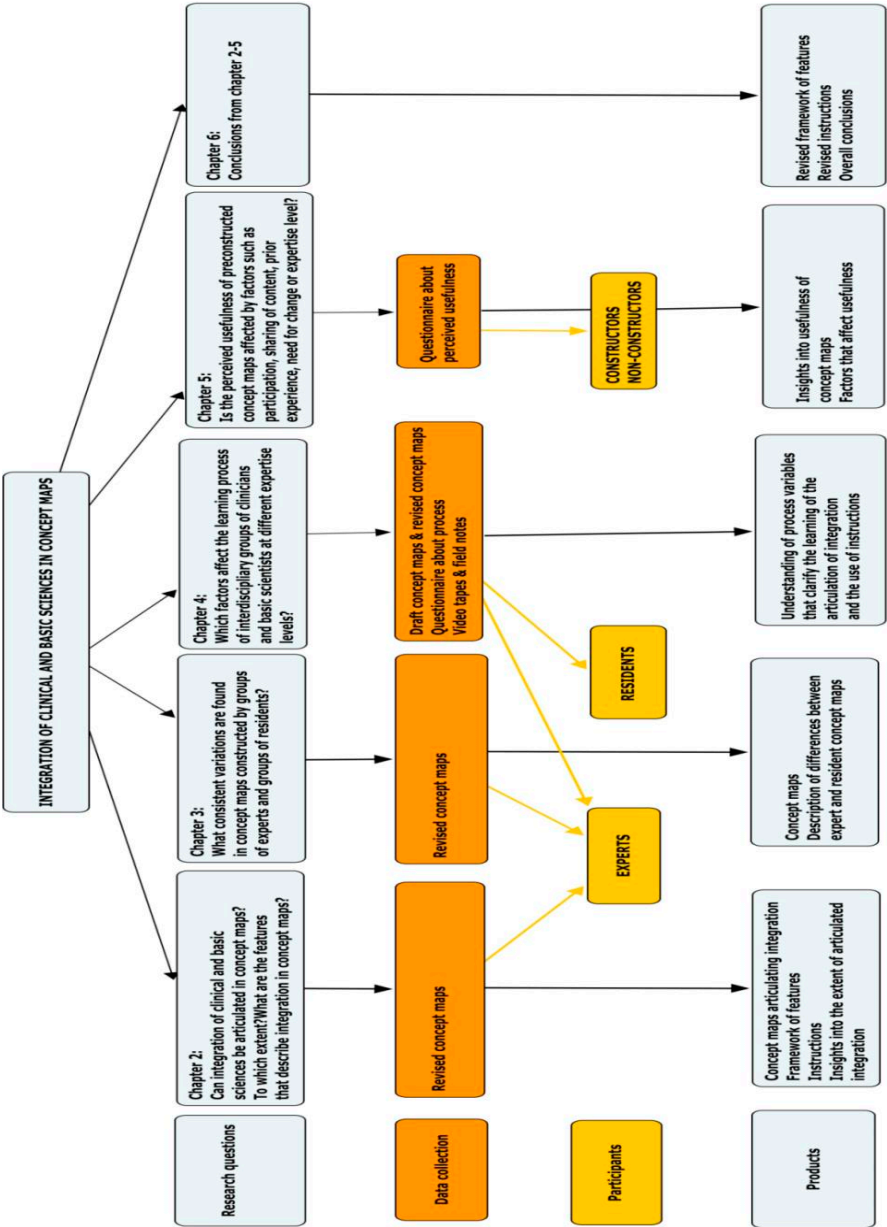


Figure 1.1 Overview of the studies

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CHAPTER 2

Towards integration of clinical and basic sciences in concept maps

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Submitted

Abstract

Background Concept maps are promising for medical education because of the potential to articulate integration of clinical and basic sciences.

Purposes The objectives were to examine whether and to which extent integration of clinical and basic sciences is articulated in concept maps and to develop a framework of features that described integration in concept maps.

Methods Teams of experienced clinicians and basic scientists constructed concept maps, using specific instructions that focused on integration. A framework of features, distilled from the data described the different ways in which clinical and basic science concepts were related. The additional value of each feature was checked by correlations.

Results Integration in the concept maps became apparent in varying degrees and different ways. One salient finding was that the teams preferred to link basic science concepts with diagnoses. Hierarchical relations were mainly articulated by the feature of clinical umbrella concepts that encapsulated basic science concepts. Correlations between features were moderate except between two features.

Conclusions This study provides a framework of features that adequately describes integration of clinical and basic sciences in concept maps. To improve articulation of integration and therefore the educational value, some adaptations of the instructions are suggested.

2.1 Background

For designers of medical curricula, the challenge is to develop a curriculum that effectively helps students to build a sound knowledge base encompassing the breadth and depth of clinical and basic science knowledge and to illuminate how both types of knowledge are integrated. Integration in medical curricula is often hindered by differences in approach, ways of thinking and taxonomy between basic sciences and clinical sciences (Magnani, 1997). Moreover, attention has been devoted to integration on curriculum level (Dahle et al., 2002), whereas clinical and basic science knowledge should also be related on a more micro level, such as clinical problems (Boshuizen & Schmidt, 2000; Rikers, Loyens, & Schmidt, 2004). A technique that might support both basic science teachers and clinical teachers to bridge the gap between their disciplines, in particular on the level of clinical problems, would therefore be welcomed. One option is to visualize clinical and basic science concepts and their relations in concept maps (Daley & Torre, 2010; Kinchin et al., 2008).

2.1.1 Integration of clinical and basic sciences in concept maps

A concept map is a schematic overview of hierarchically ordered concepts and their relations that are considered relevant for understanding a subject (Novak, 1998). Concept maps have been shown to be effective as scaffolds for text processing and as communication tools for sharing and organizing knowledge (Nesbit & Adesope, 2006; O'Donnell et al., 2002). In medical education, different functions of concept maps have been investigated (Daley & Torre, 2010; Mahler, Hoz, Fischl, Tov-Ly, & Lerna, 1991), showing their effectiveness in promoting meaningful student learning (Edmondson & Smith, 1998; Rendas et al., 2006) and for the development of a curriculum (Edmondson, 1995).

As an elicitation technique, concept mapping is particularly recommended as a tool for eliciting tacit knowledge, that is, knowledge used unconsciously (Coffey et al., 2002; Novak, 1998). This makes concept mapping promising for medical education. The potential of concept mapping to unveil basic science knowledge, often the tacit knowledge of clinicians, has been underscored (Kinchin et al., 2008; Rendas et al., 2006). Consequently, concept maps are put forward as an instrument to improve integration of basic and clinical information in medical educational programs (Daley & Torre, 2010; Pinto & Zeitz, 1997; Weiss & Levison, 2000).

In their review of concept maps used in medical education, Daley and Torre (Daley & Torre, 2010) identified a few publications that touch on the issue of integration between basic and clinical sciences in concept maps. However, the

concept maps in these publications encompass a limited number of diagnoses or symptoms in an overall pathophysiological concept map (Edmondson & Smith, 1998; Rendas et al., 2006) or -in case of one study- the concept maps are merely clinical (Torre, Daley, & Stark-Schweitzer, 2007). Studies focusing on other schematization formats of knowledge visualization emphasize basic science concepts and their relations with diagnoses (Mandin et al., 1997; McLaughlin et al., 2007). In none of the publications is integration of basic and clinical science concepts in concept maps defined.

Although concept maps appear to be promising regarding integration of clinical and basic sciences in medical education, it turns out to be not easy to construct concept maps that visualize integration. The articulation of both clinical and basic science concepts and their integration could be helped by instructions that explicitly aim to visualize this integration. Such specific concept mapping instructions could be distilled from research on knowledge and knowledge organization of clinicians, with a focus on how basic and clinical sciences are integrated in their knowledge base. Instructions that are consistent with knowledge and knowledge organization that should be acquired are expected to be helpful for teaching (Eva, 2005; Vosniadou, 1996). We assume that instructions that are congruent with the integrated knowledge base of experienced clinicians may support integration in concept maps.

2.2 Specific concept mapping instructions

In order to articulate integration of clinical and basic science concepts in concept maps, the instructions should affect the major elements of concept maps. They are the choice of concepts, the organization of the concept map and the links between concepts. Specifications of the concept mapping instructions and their theoretical rationale will be described.

2.2.1 Choice of concepts: working in multidisciplinary groups, using patient cases

Specific instructions might support decisions about the relevant clinical and particularly basic science concepts that should be adopted in concept maps. It is not so obvious which basic science concepts are necessary for understanding a clinical problem (Koens et al., 2006). Clinicians and basic scientists agree on the need for basic science knowledge, but they differ on the level of detail that is necessary for understanding a clinical problem (Koens et al., 2006). For some clinical problems, it

might be enough to know that certain basic science concepts exist, other basic science concepts require deep understanding before they are eligible for application in clinical contexts (Feltovich et al., 1993). Concept mapping instructions should aim to reconcile these different viewpoints. Basic science knowledge is often part of the tacit knowledge of experienced clinicians and can be elicited by complex patient cases (Feltovich et al., 1993). When experienced clinicians scrutinize a complex case, they reason along the lines of basic science categorizations (Boshuizen & Schmidt, 2000).

Not only the different viewpoints of clinical and basic sciences need to be bridged in an integrated concept map, clinical disciplines vary in their approach to clinical problems as well. Disciplinary variation is prevalent in which signs, symptoms and data are decisive for diagnostic conclusions (McGaghie et al., 1994; Norman et al., 2006). This is reflected in the choice of clinical concepts that are adopted in the map (McGaghie et al., 1994). Obviously, *the* preferred concept map about a clinical problem does not exist. Basic science concepts might help to reconcile these clinical disciplinary viewpoints in the concept map because they are part of disciplines' shared knowledge base (Norman, 2005a).

The first instruction aims to foster consensus about the choice of clinical and basic science concepts. Forming multidisciplinary groups consisting of both clinicians and basic scientists preclude a monodisciplinary view on a clinical problem (McGaghie, McCrimmon, Mitchell, & Thompson, 2004). Second, participants should contribute concepts from their own disciplinary viewpoint and this should be emphasized in the instruction in order to prevent predominance of one domain. Third, analysing complex patient cases can alleviate disciplinary frictions between clinical and basic science views and may facilitate discussions about the basic science concepts that should be incorporated in the concept map.

2.2.2 Organizing the concept map

Concept maps are hierarchically ordered by umbrella concepts subsuming detailed concepts (Novak & Gowin, 1984). Specific instructions for organizing the concept map should be congruent with insights into the organization of clinicians' clinical and basic science knowledge (Vosniadou, 1996). Research on strategies that clinicians use to analyse clinical problems has provided these insights.

One such a strategy is the abbreviation of the thought chains when diagnosing clinical problems. In think-aloud protocols of analyses of patient cases, experienced clinicians exhibit use of higher order clinical concepts making relatively scarce use of basic science concepts. They seem to rely mainly on clinical knowledge and the use of basic sciences appears to be minimal (Norman et al., 2006; Woods, Howey, Brooks, & Norman, 2006). However, experienced clinicians manifest a sound basic science

knowledge base when they are asked to give pathophysiological explanations. Basic science knowledge may not be expressed when routine patient cases are analysed aloud, but turns out to be implicitly supportive (Rikers et al., 2004). These findings are explained by the theory of knowledge encapsulation (Boshuizen & Schmidt, 1992, 2000). In the long run of clinical experience, basic science knowledge becomes 'encapsulated' by higher order clinical concepts and emerges when it is needed.

Another strategy of experienced clinicians is the use of basic science concepts to explain clinical phenomena. As in other domains (Koedinger & Anderson, 1990), experienced clinicians seek underlying causal mechanisms to explain clinical phenomena that they do not understand at first (Norman, 2005a; Norman et al., 2006; Woods et al., 2006). Causal, basic science mechanisms play this pivotal role in the knowledge organization of experienced clinicians (Woods et al., 2006). Basic science concepts glue the discipline-specific clinical knowledge together, helping to produce a coherent mental presentation of a clinical problem (Woods et al., 2005; Woods et al., 2006).

The knowledge organization of experienced clinicians enables them to use both strategies flexibly, depending on the complexity of the patient case (Eva, 2005; Norman et al., 2006). Two instructions might support the articulation of both strategies in the organization of the concepts in the maps. One instruction is in accordance with encapsulation theory and challenges constructors to organize the map along clinical umbrella concepts that encapsulate clinical and basic science concepts. The other instruction aims to organize the concept map along basic science umbrella concepts that subsume both clinical and detailed basic science concepts.

2.2.3 Linking clinical and basic science concepts

We do not expect all clinical and basic science concepts in a concept map to be hierarchically organized. Not only does encapsulation remain limited to 10-17% of the concepts in think-aloud protocols (Rikers, 1999), concepts are also related in a non-hierarchical manner, for instance, sequentially, as opposites (Lemieux & Bordage, 1992) or loosely connected (Magnani, 1997). In addition to hierarchical integration, an instruction to scrutinize which clinical and basic science concepts are related in some way or another and could therefore be linked, might contribute to the articulated integration in the concept map.

In Box 2.1, an overview of the concept mapping instructions is presented.

Box 2.1 Instructions for constructing concept maps about clinical problems. *In italics* are the instructions that aim to articulate integration of clinical and basic sciences

The group consists of three experts: at least one basic scientist and one clinician. The focus question is: what knowledge is relevant for a clerk to understand this clinical problem?

1. Write 4 relevant concepts. *Think of * signs, symptoms and complaints * relevant data from history and physical examination * additional diagnostics * diagnoses * relevant basic science concepts * interventions (medical and non-medical) and effects.*

Contribute concepts that are relevant from your own disciplinary perspective.

Collect the concepts. The group can categorize them in any way for the sake of overview. Repeat this procedure until the group decides that all relevant concepts have been covered.

2. Structure the collected concepts. *Try different strategies:*

** categorize the clinical concepts. A way to do this is to categorize them along axes (acute versus chronic, central versus peripheral etc. Discuss alternative ways of organizing the clinical concepts. Does this way of categorizing affect the way the basic science concepts should be organized? Do clinical concepts encapsulate basic science concepts? These inclusive clinical concepts are often the words which doctors use in order to communicate efficiently.*

** Categorize the basic science concepts. Does this way of categorizing affect the way the clinical concepts should be organized?*

** Create hierarchical structures: which concepts are the most inclusive ones and which concepts are subsumed by these inclusive concepts? Create a concept map.*

3. Relate the concepts by using lines and arrows. *Are there any (e.g. causal, sequential) relations between clinical and basic science concepts? Give extra attention to the relations between basic science concepts and clinical concepts.*

Indicate the kind of relation.

4. Read the following two patient cases.

(...)

The clinician of the group summarizes and analyses the case. The other participants listen for whether the clinician uses words/concepts which are not yet in the concept map. Add these concepts. Check whether the patient case can be explained by means of the concept map. Link the concepts.

Are there any (clinical and basic science) concepts placed in different domains of the map that can be linked or subsumed by an umbrella concept?

2.3 Purpose

The purpose of this study was to explore whether integration of clinical and basic sciences could be articulated in concept maps, and to which extent. Concept mapping is considered a promising technique for the articulation of integration (Kinchin et al., 2008; Pinto & Zeitz, 1997). However, previous studies have shown that integration is not easily expressed in concept maps, nor do these studies define the characteristics of integration in concept maps (Edmondson & Smith, 1998; Rendas et al., 2006). Specifications of the concept mapping instructions that are inferred from the literature about the integrated knowledge base of clinicians aim to support the articulation of integration. The concept maps that we aimed to develop pertained to internal clinical problems to ensure that basic science knowledge supports understanding of the clinical problem (Custers, 1995; Norman et al., 2006). Investigation of integration in concept maps requires operationalization of integration: what features describe integration in concept maps? In this study, we also ventured to develop a framework of features that may adequately describe integration of clinical and basic sciences in concept maps.

2.4 Methods

2.4.1 Participants and procedure

Seven groups of three medical experts -always at least one clinician and one basic scientist- cooperated to construct a concept map about a clinical problem in two two-hour sessions. An expert was defined as having at least 5 years' experience in his field. Each group schematized one clinical problem. The study covered different clinical problems to avoid content specificity of the findings: coughing, diarrhoea (2X), proteinuria, blood in faeces, chronic abdominal pain in women, and articular pain.

In the first session, participants were guided through all concept mapping instructions including the instructions aiming to integrate clinical and basic science concepts (see Box 2.1). A hand-out of the instructions was provided. Post-it notes and big paper sheets were used to make the concept maps, as we experienced that this “physical” way of working contributed to breaking the ice and to lively communication, which we felt were prerequisites for achieving integration in the concept map. After the first session, the concept maps were digitized as accurately as possible using *Inspiration@*, a software tool for drawing concept maps. In the second session, participants checked that no mistakes had been made during digitization and were encouraged to discuss, review and refine the ordering and relations between the

concepts. The institutional board of the medical centre where the experiments were conducted provided ethical approval for the study.

2.4.2 Data analysis

The specific concept mapping instructions were congruent with insights on the integration of clinical and basic sciences in the knowledge base of clinicians. Hence, the concept maps were expected to visualize integration.

To assess the contribution of both clinical and basic science viewpoints to the concept map, the number of clinical concepts (history, physical examination, signs and symptoms, lab, diagnoses, interventions) and basic sciences concepts were counted. In Appendix 1, the grey coloured nodes are interpreted as basic science concepts. We then developed a framework of features driven by the data, whereby features were defined, redefined and clustered (Miles & Huberman, 1994). Two researchers identified features, coded all concept maps along these features and refined the definition of the features. Discussions resulted in the final framework of features addressing two broad categories: the organization of clinical and basic science concepts and the links between clinical and basic science concepts. A third researcher counted occurrence of these redefined features. Part of the data was analysed by a fourth researcher in order to check the interrater reliability of the analysis. Cohen's kappa ranged from .87 to 1.00. The mean Cohen's kappa was .95.

Integration expressed by organization

Integration in the organization of concept maps was addressed by three features:

- Clusters: clusters are two or more concepts that are grouped close to each other, expressing that the concepts have some kind of a relation. In Appendix 1, the upper group of concepts (hemopteo, colour sputum etc.) is interpreted as a cluster but this same cluster with child/adult and ethnicity is considered as another cluster. We compared the total number of clusters and the number of clusters that comprised both clinical and basic science concepts.
- Umbrella concepts: we counted umbrella concepts that subsume other concepts in a hierarchical manner and distinguished general umbrella concepts (such as diagnostic methods and therapy in Appendix 1) and umbrella concepts that are specific to a clinical problem (such as mechanic stimulus and inflammation in Appendix 1). We hypothesized that the use of general umbrella concepts would correlate negatively with the features that described integration because they subsume concepts of one discipline or one phase of diagnostic reasoning. This precludes the integration of clinical and basic sciences. Although clinical-problem-specific umbrella concepts are

not a feature of integration in itself, they are expected to correlate positively with the features of integration.

- Hierarchies: a hierarchy consists of an umbrella concept including the concepts that are subsumed by the umbrella concept. We distinguished two types of hierarchies. First, hierarchies structured by clinical umbrella concepts encapsulating basic science concepts, reflecting the instruction to visualize encapsulation of basic science concepts by clinical concepts. An example of this is smoking that encapsulates inflammation and dysfunctional mucociliary clearance in Appendix 1. Inflammation and dysfunctional mucociliary clearance are the biomedical processes that explain cough in patients who smoke. Second, hierarchies structured by basic science umbrella concepts subsuming clinical concepts, reflecting the instruction to organize clinical concepts along a basic science framework. In Appendix 2, one example of this hierarchy is the grey node 'tractus digestivus high', subsuming the clinical concepts 'loss of weight', 'loss of blood', 'epigastricdiscomfort', 'gastric acid' and 'nausea/vomiting'.

Integration articulated by links

In our framework of features, links between (clusters of) clinical and basic science concepts were interpreted as a reflection of integration, regardless of the kind of relation (hierarchical or non-hierarchical). A link always connected (clusters of) clinical and basic science concepts directly. Indirect relations, as can be found in hierarchical structures, were not interpreted as links. In Appendix 1, the production bronchial tree secretion and hypersecretion cluster is linked with the therapy cluster.

Additionally, the integrated clusters, hierarchies and links were further analysed, mapping out relations between basic science concepts and clinical concepts: 1. history and physical examination, 2. lab research, 3. diagnosis, 4. interventions. In this way, we could gauge the role of integration in the different phases of clinical reasoning. In some studies (Mandin et al., 1997; McLaughlin et al., 2007), integration of clinical and basic science concepts is largely limited to diagnoses. We were interested in what clinical concepts were preferably connected with basic science concepts when participants were encouraged to cover both domains in the concept map.

Combination of integrative features

Finally, Pearson correlations were run in order to check whether the features that we used, contributed to our framework of operationalization of integration. The features together should measure integration. Because of the limited number of concept

maps, correlations remained indicative and were not expected to reach significance levels.

2.5 Results

Table 2.1 gives an overview of the number of clinical and basic science concepts and the features describing integration. There was a strong preference for clinical concepts (mean 70.7, SD 19.7) over basic science concepts (mean 19.1, SD 7.6): 79% of the concepts were of clinical origin. The concept maps about proteinuria and cough showed a relatively high proportion of basic science concepts (42 and 37%), the lowest proportion of basic science concepts was 10% in the concept map of chronic abdominal pain.

2.5.1 Integration expressed by organization

As Table 2.1 shows, not all features that aimed to measure integration could be found in each map. For the sake of brevity therefore, Table 2.1 does not show the figures about the role of integration in the different phases of the clinical reasoning process for each feature. Although clustering was a frequently used device to organize the concepts: an average 89.9 concepts were clustered in 20 clusters, just three concept maps (proteinuria: 53%, diarrhoea 2: 16% blood in faeces: 13%) contained clusters that combined clinical and basic science concepts. Further inquiry into these integrated clusters revealed that only in the proteinuria concept map, were basic science concepts clustered with concepts concerning history and physical examination (2 clusters), lab (1 cluster) and diagnoses (7 clusters). In the other maps, integrated clustering remained confined to diagnostic categories.

Clinical-problem-specific umbrella concepts were used more frequently (mean 9.6, SD 3.3) than general umbrella concepts (mean 5.3, SD 3.8). Table 2.2 shows that the frequency of general umbrella concepts correlated negatively with both the frequency of all features expressing integration and the number of basic science concepts.

There was a slight preference for hierarchies with clinical umbrella concepts encapsulating basic science concepts (mean 2.9, SD 3.9) although in two maps this way of organizing integration did not occur at all (Table 2.1). Basic science concepts that subsumed clinical concepts were used in only three concept maps whereby the map of proteinuria relied to a notable extent on this form of organization. Both types of hierarchies covered mainly diagnostic concepts. Only in the map of proteinuria, did basic science umbrella concepts subsume diagnoses, history and physical examination

and lab data. Proteinuria was an exception in more respects. It covered the highest number of basic science concepts, of integrated clusters, of clinical-problem-specific umbrella concepts and basic science concepts that subsumed clinical concepts addressing different phases of the clinical reasoning process.

2.5.2 Integration articulated by links

The concept maps contained an average of 6.9 links (SD 4.8) between clinical and basic science concepts. Integration by linking was used in all concept maps. Table 2.1 shows therefore the integrated links in the different phases of clinical reasoning. Although basic science concepts were mainly linked with diagnoses, links with history and physical examination, lab research and intervention also occurred.

2.5.3 Combination of integrative features

The correlations in Table 2.2 enabled us to check whether each feature contributed to our operationalization of integration in the concept maps. Due to the limited number of concept maps, significance levels were hard to reach. However, there was a very high, significant correlation of .99 ($p<.01$) between clusters that contained clinical and basic science concepts and hierarchies that were structured along basic science concepts. Salient were the negative correlations between clinical concepts and the organizational features of integration, whereas basic science concepts' correlations with all features of integration were positive. Moreover, the correlations of the latter were moderate (0.38 - 0.59) which is also illustrated in Table 2.1: concept maps with the lowest percentages of basic science concepts, painful joints and chronic abdominal pain, exhibited low numbers of integrated features.

Table 2.2 Correlations between characteristics of the concepts maps

Characteristics	Concepts		Clusters	Umbrella concepts		Hierarchies	
	clinical	basic science	clinical & basic science	general	clinical-problem-specific	clinical	basic science
clinical concepts	1						
basic science concepts	-.78*	1					
clinical & basic science clusters	-.47	.57	1				
general umbrella concepts	.76*	-.73	-.43	1			
cl.-problem-spec. umbrella concepts	-.42	.42	.62	-.61	1		
clinical hierarchies	-.14	.38	-.15	-.67	.23	1	
basic science hierarchies	-.50	.59	.99*	-.47	.65	-.12	1
links	.08	.51	.35	-.32	.28	.53	.33

* $p<0.05$

2.6 Conclusions and discussion

Research on integration of clinical and basic sciences in medical education has mainly focused on curriculum level (Dahle et al., 2002; Harden, 2000). Concept maps can be used to visualize integration at both curriculum and clinical problem level. However, studies on concept mapping have not yet produced concept maps that show overwhelming integration of basic and clinical sciences, nor described the features that expressed integration. In this explorative study, we attempted to visualize integration of clinical and basic sciences by using specific instructions for constructors of concept maps.

2.6.1 Instructions to foster integration

The seven concept maps in our study visualized integration and differed from concept maps in other studies in the following respects. While concept maps in most studies mainly present the basic science viewpoint (Edmondson & Smith, 1998; Pinto & Zeitz, 1997), the concept maps in our study emphasized clinical concepts. This emphasis might be generated by the breadth of the clinical concepts (e.g. history, physical examination, lab, interventions) that was requested during concept collection.

Clustering was a frequently used organizational device. In contrast to concept maps in other publications showing a 'tree organization' (Rendas et al., 2006; Torre et al., 2007), the presence of clusters in the maps of this study stands out (c.f. Appendix 1). The clusters often follow the –for clinicians familiar– clinical reasoning process. Clustering might be a strategy to keep an overview over an abundance of clinical concepts.

However, clusters were not often employed to visualize integration. In only three maps, were there clusters that covered both clinical and basic science concepts. Integration was more often visualized in the hierarchical organization of the concept map with a slight preference for higher order clinical concepts that encapsulated basic science concepts and in the links between concepts. Integration in organization and links were represented in all concept maps, but the extent varied greatly. In other studies (Edmondson & Smith, 1998; Pinto & Zeitz, 1997; Torre et al., 2007), integration is confined to basic science umbrella concepts subsuming clinical concepts, probably due to a limited number of clinical concepts.

The correlations between basic science concepts and the features of integration were moderate, suggesting that basic science concepts are prerequisite for articulating integration in concept maps that emphasize clinical aspects. There might even be a threshold of basic science concepts to express integration. The concept maps with the lowest number of basic science concepts –chronic abdominal

pain and painful joints—encompassed a very low number of integrative clusters, hierarchies and links. Moreover, moderate correlations indicated that the adoption of basic science concepts in concept maps does not automatically induce a congruent number of integrated clusters, hierarchies and links.

The concept maps of this study visualized integration of clinical and basic sciences, albeit not all features were equally prominent. In terms of integration, they differed from concept maps in previous research (Edmondson & Smith, 1998; Mahler et al., 1991; Pinto & Zeitz, 1997; Torre et al., 2007). This suggests that instructions can manipulate the appearance of the concept maps, as suggested by Schmidt (H. J. Schmidt, 2006), although causal relations between instructions and integration in the concept maps are hard to verify (Norman et al., 2006).

2.6.2 Features of integration

The manifestations of the features allowed us to describe integration in concept maps. First, integration in concept maps can be described as the hierarchical organization of clinical concepts encapsulating basic science concepts. Second, integrated organization can be expressed by basic science concepts subsuming clinical concepts. Both hierarchies address mainly integration between diagnostic categories and basic science concepts. Given the very high correlations between clusters covering clinical and basic science concepts and basic science concepts subsuming clinical concepts, these features seemed to overlap. For the definition of integration in concept maps, one of these features suffices. Third, links between basic science concepts and clinical concepts constitute integration whereby clinical concepts concern history and physical examination, lab, diagnoses and interventions. Finally, we propose a fourth feature that helps us to describe integration in concept maps: integration requires a minimum of basic science concepts and clinical concepts. In the concept maps in our study that covered less than 16% basic science concepts, integration was hardly articulated in organization and linking.

2.6.3 Improvement of integration in concept maps

To our knowledge, this is the first study that explicitly aimed to visualize integration of clinical and basic sciences in concept maps. The data show that integration can be articulated in concept maps. For both curriculum development and student learning, such concept maps might be helpful. However, we still seek ways to improve the articulation of integration.

General umbrella concepts seemed to hinder integration; they correlated negatively with the features that described integration. It therefore seems wise to

encourage concept map constructors to choose umbrella concepts that are clinical-problem-specific and to leave out general umbrella concepts.

Integration in concept maps became apparent merely by the relation between basic science concepts and diagnoses and did not affect history, physical examination, lab research and interventions to the same extent. This phenomenon is in accordance with the limited integration in schematizations in other studies (Mandin et al., 1997; McLaughlin et al., 2007). Experienced clinicians seem to have a hard time explicating the relations between basic science concepts and clinical concepts other than diagnoses. The challenge is to develop concept maps that incorporate relations between basic science concepts and concepts concerning history, physical examination, lab research and intervention, because these relations enable students to interpret patient cases (Norman et al., 2006; Woods et al., 2005). This might be attained by the adapted instruction to select the clinical findings from the patient cases (see Box 2.1, step 4) and subsequently relate them to the basic science concepts that are chosen as umbrella concepts in step 2.

Another adaptation of the concept mapping instructions concerns integrated organization. Integrated organization might be enhanced when the construction process starts with the analysis of patient cases instead of using the patient cases as a last step for verifying the concept map. In the studies of Van der Wiel, the task of analysing patient cases evoked clinical higher order concepts (Van de Wiel, 1997). Starting with the analysis of patient cases might thus prime hierarchal integration along clinical higher order concepts.

2.6.4 Limitations and further research

We were only able to include a limited number of concept maps in this study. Our conclusions are therefore tentative. The concept maps revolved around clinical problems in the domain of internal medicine. We expect that the features describing integration might be applicable in concept mapping research in other medical disciplines as well. However, a disciplinary bias cannot be excluded, as is suggested by the high standard deviations and the somewhat deviant organization of the concept map about proteinuria that resembles other scheme formats about nephrotic clinical problems (McLaughlin et al., 2007). In psychiatry or dermatology, basic science knowledge plays a different role from that in internal medicine (Norman, 2005a). This might influence the presence of the features.

The instructions were based on research about the knowledge base of clinicians with the same expertise level as our participants: experienced clinicians and basic scientists. A follow-up study addressing application of these instructions by residents may result in different manifestations of integration. Residents might

organize their concept maps in a different way from experienced clinicians. The theoretical framework of encapsulation predicts that concept maps of residents will cover more basic science concepts than the expert maps, because their basic science concepts are 'less tacit' due to less encapsulation (Boshuizen & Schmidt, 2000; Van de Wiel, 1997). Residents might consequently rely more heavily on basic science organization than experts do. Further study should therefore focus on differences between concept maps of residents and experienced clinicians in terms of articulated integration, for such differences might be interesting for the role of residents as teachers or as curriculum developers.

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CHAPTER 3

Consistent variations between concept maps constructed by medical experts and residents

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Abstract

Background Preconstructed concept maps are valuable for integration of clinical and basic sciences in medical education. They are mainly constructed by experts. However, concept maps constructed by residents are hypothesized to be less complex and to contain more basic science concepts organizing the map. Experts are expected to articulate more links between clinical and basic science concepts.

Aim To investigate consistent variations, particularly regarding integration of clinical and basic sciences, between expert and resident concept maps.

Method Seven multidisciplinary expert teams and seven teams of residents with an equivalent disciplinary composition constructed a concept map. The concept maps were analysed along a framework of features that described integration of clinical and basic sciences.

Results The hypotheses were partly verified: the residents used basic science concepts as a device to organize the clinical and basic science concepts. However, their concept maps also exhibited a significantly higher degree of organization and links between clinical and basic science concepts, thereby articulating links between basic science concepts and history, physical examination, lab research and diagnoses. Integration in experts' maps concerned mainly diagnoses.

Conclusions The explicitness of resident concept maps resembles the 'intermediate effect' reported by medical expertise studies. By using more organizational devices, resident concept maps seem to surpass expert maps in complexity.

3.1 Introduction

During their training, medical students need to learn to connect their clinical and basic science knowledge in order to become proficient doctors (Boshuizen, 2004; Boshuizen & Schmidt, 2000). Medical curricula aim to scaffold this learning (Dahle et al., 2002). For helping students to develop a knowledge base that integrates clinical and basic sciences, schematizations such as concept maps seem to be promising (Daley & Torre, 2010; Kinchin et al., 2008). Concept maps articulate concepts and their interrelations in a hierarchical way (Novak, 2002) and thus visualize the relations between clinical and basic science concepts that should be understood in order to understand a medical subject (Kinchin et al., 2008; Weiss & Levison, 2000). Students can construct concept maps by themselves (Daley & Torre, 2010; Edmondson & Smith, 1998) but concept maps that are constructed by teachers (hereafter referred to as 'preconstructed concept maps') also scaffold student learning (Cutrer et al., 2011; Rendas et al., 2006; Weiss & Levison, 2000).

3.1.1 Level of expertise

Using preconstructed concept maps in medical education raises the question of how complex they should preferably be. The complexity of a concept map, that is the number of concepts, links and layers in hierarchies (Novak, 2002), increases with the expertise of its constructor (Edmondson & Smith, 1998; Rendas et al., 2006). Some authors take the position that for undergraduate medical programs preconstructed schematizations such as concept maps should preferably be constructed by experienced clinicians or basic scientists in order to foster the development of an expert-like knowledge organization (Coderre, Mandin, Harasym, & Fick, 2003; Mandin et al., 1997). However, concept maps that are constructed by experts might not be optimal for educational purposes. They might be too complex and consequently impose a task on students that is too far above their current knowledge level. It is then unlikely that learning will take place (Kirschner, Sweller, & Clark, 2006).

We do not know how and to what extent integration of clinical and basic sciences is articulated in concept maps that are constructed by experts and experienced medical teachers. Nor do we know whether concept maps that are constructed by constructors on different expertise levels, such as medical experts and residents, differ consistently with respect to articulation of integration of clinical and basic sciences. Experts and residents possess both theoretical and practical medical knowledge but differ in the way that clinical and basic science knowledge are embedded in their knowledge base (Boshuizen, 2004; Boshuizen & Schmidt, 1992). This difference might be visualized in their concept maps because they visualize the

constructors' understanding (Kassab & Hussain, 2010; Rendas et al., 2006; West et al., 2000).

3.1.2 Integration of clinical and basic sciences in concept maps

Literature on the knowledge base of clinicians has fuelled expectations about the articulation of integration of clinical and basic sciences in concept maps (Boshuizen & Schmidt, 1992, 2000; Eva, Norman, Neville, Wood, & Brooks, 2002; Feltovich et al., 1993). There appear to be salient differences between experts and residents with respect to the organization of their knowledge base and the way that clinical and basic science knowledge is related. Such insights enable us to hypothesize differences in concept maps of experts and residents.

The first difference might be in the articulation of basic science concepts. As medical expertise develops, basic science knowledge gradually becomes encapsulated by clinical concepts as a consequence of clinical exposure. This is evidenced by studies showing that medical experts mention fewer basic science concepts when they diagnose patient cases (Boshuizen & Schmidt, 1992; Van de Wiel, Boshuizen, & Schmidt, 2000) than residents that have not yet 'wrapped up' their basic science knowledge in clinical knowledge to the same extent (Boshuizen & Schmidt, 1992; H. G. Schmidt & Boshuizen, 1992). It is during the residency that basic science knowledge gradually becomes intertwined with situated, clinical knowledge (Boshuizen, 2004; Boshuizen & Schmidt, 1992). Hence, residents might more easily articulate basic science concepts in concept maps than experts.

Another difference between expert concept maps and resident concept maps might be the use of clinical – often diagnostic – concepts to organize the concept map. When experienced clinicians recall patient cases, they tend to use clinical summaries or higher order clinical concepts whereas 6th year students, for example, articulate many more detailed concepts of a basic scientific nature (Boshuizen & Schmidt, 2000; Van de Wiel et al., 2000). Experts use these higher order clinical concepts to organize the information they give about a patient case. Hence, we hypothesize that the organization of expert concept maps relies more on clinical concepts that encapsulate basic science concepts, whereas residents are expected to use basic science concepts for the organization of the concepts.

The third characteristic that might distinguish expert and resident concept maps emanates from the cohesion that pervades expert behaviour. By means of a knowledge network with a high density of interrelations between concepts (Eva, Norman, et al., 2002; Feltovich et al., 1993; Genberg, 1992; Koedinger & Anderson, 1990), experts bring together symptoms and complaints into a diagnosis or underlying basic science mechanism (Eva, Norman, et al., 2002; Feltovich et al., 1993). They are

inclined to connect data from a holistic viewpoint (Eva, Norman, et al., 2002). We hypothesize that this holistic viewpoint results in more links between clinical and basic science concepts in expert concept maps compared to resident concept maps.

From the perspective of educational use, it seems worthwhile to explore differences between concept maps that are constructed by experts and residents. Insights into these differences could enable us to make decisions about the expertise level of the constructors of preconstructed concept maps and the role of residents in curriculum development in order to fit the needs of medical students and to scaffold them to build up an integrated knowledge base. Resident concept maps might be less complex than those constructed by experts, are expected to unveil more basic science concepts that help to understand clinical concepts and might differ from expert maps in how the integration of clinical and basic science concepts is organized. Expert concept maps, on the other hand, are expected to express integration by means of more links between concepts. So far, there have been no studies focusing on the articulation of integration of clinical and basic science concepts in concept maps constructed by groups of constructors with different expertise levels. Moreover, studies that map out differences in complexity of concept maps aim to elicit knowledge structures of individuals (McGaghie, McCrimmon, Mitchell, Thompson, & Ravitch, 2000; Rendas et al., 2006; West et al., 2000) whereas concept maps for educational purposes are preferably constructed by groups of constructors in order to achieve consensus about the content of the program (Coffey et al., 2002).

We questioned what consistent variations are found in concept maps constructed by groups of experts, and by groups of constructors at resident level. Variations might be expected regarding the complexity of organization, as previous research on concept mapping has shown (Markham, Mintzes, & Jones, 1994; McGaghie et al., 2000; West et al., 2000), but also regarding the number of basic science concepts and links between clinical and basic science concepts and the extent to which clinical and basic science concepts are used for organizing the concept map.

3.2 Methods

3.2.1 Context and participants

We conducted a study at Leiden University Medical Centre that aims to offer an integrated bachelor curriculum. Seven expert groups and seven resident groups constructed a concept map, each group consisting of three participants, at least one clinician and one basic scientist. The multidisciplinary character of the groups was expected to contribute to the articulation of their knowledge due to the information gap between the participants. The experts had at least 5 years' post-graduation

experience. The participants in the resident groups were doing their residency or were following their specialization program as basic scientists.

3.2.2 Materials and procedure

Each group was asked to construct collaboratively a concept map about a clinical problem. The clinical problems emanated from internal medicine but were also relevant for other clinical disciplines: coughing, diarrhoea (2x), proteinuria, blood in faeces, chronic abdominal pain and articular pain. Each clinical problem was schematized in a concept map by an expert group and by a resident group that had an equivalent disciplinary composition. Involved disciplines were internal diseases (different subspecialities), surgery, gynaecology, general practice, radiology, anatomy, immunology, microbiology and pathology. Diarrhoea was schematized twice but the disciplinary composition of the groups differed.

The concept maps were created during two sessions that lasted two hours. In the first session, the participants were guided through concept mapping instructions that were designed to support visualization of integration: the constructors were instructed to contribute concepts that were particularly relevant from the perspective of their own discipline and to explore links between clinical and basic science concepts (see Box 2.1 for the instructions). They then had to explain two complex patient cases using the concept map in order to check whether the map was comprehensive. Concept maps were created using post-it notes and big paper sheets and were digitized using *Inspiration@*, a software tool for creating concept maps. The second session was spent on checking the digitized version and on elaborating and fine-tuning the concept map. Appendix 2 shows one of the concept maps on blood in faeces constructed by a resident group: a GP who contributed general data, history, and obstipation treatment, a surgeon whose contribution focused on degenerative aspects, history and physical examination, while a pathologist contributed degenerative and inflammation aspects. The Institutional Board of Leiden University Medical Centre, where the concept maps were constructed, provided ethical approval for the study.

3.2.3 Data analysis

A framework of features was developed to describe the concept maps. The features enabled us to quantify differences between expert and resident concept maps, in particular on the issue of integration. We distinguished concepts (clinical concepts and basic science concepts); organization (umbrella concepts and clinical-problem-specific umbrella concepts); and integration (clusters, hierarchies and links).

Concepts: in Appendix 2, the clinical concepts are those concepts under general data, history-taking and physical examination, lab research, diagnosis and interventions. The basic science concepts are distinguished by grey nodes. Resident concept maps were expected to cover relatively more basic science concepts than expert concept maps. Therefore, the proportion of both were computed.

Organization of the concept maps was measured by umbrella concepts. All rectangular concepts in Appendix 2 are interpreted as umbrella concepts. We distinguished general umbrella concepts that are applicable to every clinical problem (in Appendix 2, for example, history-taking, physical examination, lab research and differential diagnosis) and umbrella concepts that are specific to the clinical problem of the concept map such as tractus digestivus high, infectious, colour: bright red in Appendix 2. Umbrella concepts that are clinical-problem-specific have been shown to correlate with level of expertise (Coffey et al., 2002; Rendas et al., 2006; West et al., 2000).

Integration is described by means of clusters, hierarchies and links. Integrated clusters are groups of at least one clinical and one basic science concept placed (either hierarchically or non-hierarchically) close to each other. See Appendix 2: tractus digestivus high and the five concepts – loss of weight, loss of blood, epigastric discomfort, gastric acid and nausea/ vomiting – are interpreted as a cluster because it contains both basic science concepts and clinical concepts.

In a hierarchy, there is always an umbrella concept that is explained by one or more other concepts. Two types of integrated hierarchies were distinguished and counted to measure differences in expert and resident concept maps: clinical concepts encapsulating basic science concepts (Appendix 2, loss of blood encapsulates tractus digestivus high and tractus digestivus low) and basic science concepts that subsume clinical concepts (Appendix 2: infectious subsuming ulcus ventriculi and ulcus duodeni).

Links between clinical and basic science concepts were counted, mapping out links between basic science concepts and 1. history and physical examination, 2. lab research, 3. diagnosis, and 4. interventions in order to gauge the role of integration in the different phases of clinical reasoning. An example in Appendix 2 is the link between the concepts “digital rectal examination” and “mechanic”. Links could articulate either hierarchical or non-hierarchical relations. Experts are expected to generate more links between clinical and basic science concepts than residents as a reflection of a more holistic view (Feltovich et al., 1993).

Two researchers analysed the concept maps and decided what should be considered as a concept or a cluster. Some concepts could be interpreted as either one or two concepts (e.g. the basic science concepts ‘inflammation: histology’ in Appendix 2). Consensus was achieved about the interpretations, so that discrepancies that were irrelevant to our aim would not blur the analysis. Subsequently, the concept maps were analysed along the feature framework described above by two researchers. Part of the data was analysed by another researcher in order to check the interrater reliability of the analysis. Cohen’s kappa ranged from .87 to 1.00. The mean Cohen’s kappa was .95. Differences between concepts of experts and residents were analyzed by paired t-tests.

3.3 Results

Table 3.1 shows the differences between expert concept maps and resident concept maps as measured by concepts, organization and integration. Overall, the number of clinical and basic science concepts used by the two expertise levels did not significantly differ. However, the resident concepts maps tended to be more elaborate. The proportion of basic science concepts and clinical concepts differed slightly between the two expertise levels. Standard deviations were relatively high.

Table 3.1: Means and standard deviations for the features that describe the concept maps

	Resident concept maps N=7		Expert concept maps N=7		
	mean	SD	mean	SD	t
Concepts					
Clinical concepts	85.6 (75%)	18.3	70.7 (79%)	19.7	1.413
Basic science concepts	28.3 (25%)	21.3	19.1 (21%)	7.6	1.025
Organization					
Total umbrella concepts:	24.9	6.7	14.6	3.6	3.449*
general umbrella concepts	7.0	3.8	5.3	3.8	.812
clinical-problem-specific umbrella concepts	17.9	6.7	9.6	3.3	3.178*
Integration					
Clusters of clinical and basic science concepts	11.9	3.3	2.3	3.7	4.330**
Hierarchies:					
clinical concepts encapsulating basic science concepts	0.7	1.5	2.9	3.9	-1.233
basic science concepts subsuming clinical concepts	9.4	3.9	2.6	4.4	2.597*
Links between clinical & basic science concepts:					
history, physical examination + basic science	6.3	3.5	0.9	1.2	4.214**
lab + basic science	4.3	2.9	0.3	0.5	3.908**
diagnosis + basic science	11.1	5.7	5.1	4.2	2.097
interventions + basic science	2.3	2.5	0.6	0.8	2.203

* p < 0.05 ** p < 0.01

constructed by residents and experts and their differences measured with t-tests

The organization of the expert concept maps and resident concept maps differed significantly. The concept maps at resident level encompassed significantly more umbrella concepts, that is concepts that subsume other concepts (24.9 versus 14.9) due to significantly more clinical-problem-specific umbrella concepts (17.9) than the expert concept maps (9.6).

To visualize integration, the resident groups gave basic science concepts a prominent role, leading to significant differences with the expert concept maps as Table 3.1 shows. They clustered clinical and basic science concepts more frequently than experts (11.9 versus 2.3) and structured the hierarchies significantly more along basic science concepts than experts did (9.4 basic science umbrella concepts that subsumed clinical concepts in contrast to experts with 2.6). Although not statistically significant due to a fairly high spread, experts employed clinical concepts as an organizational device more frequently (2.9 versus 0.7).

Contrary to our expectations, links between clinical and basic science concepts were used significantly more frequently by the residents (24.0 versus 6.9). Additionally, we investigated which type of clinical concepts were preferably linked with basic science concepts: history and physical examination, lab research, diagnosis or interventions, to get an impression of when the use of basic science concepts seems important in the clinical reasoning process. All these 4 combinations were articulated more by residents with significant differences between resident and expert concept maps when basic science concepts were linked to history and physical examination (6.3 versus 0.9) and to lab (4.3 versus 0.3), again underlining the role of basic science in the concept maps at resident level early in the clinical reasoning process.

The quantitative differences in organization and integration between the resident and expert concept maps became apparent in their appearance. In some resident concept maps, a concept-map-like appearance, that is concepts structured in a hierarchical way, was combined with a matrix in which the headings of the columns were basic science categories. One of the resident groups described this as 'the magical ruler' that helps us to understand the clinical concepts. In the expert concept maps, mainly clusters were linked (instead of concepts), resulting in a relatively low number of links. This strengthens the image of the expert concept maps as resembling archipelagos, as one of the expert groups described the process of organizing the concept maps: 'let's make islands, so that we can do some island hopping'. This metaphor adequately describes the organization of most expert concept maps: clusters of concepts based on the diagnostic process: history taking and physical examination, lab research, diagnosis and interventions.

3.4 Discussion

This study demonstrates that concept maps that are constructed by residents can be distinguished from expert concept maps on features that are relevant for curricula aiming to integrate clinical and basic sciences. Hence, it provides strong support for a consideration and investigation of the role that preconstructed resident concept maps could play in medical education. The resident groups used more clinical-problem-specific umbrella concepts to organize their maps, which is at odds with previous studies on concept mapping that show that the higher the expertise level, the higher the degree of organization (Markham et al., 1994; McGaghie et al., 2000; Rendas et al., 2006). Moreover, the resident concept maps articulated decidedly more integration between clinical and basic sciences.

How did integration become apparent in the resident concept maps in contrast to expert concept maps? We hypothesized three variations between the concepts maps at the two expertise levels. First, the hypothesis that residents would articulate more basic science concepts than experts could not be completely supported. Overall, their concept maps contained more basic science concepts but the difference was not significant, due to the fair variation with respect to the number of concepts they covered. Second, based on findings in think-aloud protocols in studies on knowledge organization (Boshuizen & Schmidt, 1992; Van de Wiel et al., 2000), the resident groups were expected to use basic science concepts for the organization of the concepts whereas medical experts were expected to rely on clinical concepts that encapsulate basic science concepts. The resident groups did indeed organize their maps through one organizational device – basic science categories – and hardly used clinical concepts and they did this significantly more than experts. The data on the organization of expert concept maps were partly consistent with our expectations and showed only a slight preference for clinical concepts that encapsulated basic science concepts. Medical experts used both devices to organize and integrate the clinical and basic science concepts in their map. Such a flexible use of two devices to organize their concept maps might develop with the expertise level of the group of constructors, a process that is equivalent to the growing flexibility in using reasoning strategies and knowledge of individual clinicians (Eva, Brooks, et al., 2002). However, overall, the experts were reluctant to organize their concept maps along hierarchical devices. Third, the hypothesis that experts would articulate more links between clinical and basic science concepts than residents due to their holistic approach to solving problems (Feltovich et al., 1993; Koedinger & Anderson, 1990) turned out not to be the case. Residents proved to be more ‘expressive’ than experts in the use of links to articulate integration of clinical and basic science concepts. Both groups preferred to connect basic science concepts with diagnoses but residents also

articulated links between basic science concepts and concepts earlier in the clinical reasoning process: history, physical examination and lab research.

The composition of the expert groups might have contributed to the finding that hierarchies and links remained unarticulated in their concept maps. Although the multidisciplinary composition of the groups was assumed to create an information gap that would affect the need to share and therefore articulate knowledge, the experts might have been aware of the fact that they all were indeed experts, evoking more concise explanations. The social dimension might have influenced the process of concept mapping: experts among experts might tend to explicate less assuming that their interlocutors could rely on the same knowledge base. This might also explain why experts left hierarchical relations unarticulated, linked clusters instead of concepts, and followed the diagnostic reasoning process by using relatively many general umbrella concepts like history and physical examination. In further research, the social dimension of constructing concept maps could be manipulated by groups consisting of both residents and experts, possibly resulting in articulation of relations by experts. Furthermore, the experts, often involved in medical teaching, aimed to reduce the complexity of the concept map. This fine-tuning of the concept map for educational purposes – scaffold for preclinical and clinical students – might have encouraged them to leave relations implicit which in other studies might have been articulated (Kassab & Hussain, 2010; McGaghie, Boerger, McCrimmon, & Ravitc, 1996; Rendas et al., 2006). Residents seemed to bother less about the complexity of the concept maps.

The expressiveness of the resident groups regarding integration reminds us of the intermediate effect described within the context of encapsulation theory: intermediates tend to mention not only more basic science mechanisms but also more clinical data than experts (Van de Wiel et al., 2000). Although the resident groups in our study are surely more knowledgeable than the intermediate levels that are referred to in these studies, they showed the same tendency when they constructed concept maps in groups. In order to explore whether there is indeed an intermediate effect in concept maps that are constructed in groups, this study should be duplicated with students who are expected to construct less elaborate concept maps. Note that the intermediate effect in previous studies addressed the knowledge structures of individuals (Van de Wiel et al., 2000), while an intermediate effect in our study concerns what *groups* of constructors jointly decided to be relevant links and organization in preconstructed concept maps.

3.4.1 Educational implications

Evidently, we need to be cautious with our conclusions because of the limited number of concept maps that we were able to include in this study. However, the consistent explicitness of concept maps constructed by the resident groups might make them more suitable for scaffolding undergraduate students than expert preconstructed concept maps. In particular, the interrelatedness between clinical and basic science concepts articulated in clusters, hierarchies and links might support students as they attempt to integrate clinical and basic science knowledge. Furthermore, the articulated relations between history, physical examination and lab research on the one hand and basic science concepts on the other hand might be helpful for medical students, because these relations often remain underexposed in medical curricula (Prince & Boshuizen, 2004). Whether students would experience resident preconstructed concept maps as a better format for scaffolding their knowledge acquisition requires further investigation. The increase in complexity due to the articulation of integration may be counterproductive for student learning.

Medical knowledge is suitable for application in clinical practice when it is organized around clinical concepts (Boshuizen, 2004; Prince & Boshuizen, 2004). Educational programs aim to scaffold medical students to achieve such fit-for-practice knowledge organization. Expert concept maps are in congruence with the knowledge organization that should be acquired in the long run, exhibiting two organizational devices: clinical concepts encapsulating basic science concepts and basic science concepts subsuming clinical concepts. It is thus counterintuitive to provide students with a scaffold that mainly visualizes one organizational device. However, organizing clinical concepts along basic science concepts might be a necessary developmental phase in the building of a sound integrated medical knowledge base. Intermediate preconstructed concept maps could therefore complement a clinically oriented medical program by bridging the gap between expert knowledge organization and student knowledge organization.

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CHAPTER 4

Concept maps and integration of clinical and basic sciences: an approach to teacher learning

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Abstract

Context The explication of relations between clinical and basic sciences can help vertical integration in medical curricula. Concept mapping can be a useful technique for this explication, in particular when clinical and basic science teachers work in cooperation and instructions make them focus on integration. So far, cognitive views have dominated concept mapping research and have unveiled differences between expertise levels. Little is known about the learning process regarding the articulation of integration.

Objectives In this study we examined which factors affect the learning process of groups of clinicians and basic scientists on different expertise levels who learn to articulate the integration of clinical and basic sciences in concept maps.

Methods After a pilot for fine-tuning group size and instructions, seven groups of expert clinicians and basic scientists and seven groups of residents with a similar disciplinary composition constructed concept maps about a clinical problem that fit their specializations. Draft and final concepts maps were compared on elaborateness and articulated integration. Participants completed a questionnaire on motivation and their evaluation of the instructions. Cooperation in the groups was investigated qualitatively.

Results Residents outshone experts as regards learning to articulate integration, but experts were more motivated and positive about the concept mapping procedure and instructions. The groups differed as to communication: residents interacted from the start (asking each other for clarification), whereas overall experts only started interaction when they had to make joint decisions.

Conclusions Our results suggest that articulation of integration can be learned, but this learning is not related to participants' motivation or their views on the instructions. Decision making and interaction, however, do relate to the articulation of integration. Expertise level turned out to be decisive not only for the level of articulation of integration, but also for the extent of learning and the cooperation pattern. Teacher learning programs in which co-construction tasks are used could further improve vertical integration.

4.1 Introduction

In publications on clinical reasoning, the roles of three kinds of knowledge have been delineated: experiential, clinical, and basic science knowledge (Charlin, Boshuizen, Custers, & Feltovich, 2007; Eva, 2005). An experienced clinician uses these three kinds in an integrated way, and it depends on the complexity of the patient case which kind of knowledge is crucial for the analysis. Familiar patient cases tap into clinicians' experiential knowledge, whereas if clinicians are puzzled by patient cases, they revert to basic science knowledge (Charlin et al., 2007; Van de Wiel et al., 2000). Basic science knowledge helps to comprehend clinical signs and symptoms, but tends to remain tacit when experienced clinicians analyse patient cases that to them are not complicated (Boshuizen & Schmidt, 1992; Van de Wiel et al., 2000). Evidently, basic science knowledge is used unconsciously for the analysis of routine patient cases.

Medical curricula are intended to help students to relate clinical and basic science knowledge, and by curriculum innovations teachers try to improve this so-called vertical integration (Dahle et al., 2002; Wilkerson et al., 2009). Localizing underlying basic science mechanisms allows teacher and students to focus on relevant relations with clinical phenomena (Kinchin et al., 2008). Vertical integration requires the articulation of basic science mechanisms and their relations with clinical concepts, because educational programs rely on knowledge that can be made explicit and discussed in the classroom (Eraut, 2000). Teachers' tacit knowledge is of little help to develop an instructive curriculum (Eraut, 2000; Kinchin et al., 2008). However, medical teachers, often experts in their domains, are not automatically able to articulate the basic science mechanisms that underlie clinical phenomena, due to the tacit nature of this knowledge (Boshuizen & Schmidt, 1992; Van de Wiel et al., 2000). It seems therefore worthwhile to support them in this task (Kinchin et al., 2008) and to investigate how they can learn to make their integrated clinical and basic science knowledge explicit.

Concept mapping is a technique by which to explicate and share knowledge (Novak, 2002, 2003). The resulting concept maps contain networks of hierarchically ordered concepts. They are recommended as a means to elicit expert knowledge (Hoffman & Lintern, 2006) and thus might help medical teachers to articulate relations between clinical and basic science knowledge (Daley & Torre, 2010; Kinchin et al., 2008). This makes the maps a promising instrument for the development of medical curricula (Weiss & Levison, 2000).

4.1.1 Teachers' learning to articulate integration

Integration of clinical and basic sciences is not receiving much attention in faculty development programmes in the medical domain (Martimianakis, Hodges, & Wasylenko, 2009). In prevalent views on learning (Darling-Hammond & Bransford, 2005) three different focuses are distinguished in teacher learning (cf (Cochran-Smith & Lytle, 1999)): a cognitive view, emphasizing teachers' knowledge as a source for improving teaching practice; a constructive view, stressing teachers' learning process as an active interpretation process of new information based on teachers' own knowledge and experiences; and a third view emphasizing the cooperative aspects of teacher learning, that is, teachers learning with and from other teachers. When it comes to teachers' learning to explicate the integration of clinical and basic sciences by means of concept maps, these three views pertain to different aspects.

The cognitive view addresses the concept maps themselves, which reflect the teachers' knowledge and knowledge organization. The maps reflect the integration of clinical and basic science concepts that teachers are able to explicate, and hence designate the integration they are likely to apply in their teaching practice. Here, the instructions guiding the teachers in constructing the concept map should be taken into account, because they influence what teachers articulate in the concept map (H. J. Schmidt, 2006). In previous studies we have taken this cognitive perspective by examining the articulation of clinical and basic sciences in concept maps (see Chapter 2 and Chapter 3).

From a constructivist point of view, it is not the concept maps, but the process of concept mapping that is vital (Novak, 2002). Examining this process helps us to understand how medical teachers apply the concept mapping instructions and how they learn to articulate the integration of clinical and basic sciences. Comparing draft and final versions of concept maps can shed light on the process of learning (Novak, 2002; Rendas et al., 2006; Torre, Durning, & Daley, 2013) and thus also on the learning process to articulate clinical and basic sciences.

The third view on teacher learning also focuses on the process of learning, but highlights the importance of cooperation. Although some studies recommend involving more than one constructor in the construction of concept maps for educational purposes, in none of these studies are concept maps constructed *jointly* (Cutrer et al., 2011; Edmondson, 1995; Rendas et al., 2006; Weiss & Levison, 2000). For the development of integrated curricula, communication between clinicians and basic scientists is deemed decisive (Harden, 2000). Thus, cooperative learning, with its strong emphasis on communication, could be helpful for the articulation of integration. Due to the information gaps in mixed groups (Slavin, 1996), establishing the relations between clinical and basic sciences is expected to be easier than when

teachers construct the maps individually. Research on the cooperation between teachers and their communication can illuminate how teachers learn (Weinberger & Fischer, 2006), and so could contribute to our understanding of how medical teachers learn to explicate the integration of clinical and basic sciences in concept maps.

4.1.2 Influence of context on teacher learning

Concept mapping with the aim to visualize integration of clinical and basic sciences is still in its infancy. Although the technique is recommended especially for this purpose (Daley & Torre, 2010; Edmondson, 1995; Kinchin et al., 2008), there are not so many examples of concept maps that show the relations between clinical and basic sciences. Evidently, the general instructions for concept mapping as proposed by Novak (Novak, 2002) do not automatically lead to concept maps that visualize vertical integration. Therefore, specific concept mapping instructions that help medical teachers to articulate the integration of clinical and basic sciences seem required.

Design-Based Research offers an approach to experiment with such concept mapping instructions. The objectives of Design-Based Research are twofold: to refine an intervention by iteratively conducting experiments in real life contexts, and to further theoretical insights (Barab & Squire, 2004). Context variables are mapped out to allow transfer to another learning context and to improve the theoretical framework in such a way that learning in these different contexts can be explained (Gravemeijer & Cobb, 2006). Because of the current explorative character of instructions intended to articulate the integration of clinical and basic sciences, it seems wise to set up different contexts to experiment with them.

In the study described in Chapter 3, we compared the concept maps constructed by groups of experts with those constructed by groups of residents, and found that residents were able to articulate the integration of clinical and basic sciences to a significantly greater extent than experts. A cognitive explanation for this could be that due to their clinical experience, experts' basic science knowledge becomes encapsulated by clinical higher order concepts, whereas the basic science knowledge of residents plays a more overt role in the understanding of clinical problems, cf. (Boshuizen & Schmidt, 1992; Van de Wiel et al., 2000). However, not all the differences between experts' and residents' concept maps could be explained by theories about their different knowledge bases. It was suggested that group dynamics and their reflection in the communication could also account for the level to which expert groups and resident groups articulate their knowledge. If this is the case, the expertise level of the constructor groups could then be a context variable that accounts for differences in the concept mapping processes and, consequently, for differences between the concept maps. Hence, the dynamics of cooperation

(Weinberger & Fischer, 2006) could be a relevant context variable (Gravemeijer & Cobb, 2006).

4.2 Aims

The goal of medical education is to teach students to build an integrated knowledge base, which means that medical teaching should elaborate on the relations between clinical and basic science knowledge. Only if medical teachers are aware of these relations and competent in articulating them will they be able to discuss them with their students. Concept mapping has been put forward as a promising technique that could support medical teachers in their endeavours to articulate this integrated knowledge. In our study, groups of clinicians and basic scientists constructed concept maps guided by instructions focusing on the articulation of the integration of clinical and basic sciences. In line with Design-Based Research (Barab & Squire, 2004), we scrutinized the process of concept mapping and searched for the factors that account for the articulated integration in the concept maps. Insights into the factors that facilitate or hinder this process can be used to refine the concept mapping instructions, in order to instruct teachers how to effectively articulate the integration of clinical and basic sciences. So far, research has focused on the concept maps themselves, i.e., taking a cognitive point of view (McGaghie et al., 1996; Rendas et al., 2006). Our focus in this study was on the process of concept mapping, thereby exploring constructivist and cooperative learning approaches. We asked ourselves:

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 the integration of clinical and basic sciences?

The answer to this question might give us insights into the explication of clinical and basic science knowledge in interdisciplinary groups.

4.3 Methods

4.3.1 Participants and procedure

Seventeen groups, all composed of both clinicians and basic scientists working at the Leiden University Medical Centre, participated in the experiments. Ten groups were designated as 'experts': the participants had at least five years' experience and were involved in preclinical and/or clinical education. Two groups consisted of five, one

group of two, and seven groups of three experts. To examine the influence of expertise level, seven resident groups with a disciplinary composition equivalent to that of the seven groups of three experts were included. Each group constructed a concept map about a clinical problem that fitted the disciplinary composition of the group, e.g., a surgeon, a pathologist and a general practitioner constructed a concept map about blood in faeces, and a lung specialist, a specialist in infectious diseases and an immunologist constructed a map about coughing. In order to minimize the influence of content bias on the findings, concept maps of seven different clinical problems were constructed.

The concept maps were constructed in at least two sessions, as recommended by Novak (Novak & Gowin, 1984). We considered the draft made during the first session to be an intermediate state in learning to articulate integration, which was further developed during the second session (Kinchin et al., 2008). The groups were guided through concept mapping instructions that included directives intended to encourage them to articulate the integration of clinical and basic sciences, such as the instruction to contribute and discuss concepts that were particularly relevant from the perspective of participants' own disciplines, the instruction to explore links between clinical and basic science concepts, and the instruction to use clinical concepts as higher order concepts that subsumed basic science concepts. As a final step, the participants had to explain two complex patient cases in order to check whether the concept map was comprehensive enough. The draft versions were constructed with the aid of post-it notes and large sheets of paper. We expected this "physical" way of constructing to enhance communication, particularly in groups in which participants met each other for the first time. This would thus contribute to the learning process (Slavin, 1996). After the first session, the first author digitized the draft concept maps by means of *Inspiration@*, a software tool for concept mapping. In the second session, participants checked whether any mistakes had been made during digitization and reviewed and refined the ordering and relations between the concepts along the same instructions as used in the first session.

Before the actual experiment started, we conducted pilots to find the optimal group size and instructions. In cooperative learning, group size has been associated with different interaction patterns and its effectiveness largely depends on the task that is carried out (Strijbos, Martens, & Jochems, 2004). We assumed that larger groups, with consequently more disciplines, would mean a greater challenge to bridge the gaps between the disciplines (McGaghie et al., 1994) and that this might be reflected in the communication patterns (Strijbos et al., 2004; Weinberger & Fischer, 2006). When group size and instructions had been optimized, leading to a

construction process that the participants experienced as feasible, we were able to investigate the context variable 'expertise level' (Gravemeijer & Cobb, 2006).

4.3.2 Data collection and analysis

Three data sources were used: the draft and final versions of the concept maps (to track learning during the concept mapping process), a questionnaire (for measuring the perceived usefulness of the instructions) and video tapes of the sessions combined with field notes (to analyse cooperation). After the sessions of the groups of five experts, the group of two experts and one group of three experts, we discussed the instructions with each group to check feasibility and clarity, so that we could adapt them to practical needs -an approach that fits into Design-Based Research- (Barab & Squire, 2004; Gravemeijer & Cobb, 2006).

Concept maps

Draft and final versions of the concept maps were compared to examine whether there was a learning effect regarding the articulation of integration. We measured both the elaborateness of the concept maps in terms of number of clinical and basic science concepts, and features that measured the articulated integration of clinical and basic sciences. When we applied this framework to the final concept maps, interrater reliability turned out to be sufficient (a mean Cohen's kappa of .95, see Chapter 3) to justify having one researcher coding the draft versions. The concept maps of the groups consisting of two and five experts were left aside, because the instructions were modified after these sessions. The learning effect between the first and the second session was measured by performing a *t*-test for two related samples on the analysis of the draft and final versions.

Questionnaire

In order to incorporate participants' points of view on what factors facilitated or hindered the articulation of clinical and basic science knowledge in concept maps, we asked them to fill in a questionnaire focusing on the usefulness of the instructions. The items were answered on a five-point Likert scale ranging from 'I do not agree' to 'Agree' or 'Very low' to 'Very high' in case of the questions on motivation. The reliability of the 20 items used in the analysis was satisfactory (Cronbach's alpha .87). In the version filled in by the residents an additional six items were used to question the different ways of organizing the concept map in detail (Cronbach's alpha .93). Because the integration as articulated in the expert concept maps differed significantly from that in the resident concept maps, ANOVAs were used to investigate whether these groups also differed regarding the perceived usefulness of the

instructions. In order to examine the impact of the sessions on motivation, *t*-tests were run on the questions concerning motivation.

Video tapes and field notes

We gathered data by means of video tapes and field notes of the pilot sessions, and 11 sessions of the three-participant groups to examine cooperation within the groups. A first rough analysis was conducted by means of a checklist matrix structured along the concept mapping instructions (Miles & Huberman, 1994). Per instruction and per participant, notes were made of questions, answers to questions, subjects of discussion, positive and negative remarks and motivations that participants gave for their contributions, in order to map out the communication in the group. Moreover, per instruction we wrote observations that pertained to the whole group, such as how much effort it took to apply the instruction and make decisions, and added quotes to illuminate the notes. One tape was analysed by two researchers in order to cross-check the interpretation and to fine-tune the checklist matrix. We felt one researcher was sufficient for video analysis, because this was triangulated by data from the questionnaires and the draft and final concept maps. A summary of the notes per instruction was briefly discussed with the groups of participants during the second session, to check whether they recognized the findings.

Initially, the data gathered in the checklist matrix were further analysed by means of communication patterns in cooperative learning as described by Weinberger (Weinberger & Fischer, 2006). However, these categories did not completely fit our data. They were more focused on obtaining consensus between different viewpoints, whereas in our data communication was also directed towards reconciliation and combining contributions. We decided to ground the categories in the data in different rounds of analysis, thus clustering the categories. Eventually, the data were clustered into (1) motivation, (2) exchange of information, (3) interaction and (4) the decision-making process. These categories combined some of the communication patterns as described by Weinberger & Fischer (Weinberger & Fischer, 2006) and some conditions for effective cooperative learning (Slavin, 1996), which we interpreted as a validation of the categories for analysis. In Box 4.1 the categories are presented in detail.

Box 4.1 Overview of the coding categories used for the analysis of the video tapes and the field notes

Category	Description	Examples
Motivation	Positive and negative drive to adopt concept mapping. Understanding of the goal of the cooperative learning task in order to stay on track.	It is great fun, this way of working. (E) My enthusiasm is reduced because I still do not understand the goal of concept mapping. (R)
Exchange of information	Explanations and explications without involvement from others, e.g., explications of the participant's own contribution to the concept map.	The basic science categorization is good to know but you should not really apply it. (E) For me, the concept map is upside down. (E)
Interaction	Active involvement reflected in questions participants ask each other, asking for and giving clarifications	I do not know whether this results in blood in feces. You know that. (R) Now I am completely confused: how do you use secretor and osmotic? Up to 2 hours ago, it was our main device. This distinction can't be that weird? (R)
Decision making	Negotiations about how to structure the concept map, implying what to adopt in the map.	Let's distinguish pathogenesis and pathophysiology. Okay, this categorization does not commit us to anything. (E) Let's stop with expanding the concept map. Every concept covers more detailed concepts. (E)

E=Expert, R= Resident

4.4 Results

4.4.1 Learning expressed by draft and final concept maps

Table 4.1 presents the differences between the draft and final versions of the concept maps. In the second session, participants added more (especially clinical) concepts to the concept map, and articulated integration to a significantly higher extent via links between clinical and basic science concepts, and via basic science concepts subsuming clinical concepts. Additional analysis comparing resident and expert concept maps revealed that only the residents were responsible for the significant improvements in articulated integration.

Table 4.1 Differences between draft and final versions of the concept maps, measured by the number of clinical and basic science concepts and features describing articulation of integration

	Draft N=14		Final N=14		T
	mean	SD	mean	SD	
Clinical concepts	67.1	15.2	78.1	19.9	3.44**
Basic science concepts	18.6	8.5	23.7	16.1	1.34
Proportion of basic science/clinical concepts	21.7%		23.3%		
Clinical concepts subsuming basic science concepts	0.6	1.2	1.8	3.0	1.4
Basic science concepts subsuming clinical concepts	4.3	4.8	6.0	5.3	3.07**
Links between clinical and basic science concepts	12.4	9.0	15.4	10.3	3.05**

* $p < 0.05$ ** $p < 0.01$

4.4.2 Participants' views on concept mapping

Regarding the views on procedure and instructions, we distinguished between experts and residents, for their concept maps differed significantly in the articulation of integration. Overall, experts were significantly more positive about the procedure and instructions of concept mapping than residents; seven out of twenty questions showed a significant difference between the two groups, as Table 4.2 shows. The experts really enjoyed the concept mapping sessions; their motivation increased significantly, whereas residents' motivation grew no more than slightly. Additional *t*-tests revealed that residents were significantly more positive about the instruction to order the concepts along clinical concepts than about the instruction to order the concepts along basic science concepts ($p < .05$).

Table 4.2 Differences between experts and residents concerning the value they attached to the concept mapping procedure and the instructions (rated on a 5-point Likert scale)

	Residents N=19		Experts N=21		F
	Mean	SD	Mean	SD	
Before this session, my motivation to participate was	3.4	0.5	3.8	0.8	3.219
After this session, my motivation to participate was	3.5	0.8	4.2	0.6	13.139**
Procedure: making a concept map					
Is feasible	3.4	0.8	3.8	0.8	2.172
Is inspiring	3.9	0.7	4.2	0.5	3.853
Is a good way to assemble concepts of various disciplines	3.9	0.6	4.4	0.6	5.127*
Enhanced my understanding of what knowledge should be incorporated in the educational program	3.6	0.8	3.7	0.8	0.303
Facilitates multidisciplinary cooperation	3.6	0.7	4.0	0.7	2.828
I enjoyed the multidisciplinary way of working	4.0	0.7	4.6	0.7	7.241*
Consists of logical steps	3.3	0.8	3.6	0.9	1.086
Time investment and result are balanced	3.2	1.0	3.5	1.0	3.296
Total	3.6	0.4	4.0	0.4	7.302**
Instructions					
The introduction was understandable	3.9	0.8	4.2	0.7	1.984
Collecting concepts & first categorization was useful	4.0	0.7	4.3	0.7	2.396
Collecting concepts & first categorization was understandable	3.8	0.9	4.1	0.8	0.629
Ordering was useful	3.7	0.7	4.5	0.6	15.366**
Ordering was understandable	3.7	0.9	4.3	0.7	5.372*
Linking concepts was useful	3.4	1.1	4.0	0.7	3.008
Linking concepts was understandable	3.8	0.7	4.0	0.8	0.445
Using patient cases was useful	3.8	0.6	4.4	0.8	5.338*
Using patient cases was understandable	3.9	0.8	4.3	0.7	2.069
Total	3.8	0.6	4.2	0.4	7.443**
Overall					
I am satisfied with this concept map	3.9	0.8	4.4	0.7	5.065*
Ordering:					
Along basic science concepts is useful	3.3	1.0			
Along basic science concepts is understandable	3.6	1.1			
Along clinical science concepts is useful	4.1	0.6			
Along clinical science concepts is understandable	4.0	0.8			
Total	3.7	0.7			

* p < 0.05 ** p < 0.01

4.4.3 Cooperative learning

After clustering the data from the video tapes and the field notes, four categories emerged: 1. motivation, 2. exchange of information within the group, 3. interaction between participants and 4. the decision-making process. Quotations below have been translated from Dutch to English, and expertise level is indicated by (E) for experts and (R) for residents in order to illustrate the impact of the context variable 'expertise'.

1. Motivation

Regarding motivation, concept mapping cut two ways: enthusiasm about the activity of concept mapping itself and motivation that came from working towards a goal. The multidisciplinary approach obviously motivated the experts: they expressed their surprise about the input of the others, and the disciplinary differences that became apparent. One of the expert groups decided to meet a third time because the gynaecologist did not agree with the internist's viewpoint about how to categorize diagnoses.

"As clinicians you always concentrate on this part of the concept map (points to the patient-related concepts) but the most important piece of clinical reasoning is this (points to basic science concepts)." (E)

"We, surgeons, are not so important." (regarding diarrhoea) (E)

The pilot groups showed less motivation. Unlike the experts, the residents took the different viewpoints more for granted. They showed less motivation for the sessions. Although the target users (medical clerks) of the concept maps were described, it was especially the residents who remained uncertain about the level of knowledge of these target users.

"Who is the target group?" (R)

"My enthusiasm is reduced because I still don't understand the goal." (R)

Some groups expressed difficulties with the task to construct a concept map about all knowledge they considered absolutely relevant *for understanding* a clinical problem. This seemed to have to do with their previous experiences with schematizations. The experts were inclined to create a decision tree, and thus seemed to be guided by the question: what knowledge does one use *for diagnosing* a clinical problem?

"I have trouble knowing where to start the thinking process." (E)

2. Exchange of information

Explanations and motivations of contributions were clustered as 'exchange of information' (see Box 4.1). Participants explained how their disciplines coloured their views on the concepts. Information was exchanged right from the start of the concept mapping process, when participants were collecting concepts. In the resident groups, these explanations already in this first stage often led to questions and hence interaction, which was the case in one expert group. There was only one resident group in which the emphasis in the communication was on exchange of information. In this group, one of the participants joined later.

"You think of the patient, as a first step, I think of the context." (E)

"What does MALT mean?" (R)

3. Interaction

In the expert groups, interaction occurred in particular when the participants started to order concepts, requiring joint decisions. The pilot group of two experts exhibited hardly any interaction. For residents, decision making was not a prerequisite to interact; most resident groups started interaction while collecting concepts, triggered by the contributions of the others. These contributions entailed concepts they did not know, leading to interaction, that is, asking for explanations or joint consultations of the Internet and subsequently explorations of whether the concept maps should be adapted. There was much more interaction in the expert groups when joint decisions had to be taken, i.e., about links, the organization of the concepts and labelling the links. Although labelling the links was deemed unnecessary -most relations were causal or sequential-, it provoked discussions about what was cause and what consequence.

“This blood test, what information do you want to get from that?” (when trying to link concepts) (E)

“I have added these concepts with another meaning in mind. Now, I discover that when you replace them, their meaning is changed.” (E) (indicating that by relating a concept to other concepts, meanings change somewhat)

Most resident groups spent much time organizing the concepts along the two structures offered: clinical concepts subsuming basic science concepts or the other way around, basic science concepts subsuming clinical concepts. Although some resident groups expressed having difficulties categorizing clinical concepts within a framework of basic science concepts, they all maintained a basic science categorization. In most resident groups this categorization provoked interaction: residents expressed doubts about which category to place some of the clinical concepts in, asked each other and consulted the internet.

“Is there a third group of pathophysiological explanations of proteinuria?” (R)

“I should have studied proteinuria before I came to this meeting.” (R)

“I do not know whether this results in blood in faeces. You know that.” (R)

The instruction to analyse, summarize and explain the patient cases raised questions and therefore led to interaction. If a case did not belong to the domain of a particular participant, he/she tended to participate less in the discussion.

4. Decision-making process

The pilot groups of five participants had difficulties to reconcile five disciplinary viewpoints. Too many disciplinary viewpoints hindered the decision-making process

about the organization of the concept map. This resulted in a bunch of concepts that to some extent were grouped, but not really organized or related.

“There are too many view points. I don’t see how we can structure this.” (E)

“You seem to make a decision tree. But we are making a scientific ordering.” (E)

The residents started to order the concepts before they were instructed to do so. For them, an explicit instruction to consider different ways to order the concepts seemed to hinder rather than help decision making. Six of the seven expert groups did not start ordering until they received the instruction. They had frequently to be reminded to organize the concept map. All groups started with an ordering of the concepts that adhered closely to the phases of clinical reasoning (e.g., history, lab, diagnoses) and subsequently added an ordering as instructed: clinical concepts subsuming basic science concepts and basic science concepts subsuming clinical concepts. Basic science ordering sometimes evoked doubts about whether clinical or basic science concepts should be the organizational device, and slowed down decision making.

“In this schematization, you are trying to do two things at the same time: from basic science to differential diagnosis and from patient case to basic science knowledge. (R)

“The basic science categorization is good to know but you should not really apply it.” (E)

“But how do students learn? First anatomy, embryology. No, that does not work.” (E)

Decisions about linking concepts were based on considerations about complexity; too many links would make the concept map chaotic. This practical viewpoint accelerated decision making. In all groups, the instruction to analyse patient cases led to adaptations and helped to decide about the final version of the map. When the concept map was deemed not comprehensive, and therefore not a sufficient help to explain the patient case, it was accepted as ‘temporarily definitive’. It was especially the residents who used the concept map for their own analysis and explanation of the case.

“Yes, I can reason along these lines” while pointing to a part of the concept map (R)

“This concept map is unclear, complex.” After analysis of a patient case:

“Yes, our ordering is probably the best. You can exclude causes by using this concept map.” (E)

“Let’s stop expanding. Every concept covers more detailed concepts. This is a framework.” (E)

4.5 Conclusions and discussion

Our results indicate that interdisciplinary groups of medical teachers can learn to articulate the integration of clinical and basic sciences in concept maps if they are guided by specific instructions. In our study, this learning process was influenced by several factors. First, group size mattered: five disciplines in a group made decision making difficult. Optimal group size depends on the task (Strijbos et al., 2004), and for the task of constructing multidisciplinary concept maps three participants seems optimal. Second, the learning process of these groups of three were found to be highly influenced by expertise level. Residents not only *articulate* integration of clinical and basic sciences to a greater extent (cf. Chapter 3), they also *learn* to articulate integration via concept mapping to a greater extent, as the differences between draft and final versions showed.

Which other factors played a role in the articulation of integration in concept maps and could explain the differences between expert and resident concept maps? In the cooperation between residents interaction was vital, whereas experts relied more on an exchange-of-information pattern. Taking the viewpoint of the theory of cooperative learning, which underscores interaction as a factor that affects learning, we assume that this interaction is a facilitating factor for the articulation of integration in the concept maps (Weinberger & Fischer, 2006). The decision-making process is another factor that showed to be decisive for the articulated integration in concept maps. Decision making as an aspect of co-construction is considered to contribute to effective cooperative learning (Slavin, 1996; Weinberger & Fischer, 2006). In groups with too many participants decision making was rather difficult, probably due to too many gaps between disciplines that had to be bridged. Moreover, decision making generated interaction in the expert groups. Whereas joint decisions and interaction are reported as two different factors that account for learning in cooperative learning settings (Slavin, 1996; Weinberger & Fischer, 2006), our results suggest that decision making and interaction are related: decision making turned out to be a means to induce interaction.

The articulation of integration in concept maps did not correspond with motivation, nor with the value participants attached to the procedure and the instructions. Although the residents considered the instruction to order clinical concepts along the lines of basic science concepts less helpful, they not only used this ordering device more, but also learned to use it more frequently during the concept mapping sessions. Our data suggest that this learning was due to the interaction evoked by the instruction. Hence, participants' views on the procedure and

instructions turned out to be irrelevant for the articulation of integration in concept maps.

Our understanding of the differences between expert and resident concept maps regarding the articulation of integration (see Chapter 3) fell short when we confined our view to a cognitive perspective only. It is the combination of the cognitive, constructive and cooperative learning perspectives that deepened our understanding of the use of concept mapping instructions on different expertise levels. The concept maps in our study not only disclosed characteristics of the shared knowledge of groups of clinicians and basic scientists on different expertise levels, as in cognitive psychological studies (Boshuizen & Schmidt, 1992; Van de Wiel et al., 1999). They also showed that the articulation of integration can be *learned* by discussing and improving concept maps constructed previously, an explanation from the constructivist viewpoint. Thus, the articulation of the integration of clinical and basic sciences is not a static reflection of cognitive structures but a dynamic phenomenon, subject to being influenced, as suggested elsewhere (H. J. Schmidt, 2006). Note that we did not measure the process of learning the articulation of integration during the first concept mapping session. The cooperative learning view helped to detect decision making and interaction as facilitating factors for learning to articulate integration in expert and resident groups. Cooperative learning is usually an approach for peer learning (Slavin, 1996). Both expert and resident groups were supposed to be peers: experts among experts and residents among residents. However, the definition of 'peer' might need to be differentiated. Experts might regard each other less as peers than residents do. Because of their specialized knowledge, the knowledge gap between experts might be larger than between residents. If this is the case, interaction might be a confounding variable for expertise level.

We placed this study in the tradition of Design-Based Research because we aimed to refine the concept mapping instructions, and to link the articulated integration in concept maps with theoretical insights. Decision making and interaction do not seem independent factors that correlate with the articulated integration in concept maps, but they seem to be correlated and are affected by group size and expertise level. However, Design-Based Research is usually conducted along experiment cycles exploring new context variables (Gravemeijer & Cobb, 2006). This explorative study should therefore be continued in new experiments, for further refinement of the instructions and procedure. We will here discuss three limitations of this study and their potential consequences for follow-up research.

First, our results allowed us to state only the relatedness of interaction and articulation of integration. Follow-up research should examine whether there is a causal relationship. This might be investigated by triggering interaction in the expert

groups by means of advancing decision making in the concept mapping session, and measuring the integration in the resulting concept maps. A next step is to quantify interaction and decision making, and correlate this to the integration articulated in the concept maps. Second, we conducted this study in one medical centre. Its specific organizational culture might have coloured the interaction between the experts and the way they have cooperated. This context variable should be taken into account in a follow-up study. Third, we endeavoured to detect patterns in the data from the video tapes and field notes, and decided to make a qualitative analysis with the risk of bias in the interpretation (Barab & Squire, 2004; Gravemeijer & Cobb, 2006; Miles & Huberman, 1994). Such an explorative approach should be followed by research intended to quantify this qualitative information (Raudenbush, 2010).

A practical implication of this study concerns teacher learning programs that aim to support vertical integration. It does not go without saying that medical specialists are able to explicate integration, which makes the challenge of vertical integrated programs even bigger, cf. (Eraut, 2000). The good news is that teachers are able to learn to articulate integration. For teacher learning programmes it seems wise to support this learning, in which interaction shows to be the key word. In line with cooperative learning research (Slavin, 1996), our study points to co-construction tasks as means to evoke interaction, in particular for groups that do not interact easily. The concept mapping procedure we proposed seems to fit this purpose. Another practical implication is that we should be more aware of the gaps between disciplinary points of view on clinical problems when developing vertical integrated programs. Integration on the level of clinical problems seems to be best established by three teachers with different disciplinary backgrounds. With more disciplines involved, we might run the risk that integration remains confined to discussing separate viewpoints instead of relating them, a phenomenon that is also reported in PBL classes (Prince & Boshuizen, 2004). Finally, we want to recommend involving residents in the development of educational programs, besides their role of teacher. They might be better able to pinpoint relevant relations between clinical and basic science concepts than experts. Often the concepts themselves are not a cognitive challenge for students, it is the basic science concept in different clinical contexts that challenges understanding (Feltovich et al., 1993). Residents have shown that they are able to articulate the relevance of basic science concepts for the understanding of clinical concepts, and it is this explication that constitutes an educational program (Eraut, 2000).

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CHAPTER 5

Concept maps in medical education: do medical teachers consider preconstructed concept maps useful?

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Abstract

Context The value of preconstructed concept maps for medical education has been underlined, particularly for the integration of basic and clinical sciences. Little is known about medical teachers' perceptions on the usefulness of preconstructed concept maps, while their perceptions are likely to play a pivotal role in whether preconstructed concept maps are adopted as a feasible innovation. This study aimed to investigate the perceived usefulness of concept maps constructed collaboratively by clinicians and basic scientists and the factors that influence their perceived usefulness for teachers who did not participate in their construction.

Methods A questionnaire to assess the perceived usefulness of concept maps was filled in by constructors and by teachers who were not involved in the construction of the concept maps. Non-constructors assessed two concept maps on the same clinical problem, constructed by clinicians and basic scientists at either expert or resident level.

Results Constructors perceived the concept maps as significantly more useful than non-constructors. Concept maps constructed by either experts or residents were not valued differently, although the latter articulated integration of clinical and basic sciences to a greater extent. Pearson correlations showed that the perceived usefulness of the concept maps was strongly influenced by non-constructors' views on the adequacy of the content of the map but not by a need to improve integration between clinical and basic sciences in their teaching.

Conclusions This study found that teachers playing an active role in the construction of concept maps seems to be a prerequisite for their implementation, because their content is not easily accepted by teachers who did not construct them. The process of concept mapping itself seems to evoke appreciation for the articulation of integration of clinical and basic sciences and its importance for daily teaching practice.

5.1 Introduction

Concept maps are recommended as an innovative tool to improve integration of clinical and basic sciences in medical curricula (Daley & Torre, 2010; Edmondson & Smith, 1998; Kinchin et al., 2008). They are schematizations of concepts and their interrelations in a hierarchical organization (Novak & Gowin, 1984). Concept mapping appears to reveal the tacit dimension of knowledge (Hoffman & Lintern, 2006) by prompting medical experts to go beyond their automated thought processes, because it encourages them to seek out the underlying basic science knowledge (Kinchin et al., 2008). It is this aspect that is appealing for medical education (Daley & Torre, 2010; Edmondson & Smith, 1998; Kinchin et al., 2008; Weiss & Levison, 2000). Concept maps are put forward as a means to share points of view about how clinical and basic science concepts are related and which of them are relevant for an educational program and, by doing so, to view the course content as an integrated whole (Edmondson, 1995; Edmondson & Smith, 1998; Kinchin et al., 2008). For teachers, concept mapping turns out to be helpful for developing and designing curricula (Amundsen et al., 2008; Harden, 2001; Mahler et al., 1991; Weiss & Levison, 2000). For students, concept mapping has been shown to promote their learning (Mahler et al., 1991; Rendas et al., 2006; Torre et al., 2007).

Not only is the process of making a concept map valuable for students and teachers, preconstructed concept maps and other schematizations have also been shown to be valuable (Cutrer et al., 2011; Rendas et al., 2006; Woloschuk et al., 2000). Preconstructed concept maps are used alongside more traditional teaching activities and in student-centered learning activities because they enhance meaningful learning (Edmondson & Smith, 1998; Laight, 2006), scaffold student learning (Rendas et al., 2006) and are used to introduce new subjects (Edmondson & Smith, 1998; Rendas et al., 2006; Weiss & Levison, 2000). In clinical programs, the use of preconstructed concept maps is not so common. Clerks and residents mainly create their own concept maps (Daley et al., 2006; Mahler et al., 1991; Torre et al., 2007; West et al., 2000).

Whether preconstructed concept maps will actually be used in medical education depends, as with any other educational innovation, on teachers' knowledge and beliefs. When the gap between teachers' knowledge and beliefs and an innovation such as the use of preconstructed concept maps is too large, it is unlikely that teachers will perceive them as useful and accept them as an innovation that adds value to their teaching practice (Pajares, 1992; Verloop et al., 2001). Theoretical frameworks such as those proposed by Fullan (Fullan, 1993), Janssen (Janssen et al., 2013) and Verloop (Verloop et al., 2001) incorporate both involvement or active participation in the innovation and teachers' own experiences and their need for

change as important factors to bridge this gap and therefore facilitate acceptance of the innovation.

Teachers' involvement in innovating their teaching practice with preconstructed concept maps remains limited to decisions about how to use the concept maps. Teachers who did not participate in the construction of the concept maps are not able to exert influence on their content. Consequently, non-constructors' perceptions on their usefulness might depend on whether the preconstructed concept maps reflect content knowledge that they share i.e., knowledge that they want to use in their lessons (cf. the acceptance of a new didactic approach (Verloop et al., 2001)). It is unlikely that teachers would use preconstructed concept maps if they did not share the concepts and relations visualized in them. Concept maps jointly constructed in a multidisciplinary team are expected to be more acceptable to teachers who were not involved in the construction, because team work compels the constructors to negotiate which concepts and relations should be incorporated (Harden, 2001; Novak & Gowin, 1984). These concept maps are by definition the result of consensus. Bridging the gap between teachers' knowledge and beliefs and the use of preconstructed concept maps should also take into account teachers' prior experiences with concept maps or other schematizations. If teachers are not acquainted with concept maps, their perception of their usefulness is expected to be negatively affected (Janssen et al., 2013).

A proposed educational innovation should fit a need for change that teachers experience (Janssen et al., 2013). Preconstructed concept maps might alleviate the challenge of integrating clinical and basic sciences that is reported as a prevalent theme for curricular development (Dahle et al., 2002; Wilkerson et al., 2009). If medical teachers actually experience the need to improve integration in their teaching, multidisciplinary concept maps that articulate clinical and basic science knowledge might fit this need, and this is likely to have a positive impact on their perceptions of their usefulness.

Viewed from the perspective of improving integration of clinical and basic sciences, the level of expertise of the constructors of the concept maps might be a relevant factor to take into account. Not only the complexity of concept maps (McGaghie et al., 2000; West et al., 2000) but also the articulation of integration of clinical and basic sciences depends on the level of expertise of the constructors (see Chapter 3). Concept maps constructed by residents and basic scientists in training ('residents' concept maps' for short) turn out to be more organized than expert concept maps and integration of clinical and basic sciences is articulated to a greater extent. Residents' concept maps might thus fit the need to improve integration of clinical and basic science concepts.

This study explores whether concept maps that are constructed collaboratively by clinicians and basic scientists are perceived as useful instruments for curriculum development and for student learning in preclinical and clinical education. Teachers' perceptions of their usefulness determine the likelihood that preconstructed concept maps will be adopted as a feasible innovation (Janssen et al., 2013). We addressed the following research question.

Is the perceived usefulness of preconstructed concept maps, constructed collaboratively by groups of clinicians and basic scientists, affected by factors such as:

1. teachers' participation in the construction of the concept map;
2. the degree to which non-constructing teachers share the content of the concept map;
3. teachers' prior experience with schematizing or concept mapping;
4. teachers' need for change to improve integration in their teaching practice;
5. the degree of articulated integration in the concept maps?

Both constructors of concept maps and medical teachers that were not involved in the construction were asked to give their views on the usefulness of multidisciplinary concept maps.

5.2 Methods

5.2.1 Context, participants and procedure

We surveyed medical and biomedical specialists of the medical schools in the Netherlands. The curricula of these medical schools all aim to integrate clinical and basic sciences. We used a questionnaire to ask participants to judge multidisciplinary concept maps on their usefulness for medical education.

In order to investigate the impact of participation in the construction of the concept maps (the first factor in the research questions), both constructors and non-constructors were surveyed. The constructor group consisted of the twenty-one specialists from Leiden University Medical Centre, who were experts in the clinical problem of the concept map. They had constructed the expert concept maps in a previous study (see Chapter 2). For the non-constructor group, 133 medical specialists and basic scientists, affiliated to the eight medical centres in the Netherlands, were invited to participate by e-mail. The disciplinary networks of the constructors and their national professional associations delivered the names of their active members from whom participants were selected. This sampling ensured that participants in the non-constructor group had ample experience with the clinical problem of the concept map. They were required to have at least one year's experience in medical education, either in clerkships or in preclinical programs or both. Constructors and non-

constructors belonged to the same discipline, enabling us to investigate differences between them without disciplinary interference. Some non-constructors were requested to assess concept maps of two clinical problems, depending on their domain of expertise. In order to balance out local curricular influence, each clinical problem was assessed by medical teachers affiliated to at least five different medical centres.

The constructors filled in a questionnaire that was sent to them by e-mail, estimating the usefulness of the expert concept map they had constructed themselves. The non-constructors received an expert concept map and a resident concept map, each accompanied by a digital questionnaire, enabling us to investigate whether expert concept maps and resident concept maps differ significantly with respect to the perceived usefulness (factor 5). They were blinded for the constructors' level of expertise. Half of them received the expert concept map first, the other half started with the resident map, eliminating bias or halo-effects. Two reminders were sent to non-responders. This study was exempt from ethical approval under Dutch law, which was affirmed by the ethical committee of Leiden University Medical Centre.

5.2.2 Instruments

Concept maps and their characteristics

The concept maps illuminated clinical problems by articulating clinical and basic sciences. The aim of the concept maps was to provide preclinical and clinical students with an overview of the relevant knowledge for understanding these clinical problems (see for an example Appendix 1 and 2). There were two concept maps per clinical problem: one expert concept map and one constructed by residents and basic scientists in training. In order to rule out content bias, concept maps of seven clinical problems were included in the study.

Numbers of the characteristics that described significant differences between expert and resident concept maps were available for each concept map. These characteristics were umbrella concepts that subsumed other concepts as indicators of the extent of organization in the map. Integrated hierarchies, clusters and links that combined clinical and basic science concepts served as indicators of articulated integration.

Questionnaires

A set of statements was developed to estimate the perceived usefulness of the concept maps for curriculum development and preclinical – mainly theoretical – student learning as well as for clinical student learning. The statements were rated on a 5-point Likert scale with an additional 'don't know' choice.

We endeavoured to validate the content of the statements in two ways. The statements on the usefulness of the concept maps were based on literature on how concept maps are used: in educational settings such as curriculum development (Edmondson, 1995; Harden, 2001; Weiss & Levison, 2000) and in preclinical and clinical education (Rendas et al., 2006; Torre et al., 2007), for supporting self study (Nesbit & Adesope, 2006; O'Donnell et al., 2002), supporting lectures (O'Donnell et al., 2002) and analysis of patient cases (Edmondson & Smith, 1998; Rendas et al., 2006). Subsequently, three groups of constructors were invited to comment on the list of statements and to suggest additional ways of using the concept maps. This enabled us to list a set of statements that was both comprehensive and worded in a way that was familiar to medical teachers.

The questionnaire put to the non-constructors contained additional items that were not relevant to the constructors. These items focused on the degree to which the non-constructors shared the content of the preconstructed concept map (factor 2 in the research questions); their prior experience with schematizing or concept mapping (factor 3); non-constructors' need to improve integration in their own teaching and the role of preconstructed concept maps in satisfying this need (factor 4); and non-constructors' intention to use the preconstructed concept maps. The non-constructors version of the digital questionnaire consisted of 22 statements and 5 open questions that they filled in for both experts' and residents' concept map. Questions about affiliation, years of experience and disciplinary background of the non-constructors enabled us to check whether the data met the inclusion criteria.

Analysis

By means of a factor analysis (Varimax rotation) and subsequently Cronbach's alpha, we determined internal consistency of the statements that were supposed to measure the degree that non-constructors shared the content of the concept map (factor 2), non-constructors' prior experiences with schematizing or concept mapping (factor 3) and teachers' need to improve integration in their teaching (factor 4). These three factors did indeed emerge, which we interpreted as validation. Cronbach's alphas were high (above .80) or sufficient (.63). One of the three statements on integration was left out of the analysis to achieve cohesiveness within the factor. We decided to use the means of each set of statements for further analysis. Analyses of variance (ANOVAs) were run to check whether the responses per concept map differed significantly. When no significant differences showed up, we assumed that we could aggregate the data. Before analysis, the 'don't know' category was transformed into a missing value. Missing data were deleted pair wise.

The influence of participation in the construction of the concept maps (factor 1) was determined by ANOVAs. Additional paired t-tests were computed to check

whether, within the group of constructors or the group of non-constructors, there were significant differences between usefulness for preclinical and clinical student learning and between curriculum development and student learning.

Pearson's correlations were calculated to determine influences of the degree to which teachers shared the content of the preconstructed concept maps (factor 2), teachers' prior experience (factor 3) and the need to improve integration (factor 4) on the perceived usefulness of the concepts maps.

T-tests were used to investigate differences in perceived usefulness of expert concept maps and resident concept maps (factor 5). In addition, Pearson's correlations were calculated to explore which of the characteristics that described the differences between expert and resident concepts maps in terms of the articulation of integration of clinical and basic sciences might account for non-constructors' views on their usefulness.

The answers to the open questions were screened on main topics by the first author in order to use them as illustrations for the quantitative analysis.

5.3 Results

Twenty constructors completed the questionnaire. Of the 133 medical specialists and basic scientists who were approached for the non-constructor group, 68 took part in the study (51%), completing 139 questionnaires. Non-respondents often gave lack of time as their reason for not responding. One respondent was excluded because he did not meet the criterion of at least one year's experience in medical education. The non-constructors worked at the 8 Medical Centres in the Netherlands and 5 teaching hospitals and covered all disciplines that were involved in the constructor groups (Table 5.1). The ANOVAs showed that none of the concept maps evoked an appreciation of usefulness that differed significantly. We concluded that differences in number of responses per concept map could therefore be ignored and that we could aggregate the data.

Table 5.1 Numbers of questionnaires per affiliation and per discipline

Affiliation	N	Discipline	N
Amsterdam MC	15	internal diseases	40
ERASMUS Rotterdam	9	lung diseases	11
Leiden UMC	39	rheumatology	4
Maastricht UMC	19	surgery, orthopaedics	13
UMC Groningen	13	gynaecology	11
UMC Nijmegen	14	GP	6
UMC Utrecht	2	radiology	10
VU MC Amsterdam	20	anatomy	8
others	8	immunology	10
		microbiology	8
		pathology	18
Total	139	Total	139

*(U)MC= (University) Medical Centre

5.3.1 Participation in the construction (factor 1)

An overview of the means and standard deviations of perceived usefulness of all concepts maps (constructed by experts or residents) is provided in Table 5.2. These data show that it is difficult to approach the usefulness of concept maps in an undifferentiated way. There are remarkable differences between constructors and non-constructors: constructors scored the usefulness of the concept maps much higher (curriculum development: $M = 3.9$ $SD = 1.0$, preclinical usage: $M = 3.9$ $SD = 0.7$, clinical usage: $M = 4.0$ $SD = 0.5$) than the non-constructors ($M = 2.8$ $SD = 1.2$, $M = 3.0$ $SD = 1.1$, $M = 3.1$ $SD = 1.1$ respectively). All differences but one were significant, even at the level of the separate statements. Running paired t-tests within either the group of constructors or non-constructors revealed that the constructors valued the usefulness of concept maps almost regardless of how they were used, whereas the non-constructors differentiated slightly between use in the clinical phase, on one hand, and use for the preclinical phase and curriculum development, on the other hand (respectively $t(123) = 4.74$ $p = .000$, $t(124) = 6.093$ $p = .000$, not shown in Table 5.2). In their answers to the open questions, the non-constructors pinpointed the complexity as a reason for their reluctance to use them for preclinical purposes: 'too many details', 'students may not know a lot of concepts', 'at first sight, disordered'.

Table 5.2 Comparison of constructors and non-constructors on statements about the usefulness of preconstructed concept maps (expert and resident maps): Mean (M), standard deviation (SD), number of responses (N) and the ANOVA's

	Non-constructors			Constructors			
	Mean	SD	N	Mean	SD	N	F
Usefulness for curriculum development							
The concept map gives an overview of the concepts and relations to be incorporated in the program.	2.8	1.2	137	3.9	1.0	20	12.561**
The concept map can be used to structure the content of a program.	2.7	1.3	136	4.0	1.1	20	16.753**
Mean curriculum development	2.8	1.2	136	3.9	1.0	20	15.665**
Usefulness for preclinical student learning							
With scaffolding assignments, the concept map is understandable for students.	3.1	1.3	136	4.0	0.9	19	9.103**
The teacher can use the concept map to support his explanation.	2.8	1.3	137	4.1	0.8	20	17.910**
Students can use the concept map while studying literature.	3.0	1.2	135	3.8	0.8	19	7.953**
Students can use the concept map while analysing a patient case.	3.1	1.2	134	3.8	0.8	19	6.378*
The concept map inspires me to encourage students to use concept mapping.	2.8	1.3	136	3.8	0.9	20	12.572**
Mean preclinical usefulness	3.0	1.1	131	3.9	0.7	19	12.722**
Usefulness for clinical student learning							
With scaffolding assignments, the concept map is understandable for clerks.	3.4	1.3	129	4.2	0.5	19	7.237**
The teacher can use the concept map to support his explanation.	3.1	1.3	130	4.1	0.6	18	10.648**
The concept map can be used while studying literature.	3.0	1.2	131	4.1	0.5	18	14.054**
The concept map can be used while analysing a patient case.	3.2	1.2	129	3.7	0.8	18	2.844
The concept map inspires me to encourage clerks to use concept mapping.	3.0	1.3	130	3.8	0.6	18	6.189**
Mean clinical usefulness	3.1	1.1	127	4.0	0.5	18	9.830**
Usefulness for integration of clinical and basic sciences							
The concept map explicates relevant clinical & basic science knowledge.	3.1	1.1	123	4.1	0.8	20	13.521**
Concept maps are a good instrument to support integration.	3.8	1.0	129	X	X	X	
Implementation: own use of the concept map							
Curriculum development: the concept map inspires me to incorporate subjects into my teaching program.	2.8	1.2	121	X	X	X	
Student learning: I intend to use the concept map in my program. (1=yes, 2=no, 3=maybe)	1.5	0.7	138	X	X	X	

* p< 0.05 **p< 0.01

According to the non-constructors, concept maps might be instrumental for the articulation of integration. However, they differed significantly from the constructors in their view on whether the concept map at hand explicates relevant clinical and basic science knowledge: $M = 3.1$, $SD = 1.1$, and $M = 4.1$, $SD = .8$ respectively. Considering the open questions, non-constructors did not always view integration in the concept map as an advantage: 'I wouldn't use schematizations with too many domains'; 'It's better to present the schematization in parts'. This is also reflected in non-constructors' reluctance to use the map by themselves for both curriculum development ($M = 2.8$, $SD = 1.2$) and student learning ($M = 1.5$ (on a 3 point scale), $SD = 0.7$).

5.3.2 Shared content (factor 2), prior experience (factor 3) and need for integration (factor 4)

We computed means and standard deviations for each group of statements: shared knowledge ($M = 3.1$, $SD = 1.1$), prior experience ($M = 3.5$, $SD = 1.1$) and need for integration ($M = 3.1$, $SD = 0.8$) and used these means to explore correlations with perceived usefulness and the intention to use the concept map (Table 5.3). The statements on shared content correlated significantly with perceived usefulness and the intention to use the concept maps for curriculum development: correlations varied from $r = .64$ to $r = .80$. Prior experience with schematizing only correlated significantly with the statement on the intention to use the concept maps for curriculum development: $r = .26$. We found no significant correlations on need for integration.

Table 5.3 Pearson's correlations between perceived usefulness of the concept maps and degree that teachers shared the content of the concept maps (mean 3.1 (1.1), $N = 123$), their prior experience with schematizing (mean 3.5 (1.1), $N = 124$) and their need to improve integration (mean 3.1 (0.8), $N = 135$)

	Shared content	Prior experience	Need to improve integration
Perceived usefulness			
mean curriculum development	.76**	.05	.09
mean preclinical usefulness	.79**	.15	.09
mean clinical usefulness	.80**	.17	.04
Implementation: intention to use the concept map			
Curriculum development: the concept map inspires me to incorporate subjects into my teaching program	.64**	.26**	.10
Student learning: I intend to use the concept map in my program	.11	-.06	-.05

* $p < 0.05$, ** $p < 0.01$

5.3.3 Degree of articulated integration (factor 5)

Table 5.4 Comparison of perceived usefulness of expert maps and resident maps by paired t-tests

	Expert concept maps		Resident concept maps		N	t
	Mean	SD	Mean	SD		
Usefulness for curriculum development						
The concept map gives an overview of the concepts and relations to be incorporated in the program.	2.8	1.3	2.9	1.2	61	-.05
The concept map can be used to structure the content of a program.	2.7	1.4	2.7	1.3	60	.16
Mean curriculum development	2.8	1.3	2.9	1.2	59	-.12
Usefulness for preclinical student learning						
With scaffolding assignments, the concept map is understandable for students.	3.3	1.3	2.9	1.3	59	1.90
The teacher can use the concept map to support his explanation.	2.9	1.4	2.8	1.3	60	.65
Students can use the concept map while studying literature.	3.0	1.2	3.0	1.2	60	.27
Students can use the concept map while analyzing a patient case.	3.1	1.2	3.0	1.2	59	.69
The concept map inspires me to encourage students to use concept mapping.	2.8	1.4	2.7	1.2	59	.49
Mean preclinical	3.1	1.1	2.9	1.1	56	1.14
Usefulness for clinical student learning						
With scaffolding assignments, the concept map is understandable for clerks.	3.5	1.3	3.3	1.3	58	1.16
The teacher can use the concept map to support his explanation.	3.2	1.4	3.1	1.2	59	.52
The concept map can be used while studying literature.	3.0	1.3	3.1	1.2	58	-.36
The concept map can be used while analyzing a patient case.	3.2	1.2	3.2	1.2	57	.10
The concept map inspires me to encourage clerks to use concept mapping.	3.0	1.3	2.9	1.4	58	.30
Mean clinical	3.2	1.1	3.1	1.2	56	.52

* p< 0.05 ** p< 0.01

Table 5.4 shows that the perceived usefulness of expert maps and resident maps did not differ significantly although these maps differed significantly with respect to the articulation of integration. Pearson's correlations showed that none of the characteristics that express significant differences between experts' and residents' maps accounted for non-constructors' views on the usefulness of the concept maps (not shown). Additional analysis on the most and least valued expert and resident concept maps revealed significant negative correlations between the number of basic

science umbrella concepts and means for perceived usefulness for curriculum development ($r = -.40$), preclinical use ($r = -.38$) and clinical use ($r = -.31$), suggesting that the use of basic science umbrella concepts was not perceived as contributing to the usefulness of the clinical concept maps. As stated in the open questions: 'Too many points of view!'.

5.4 Discussion

This study found a differentiated picture of the perceived usefulness of multidisciplinary preconstructed concept maps for medical education. Two factors out of the five we investigated had an impact on perceived usefulness. The first factor was participation in the construction of concept maps. Teachers who did not construct the concept maps perceived them as significantly less useful than the teachers who assessed their own constructed concept maps. This might be explained by the strong correlations with the degree to which teachers shared the content of the preconstructed concept maps (factor 2). For a number teachers, the multidisciplinary view on the clinical problem and the consequent consensus reflected in the concept map did not suffice to get them to accept wholeheartedly the content of concept maps that they did not construct themselves. Concept mapping is a feasible activity for sharing points of view (Amundsen et al., 2008; Harden, 2001) but using concept maps that are constructed by groups of other teachers was found not to contribute to shared views on a clinical problem. Preconstructed concept maps might thus be useful for students (Cutrer et al., 2011; Rendas et al., 2006) but teachers appeared to be somewhat reluctant to use them because of the moderate extent to which they shared the content.

Although use of preconstructed concept maps in clinical student learning is rare (Cutrer et al., 2011), the non-constructors perceived concept maps as significantly more useful in the clinical phase than for preclinical student learning or for curriculum development. The complexity of the maps cannot completely explain the preference for clinical use over curriculum development. For curriculum development, complex preconstructed concept maps aim to serve as a source of inspiration for teachers about the relevant concepts and relations to incorporate into a program and complexity is thought to be less intimidating for this aim (Harden, 2001; Weiss & Levison, 2000). We conclude therefore that active participation in the construction of the concept maps seemed crucial for their perceived usefulness in medical education and not their complexity, for teachers do not easily share the content of concept maps that are constructed by other teachers.

The other factors that we hypothesized might influence the perceived usefulness of preconstructed concept maps turned out to be less relevant. Contrary to our expectations, prior experience with schematizing or concept mapping (factor 3) and perceived usefulness hardly correlated. Experience with simple schematizations might account for this lack of correlation. There might have been a gap between the elaborate concept maps of this study, mapping out concepts and relations that are relevant for the understanding of a clinical problem (see Appendix 1 and 2) and the decision trees and simple schematizations, which are often used in medical education (cf. Woloschuk et al., 2000). Such schematizations aim to simplify or represent chains of practice, leaving the basic sciences underexposed (Kinchin et al., 2008). The negative correlations with the number of basic science concepts also pointed in this direction.

In the literature, integration of clinical and basic sciences is highlighted as a challenge for medical education (Dahle et al., 2002; Harden, 2001; Kinchin et al., 2008; Van de Wiel et al., 1999). In concordance with the literature (Daley & Torre, 2010; Kinchin et al., 2008), the non-constructors in our study perceived concept maps as valuable support for the integration of clinical and basic sciences. However, they did not experience integration as a major challenge in their day-to-day teaching, nor was integration a factor that influenced their perception of the usefulness of the concept maps (factor 4). This may also account for the finding that non-constructors hardly differentiated between the usefulness of the expert maps and the resident maps, although the latter expressed more integration of clinical and basic sciences. The non-constructors did not view the articulated integration in the resident concept maps as an advantage from the perspective of their usefulness for medical education (factor 5). Combining basic and clinical sciences in a concept map implies reconciling the taxonomy of clinical sciences (symptoms and diseases) with the taxonomy of basic sciences (general principles and causal mechanisms), a feature that the non-constructors did not appreciate.

The results of this study suggest that constructing concept maps with the intention of disseminating them among teachers would be a rather fruitless enterprise. It is most likely the construction process itself that evokes shared knowledge and helps to achieve consensus about the concepts and relations that should be taught to students. The findings of studies that suggest that students benefit from using preconstructed concept maps (Edmondson & Smith, 1998; Laight, 2006; Rendas et al., 2006) were not supported by our teachers' perceptions. The lack of shared knowledge, that accounts for the reluctance of teachers to use preconstructed concept maps, might be not an issue for students because they might be less inclined to question the content of the map. Students consider the concept maps as a role model and a scaffold (Cutrer et al., 2011; Rendas et al., 2006). This implies that teachers should

preferably construct their own concept maps and provide students with preconstructed ones.

There has been very little research on teachers' views on integration in their own teaching. This study reveals that they do not feel a major need to improve integration in their own day-to-day practice nor does integration on the level of clinical problems appeal to them. We can not completely rule out misunderstandings of the statements ('Students experience difficulties integrating clinical and basic sciences' and 'In teaching, it is difficult to discuss clinical and basic sciences in an integrated way'). However, the data suggest that the importance that teachers attach to integration in their own practice is a matter of actively sharing knowledge by means of communication and thus sharing content. Concept mapping provokes in-depth discussions (Hoffman & Lintern, 2006) that might go beyond the interdisciplinary consultations that are common in the medical workplace and might contribute to discussions between clinical and basic science teachers about which concepts of their domains should be related and how they should be related in order to help students understand a clinical problem.

Non-constructors considered the explicitness of the relations between clinical and basic science concepts as confusing. It was the expressiveness of resident maps that stood out. The question arises whether students and residents hold the same view. They might perceive resident maps as useful just *because* of the explicitness of the relations between basic and clinical science concepts (cf. Kinchin et al., 2008; Weiss & Levison, 2000). We would therefore recommend replication of this study with students and residents which also contributes to the validation of this questionnaire (Messick, 1995).

Although our results pointed unequivocally to the relevance of participation and shared content, we should take into account some limitations of the study. There was a response rate of 51%. However, considering the broad sampling of non-constructors and the condition that each concept map was assessed by representatives of at least 5 medical centres, we assume that this limitation did not affect our results severely. Moreover, the constructors' answers to the questionnaire might have been biased: the effort they put into the construction of the concept map might have positively coloured their assessment of its usefulness, in a similar way to examiners' positive ratings of their own students (Stroud, Herold, Tomlinson, & Cavalcanti, 2011). Follow-up studies should further validate the questionnaire and, for example, explore real use of the preconstructed concept maps in order to shed light on the conditions for and ways of using multidisciplinary preconstructed concept maps.

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CHAPTER 6

Conclusions and discussion

6.1 Background and overview of the research project

The point of departure of this research project was the observation that integration is a predominant theme in medical education, both in research and in curriculum innovations (Dahle et al., 2002; Harden, 2000; Wilkerson et al., 2009). Integration in medical education refers to the integration of theory and skills, of different clinical disciplines (horizontal integration), and of clinical and basic sciences (vertical integration) (Dahle et al., 2002). In the studies described in this thesis we exclusively investigated integration of clinical and basic sciences, i.e., vertical integration.

In the literature on integration of clinical and basic sciences the focus often is on curriculum level (Dahle et al., 2002; Harden, 2000; Wilkerson et al., 2009). To achieve integration at curriculum level, cooperation and hence communication between teachers with a different disciplinary background are acknowledged as a prerequisite (Harden, 2000), which has led to decisions to impose the task of designing educational modules on duos of clinicians and basic scientists, and to plan basic science and clinical lectures in tandem (Dahle et al., 2002; Wilkerson et al., 2009). Whether clinicians and basic scientists actually communicate about the relatedness of concepts is not at all a matter of course. They speak different languages and use different taxonomies (Magnani, 1997), which hampers integration. Working together in the medical workplace does not necessarily imply integration of clinical and basic sciences in educational programs.

Integration of clinical and basic sciences on the level of clinical problems is crucial for clinical reasoning, but in the literature it remains unclear what this integration looks like (Boshuizen, 2004; Feltovich et al., 1993). In our research we have therefore tried to elucidate the extent to which clinical and basic science teachers were able to articulate integration on the level of clinical problems, and how they related concepts that illuminated a clinical problem from different disciplinary angles. In addition to the organizational and planning measures that can be taken to improve integration in curricula (Dahle et al., 2002; Wilkerson et al., 2009), the articulation of these relations is assumed to be a step towards supporting the development of integrated curricula (Cutrer et al., 2011; Kinchin et al., 2008). For integration on the level of clinical problems, cooperation and communication could be even more intensive than on curriculum level: clinicians and basic scientists need to communicate their understanding of the concepts involved on a rather detailed level.

In our research we examined the role that concept maps can play for the articulation of integration. In concept mapping research in the medical domain it is mainly assumed that concept maps exhibit integration of clinical and basic sciences, but whether this is indeed the case and how integration is depicted in the concept map has not been investigated (Daley & Torre, 2010; Edmondson, 1995; Hill, 2004;

Kinchin et al., 2008). When we took a closer look at published concept maps (Edmondson & Smith, 1998; Rendas et al., 2006; Torre et al., 2007), we noticed that they visualize predominantly either clinical or basic science aspects of the clinical problem.

We added four perspectives to the existing body of knowledge regarding concept mapping, intended to articulate integration of clinical and basic sciences. *First*, because the concept maps published earlier do not articulate the integration of clinical and basic sciences to any great extent, we endeavoured to help medical teachers to articulate integration by tailoring the concept mapping instructions to the medical domain. The general concept mapping instructions as proposed by Novak (Novak, 2002) were extended by specific instructions that focused on integration of clinical and basic sciences. Integrated curricula are primarily a cooperative enterprise on the part of teachers (Harden, 2000), and hence the concept maps in our research project were constructed in cooperation. We examined whether groups of clinical and basic science teachers (either specialists or residents) were able to articulate integration of clinical and basic sciences when they used these specific instructions. However, because there was no instrument by which to describe this kind of integration in concept maps, we had to design a framework suitable of mapping out integration on the level of concepts and their relations. The resulting concept maps were investigated on the basis of this framework. *Second*, the complexity of concept maps appears to depend on the constructors' expertise level (Kassab & Hussain, 2010; West et al., 2000). We investigated whether this is also the case for the articulated integration of clinical and basic sciences, by comparing concept maps constructed by groups of clinicians and basic scientists on different expertise levels. *Third*, so far, concept mapping research in the medical domain has been limited to a cognitive perspective focusing on differences between maps. Variations in complexity have been interpreted in terms of differences in expertise and mental knowledge structures (Kassab & Hussain, 2010; McGaghie et al., 1996; Rendas et al., 2006). In our research project we attempted to clarify the articulated integration in concept maps by scrutinizing the construction process. In this way, we were able to reveal factors that facilitated or hindered the construction of these maps. This is an aspect that both inside and outside the medical domain has hardly received any attention from researchers. As a *fourth* perspective we looked at the acceptability of concept maps for teachers that had not been involved in the construction process. Teachers could benefit from concept maps constructed by others, as a source of ideas about the content of their program or as an instrument to teach their students about relevant concepts and their relations. Students benefit from preconstructed concept maps (Nesbit & Adesope, 2006; O'Donnell et al., 2002; Rendas et al., 2006) but in order for these maps to contribute to student learning the teachers should endorse the

content of the concept maps. This raised the question whether medical teachers perceived preconstructed concept maps, i.e., concept maps constructed by other clinical and basic science teachers, as useful as the constructors of these concept maps considered them, and what factors affected this perceived usefulness.

Each study reported in this thesis had one of the above described perspectives as point of departure, with all revolving around the teachers' point of view: educational innovations start with a change in teachers' cognitions and behaviour (Tillema & Knol, 1997; Verloop et al., 2001).

In this last chapter we will first assemble the conclusions of the four studies along three research lines, and discuss them in their mutual relations. This will enable us 1. to refine the set of concept mapping instructions we used in this research project to improve the articulation of integration of clinical and basic sciences in concept maps, 2. to ameliorate the framework of features for describing the integration of clinical and basic sciences in concept maps that experts and residents were able to articulate, and 3. to reflect on the perceived usefulness of the concept maps. Next, we will examine our main conclusions against the background of other theoretical discourses that we have not discussed yet, in order to deepen our insights into what constitutes articulation of integration on the level of clinical problems. In closing, we will discuss the strengths and limitations of this research project, propose suggestions for further research and consider the implications for medical education that ensue from our studies, taking into account lessons learned about the articulation of integration of clinical and basic sciences.

6.2 Research lines and main findings

The research project presented in this thesis contained three lines of research:

1. developing a *framework of features* by which to describe integration of clinical and basic sciences in concept maps. By means of this framework we were able to measure differences between concept maps constructed by clinicians and basic scientists at different expertise levels. This line fitted the tradition of description research (Cook, Bordage, & Schmidt, 2008);
2. developing *instructions* intended to support medical teachers in the articulation of the integration of clinical and basic sciences in concept maps. This research line could be characterized as Design-Based Research (Barab & Squire, 2004; Gravemeijer & Cobb, 2006); here, we also endeavoured to clarify the actual use of the instructions by constructors at different expertise levels (Cook et al., 2008);

3. describing the *perceived usefulness* of concept maps in which integration of clinical and basic sciences was articulated, and clarifying this perceived usefulness by pointing to factors that have shown to affect acceptance of educational innovations.

Note that research lines 1 and 2 elaborate on the visualized integration in concept maps. Below, we will discuss the three lines of research in order, by connecting the conclusions of the studies in this thesis.

6.2.1 A framework describing integration on different expertise levels

The first research line pertained to a framework suitable to describe integration in concept maps. With such a framework it would be possible to report expertise differences. Within this research line we formulated the following research questions in Chapter 1:

1. *B. What features describe integration in concept maps?*
2. *What consistent variations are found in concept maps constructed by groups of experts and by groups of constructors at resident level?*

Research on a framework of features is by definition descriptive, because we need to know *what* integration of clinical and basic sciences entails before we can explain *how* it is realized (Cook et al., 2008). In Chapter 2 we concluded that a framework of four features was adequate to describe integration of clinical and basic sciences in concept maps. All features we proposed in Chapter 2 were used in the study reported in Chapter 3 to measure differences between concepts maps constructed by experts and residents. Applying the features to more data yielded additional information about their adequacy to measure integration of clinical and basic sciences. In this chapter, we report the conclusions that can be drawn with respect to the validation of the features. The study described in Chapter 3 showed that the following features adequately described the extent of articulated integration in both expert and resident concept maps, and the differences between them:

- clinical concepts encapsulating basic science concepts;
- basic science concepts subsuming clinical concepts.
- links between clinical and basic sciences. For the interpretation of these links, the subdivision of clinical concepts into history and physical examination, lab, diagnosis and interventions added valuable information about the role of integration in the different phases of the clinical reasoning process.

We concluded in Chapter 2 that a minimum of 16% of basic science concepts seemed to be required in order to find the other features of integration, and proposed this percentage as an extra feature. However, whereas the percentage of 16% basic

science concepts contributed to the description of articulated integration in the expert concept maps, this feature did not hold in case of the resident concept maps.

Neither did the number of clusters containing clinical and basic science concepts add information about integration in concept maps, because this feature correlated significantly with the 'basic science concepts subsuming clinical concepts' feature. Moreover, we described the concept maps by means of the number of general umbrella concepts such as 'history', 'physical examination' and 'lab research' and clinical-problem-specific umbrella concepts. These features in itself did not describe integration, but indicated non-integration and integration, respectively; the number of general umbrella concepts correlated negatively with most of the features of integration, and the number of clinical-problem-specific umbrella concepts correlated positively (but not significantly) with the integration features. Thus, in order to enhance the extent of articulated integration of clinical and basic sciences in concept maps, it could be fruitful to instruct constructors to avoid general umbrella concepts or purposefully add clinical-problem-specific umbrella concepts. We therefore suggest adopting them in the framework of features.

By means of our framework we were able to answer research question 2 by describing salient differences between expert and resident concept maps with respect to articulated integration. Significant differences pointed to the resident concept maps as the more successful products of articulation of integration. The differences pertained the number of basic-science umbrella concepts by which to organize clinical concepts in the maps, the number of links relating clinical and basic science concepts, and the variety of clinical concepts linked to basic science concepts. The resident concept maps contained significantly more clinical-problem-specific umbrella concepts, which again led to the conclusion that clinical-problem-specific umbrella concepts help to articulate integration. Although in other concept mapping studies lower expertise levels were generally found to result in less elaborate concept maps (Kassab & Hussain, 2010; West et al., 2000), in concept maps revolving around the articulation of integration residents outshone experts in elaborateness. This resembles the intermediate effect as reported elsewhere (Van de Wiel et al., 2000): patient analyses by expert clinicians are more concise than those by intermediates. Hence, the framework enabled us to measure the extent of articulated integration in the concept maps and to differentiate between maps in terms of how integration was visualized.

6.2.2 Instructions for articulating integration in concept maps

For the development of instructions to facilitate the articulation of integration we adopted an approach that fitted into Design-Based Research (Barab & Squire, 2004; Gravemeijer & Cobb, 2006). In line with the phases usually completed in Design-Based Research, we conducted studies for the analysis and subsequent design of the instructions (Chapter 2), experimental testing with active involvement of participants (Chapters 2, 3 and 4), evaluation (Chapters 2 and 4) and implications for revision (this chapter), to improve both the instructions and the procedure for concept mapping. Within this research line, we endeavoured to answer the questions presented in Chapter 1:

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?*
3. *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 that focus on the articulation of integration of clinical and basic sciences?*

Although much Design-Based Research focuses on student learning (Barab & Squire, 2004), we considered this research approach suitable for teacher learning as well. We tested the theory-based concept mapping instructions in a semi-real life setting: all teachers were somehow involved in a medical educational program emphasizing clinical problems as a starting point for learning, but at the time of the experiments revision of their educational program was not their main concern. In concordance with Design-Based Research (Barab & Squire, 2004; Gravemeijer & Cobb, 2006), our objective was to generate an educational intervention, i.e., instructions for medical teachers (Chapters 2 and 3), and account for context variables (Chapters 3 and 4) to clarify the use of these instructions. Each study yielded some new questions, which we tried to answer in next chapter, presenting either another study, or another view on the experiments by using additional data. Design-Based Research aims to generate not only an intervention grounded in real life settings, but also theoretical insights that throw light on contextual differences of the effects of the intervention (Barab & Squire, 2004). In this section we will discuss the implications of the findings reported in Chapters 2, 3 and 4 for the revision of the concept mapping instructions. In Section 6.3 we will elaborate on the theoretical insights about the process of articulation of integration and the resulting concept maps, brought forth by investigating different contexts.

Designing instructions

In our first study (Chapter 2), we attempted to optimize the articulated integration of clinical and basic sciences in concept maps. We described implications of cognitive psychological insights for concept mapping instructions aimed at articulating integration, focusing on the knowledge base of experienced clinicians. With this approach we brought the concept mapping instructions into line with what is known about the knowledge base of experienced clinicians, in order to maximize effectiveness of these instructions (Regehr & Norman, 1996; Vosniadou, 1996).

Experiments and evaluation

In Chapter 2 we also described the first experiment with the concept mapping instructions we designed. We explored whether and to what extent groups of expert clinicians and basic scientists articulated integration of clinical and basic sciences in concept maps made on the basis of these instructions. We cautiously concluded that the instructions appeared to result in concept maps in which integration of clinical and basic sciences was articulated to varying degrees. An explorative study, such as the first experiment, does not justify proposing causal relations between instructions and resulting concept maps.

We suggested adaptations of the set of instructions we designed, to improve the articulation of integration. One proposed adaptation concerned the timing of the instructions: starting (instead of finishing) concept mapping with the analysis of a patient case. Additional instructions were also suggested: encouraging constructors to relate concepts concerning history, physical examination and lab research from patient cases to basic science umbrella concepts in the concept map, and leaving out general umbrella concepts such as 'history', 'physical examination' and 'lab research'. General umbrella concepts turned out to jeopardize the articulation of relations between clinical and basic science concepts.

In Chapter 3 the second experiment was reported. We examined the constructors' level of expertise as a context variable that could influence the use of the concept mapping instructions. In an experiment in which the concept mapping instructions of the first experiment were used, it became clear that the concept maps made by residents reflected integration to a significantly higher extent than the expert concept maps. Whereas general umbrella concepts hindered the articulation of integration for groups of experts, these concepts did not hinder residents' articulation of integration, nor was integration in their concept maps limited to relations between diagnoses and basic sciences. Thus, the adaptations of the instructions proposed in Chapter 2 seemed necessary for experts but not for residents. The concept maps confirmed our assumption that instructions based on insights into the knowledge base of experienced clinicians helped to articulate integration. Moreover, the results

increased our understanding of the value of the instructions for the articulation of integration: expertise level strongly influenced how and to what extent integration of clinical and basic sciences was articulated. This could indicate differences between experts and residents regarding the way the instructions were used. Evidently, concept mapping instructions should fit the constructors' expertise level. Besides the intermediate effect, which is a cognitive psychological explanation, we also proposed explanations related to the group composition and to experts' role as teachers, which means that they would try to reduce the complexity of the maps. Experts among experts would be more concise in their communications, assuming that the others understand the concepts involved.

Chapter 4 followed up on this last explanation. In this study we scrutinized the process of concept mapping as an information source by which to clarify the articulated integration in concept maps and the impact of the instructions (Gravemeijer & Cobb, 2006). In this way we hoped to be able to not only *generate* a set of concept mapping instructions to enhance the articulation of integration, but also *understand* the use of the instructions. For the analysis of the qualitative data we used motivation, interaction, exchange of information and decision making as coding categories, which corresponded with factors accounting for communication in cooperative learning and its effectiveness (Slavin, 1996; Weinberger & Fischer, 2006). We found that the coding categories 'interaction' and 'exchange of information' enabled us to further nuance the assumption put forward in Chapter 3, i.e., that experts among experts tend to be more concise in their communication than residents. Experts exchange information by justifying and explaining their contributions, but do not interact spontaneously in the sense that they ask each other questions, ask for clarification, or explicitly relate their knowledge to the knowledge of another constructor. Unlike the experts, residents interacted spontaneously and early in the process of concept mapping (during the collection and first categorization of the concepts). They asked each other for clarification, and indicated on which aspects their knowledge fell short. This might have improved the articulation of integration. Interaction such as answering each others' questions seemed to elicit clinical-problem-specific umbrella concepts, which were subsequently used to organize the concepts in the map. The coding category 'decision making' turned out to be connected with interaction: interaction among experts flourished by decision making. Decision making was strongly influenced by group size: groups of five constructors reached hardly any decisions; three constructors turned out to be optimal.

In Chapter 4 we also reported on experts' and residents' views on the instructions, and their motivations for the task to construct concept maps in which integration was articulated. Motivation and perceived usefulness of the instructions

did not help to explain the extent to which integration of clinical and basic sciences was articulated in the concept maps. Residents were less motivated and less positive about the instructions than experts, but they articulated integration and learned to do so during the concept mapping sessions to a significantly higher degree than experts.

Revision and context specification

What conclusions regarding the concept mapping instructions and context variables can we draw from Chapters 2, 3 and 4? First, the use of instructions focusing on the articulation of integration seemed to help groups of clinicians and basic scientists to actually articulate integration in concept maps. Thus, it seems advisable to provide constructors with such instructions. Second, the group should preferably consist of three constructors. Third, the contextual factor 'expertise' played an important role, both in the process of concept mapping and in the resulting concept maps in terms of articulated integration. This indicates that concept mapping instructions aiming at articulating integration of clinical and basic sciences should be adapted to the level of expertise. Fourth, interaction in the constructors group turned out to be vital for the articulation of integration; hence, depending on group expertise level, interaction should be intensified. A way to do this is to advance decision making in the concept mapping procedure, for example by giving instructions that force joint decisions earlier in the procedure. This pertains to the instructions to organize the concepts in the map along clinical-problem-specific umbrella concepts, and to link clinical and basic science concepts. Instructions that did not have any effect on the resulting concept maps can still be valuable for arousing interaction. An example is labelling the links; this instruction was a trigger for interaction, but often the groups decided to label just a few links, because the kinds of relationship between clinical and basic science concepts did not really vary.

6.2.3 Perceived usefulness

The third research line focused on the usefulness of the concept maps from the teachers' perspective, and was intended to answer the fourth research question of Chapter 1:

4. *Is the perceived usefulness of preconstructed concept maps, constructed collaboratively by teams 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, teachers' need for change to improve integration in their teaching practice, or the degree of articulated integration in the concept maps?*

The medical teachers who constructed the concept maps as well as those who had not been involved in their construction assessed the expert and resident concept maps for their usefulness for medical education by filling in a questionnaire. We endeavoured to unveil the factors that could clarify the perceived usefulness of preconstructed concept maps, and therefore examined the factors that generally account for a successful implementation of educational innovations (Janssen et al., 2013; Verloop et al., 2001).

The most important factor determining the perceived usefulness of the concept maps was whether or not teachers had been involved in the construction of the concept maps, and this appeared to be correlated with the content of the concept maps. The fact that the concept maps were constructed by consensus between representatives of three disciplines could not prevent a significant difference between constructors' and non-constructors' views on the usefulness of the concept maps. In Chapter 5, we argued that it was the construction process itself that contributed to the value teachers attached to integration, and hence to the content of the concept map. Non-constructors did not perceive integration as a major challenge in their own teaching. The multidisciplinary character of the concept maps was recognized, but not acknowledged as beneficial for student learning or curriculum development. Some respondents even perceived articulated integration in the concept map as disadvantageous because there were too many points of view. Hence, the explicitness of the resident concept maps regarding the relations between clinical and basic sciences was not regarded as an advantage.

Non-constructors were significantly more positive about the usefulness of the preconstructed concept maps for clerkships than about any advantages for preclinical teaching or curriculum development. We reasoned that this was not only due to the complexity of the concept maps. If complexity was the sole reason the use of preconstructed concept maps for curriculum development would be valued more highly than for (pre)clinical student learning, because the maps can serve as a source of inspiration for deciding which concepts are important to adopt in the curriculum. This finding seemed to argue in favour of using preconstructed concept maps in clerkships, and to beg the question why they are not used more frequently in clinical programs. In a study on preconstructed expert concept maps as role models for resident learning (Cutrer et al., 2011), the detailed expert map was simplified before it was given to residents. Our results question the necessity of simplifying expert concept maps, because residents were found to outdo experts in the elaborateness of their concept maps.

6.3 General conclusions and discussion

We will briefly present the general conclusions and relate them to theoretical viewpoints.

6.3.1 General conclusions

From the main findings as described above, five general conclusions can be drawn.

1. Understanding integration of clinical and basic sciences in concept maps started with a framework of features. The framework we developed enabled us to quantify the articulated integration of clinical and basic sciences in the concept maps made during our study and to differentiate between these maps in terms of how integration was articulated.
2. Concept maps constructed by residents showed significantly more integration of clinical and basic sciences than expert concept maps, as measured by the features of the framework. Moreover, residents linked not only diagnoses to basic science concepts, as experts did, but also clinical concepts related to history, physical examination and lab research.
3. Instructions derived from the knowledge base of clinicians were found to help constructors articulate integration of clinical and basic sciences in concept maps. The use of these instructions was affected by context variables such as group size and constructors' expertise level. The instructions were rooted in cognitive psychological literature, but process variables that play a role in cooperative learning theory also contributed to our understanding of the actual use of the instructions. The articulation of integration seemed to profit from the process variables 'interaction' and 'decision making'. Some adaptations of the concept mapping instructions we proposed were intended to influence these process variables.
4. The usefulness of concept maps for medical education as perceived by medical teachers appeared to be largely determined by their involvement in the construction process. The views of medical teachers who were not involved in the construction of a concept map seemed to be greatly affected by the content. Moreover, they differentiated between the purposes for which the maps were used, whereas constructors valued the usefulness of the concept maps highly, regardless of whether the maps were used for curriculum development or for preclinical or clinical student learning.
5. Integration was not found to be a major challenge in teachers' day-to-day practice and this 'sense of urgency' did not greatly affect their perception of the usefulness of the preconstructed concept maps.

6.3.2 Describing integration by a framework

The framework to describe integration was grounded in the data from the experiments on two different expertise levels. The next step will be to lend the framework more construct validity. However, this cannot be achieved by examining concurrent validity. Other scoring instruments, such as those described by Kassab et al., Ruiz-Primo and Shavelson and West et al. (Kassab & Hussain, 2010; Ruiz-Primo & Shavelson, 1996; West, Park, Pomeroy, & Sandoval, 2002) have another focus: these instruments are not intended to measure integration. Moreover, the contexts of these concept mapping experiments (H. J. Schmidt, 2006) are different: these concept maps were constructed by individuals instead of the group work we organized, with its own process dynamics. As argued above, it could be these process dynamics that account for differences between concept maps. Also, the objective of the concept maps in our studies was to use them in medical education, either for curriculum development or as a scaffold for student learning, whereas most concept maps from previous studies were not constructed to be used for these educational purposes. Different goals might account for differences in content of the concept maps (Novak, 1998). Indeed, in Chapter 3 we noticed that there are salient differences between our findings and those from the studies mentioned above in terms of elaborateness.

6.3.3 Expertise differences

In Chapter 3, we predicted, on the basis of cognitive psychological insights, differences between concept maps of residents and of experts and found some of these predicted differences. We suggested that the expressiveness of the residents' concept maps resembled the 'intermediate effect' as described in the literature on the knowledge base of clinicians of different expertise levels. Intermediates tend to articulate (and are therefore assumed to use) more basic science concepts when analysing patient cases than experts (Boshuizen & Schmidt, 1992). Concept mapping is a technique aimed at elicit tacit knowledge (Hoffman & Lintern, 2006) and it is experts' basic science knowledge that is found to be much more tacit than residents' (Boshuizen & Schmidt, 1992). Thus, concept mapping is expected to open up the tacit knowledge of particular experts. However, the intermediate effect might be stronger than the elicitation power of concept maps. The concept maps in our studies appeared to fit predictions in the cognitive psychological literature regarding the knowledge base of clinicians (Boshuizen & Schmidt, 1992).

Our hypothesis predicting that experts use more links due to their holistic views, a hypothesis based on general expert behaviour, had to be rejected. This might be due to the quality of the prediction; the number of links between clinical and basic

science concepts might not be an adequate operationalization of the experts' holistic views. Another explanation might be that purposefully linking clinical phenomena with basic science concepts, as was done in our studies, might not be the same as seeking underlying patterns, which has been found to be a manifestation of experts' holistic views when problems have to be analysed in a short time (Koedinger & Anderson, 1990). According to this explanation, seeking underlying patterns, which in the case of clinical reasoning refers to basic science knowledge (Magnani, 1997; Woods et al., 2007) might occur less deliberately and be more directed at efficiently finding a solution for a problem.

6.3.4 Process variables as explanation for articulated integration

As our data suggest, the concept mapping instructions we designed helped the constructors to articulate integration of clinical and basic sciences. We also found that the instructions based on the knowledge base of experienced clinicians helped residents to articulate integration more than they did the experts. Process variables that were in line with cooperative learning theory enabled us to understand the use of the instructions in the expert and resident groups.

Appraising our conclusions regarding the process differences between the expert and the resident groups from another theoretical perspective might deepen our understanding of these process variables and might point us to new research paths in our exploration of the integration of clinical and basic sciences. The model we chose for this purpose is Decuyper's team learning model (Decuyper, Dochy, & Van den Bossche, 2010), because concept mapping in multidisciplinary groups is by definition a team learning activity (Novak, 1998). Moreover, this model relates to both process and product, an approach also followed by us. The model is rather comprehensive and exceeds the scope of our research issues. We will concentrate on some of the process variables included in the model.

Of the process variables proposed by Decuyper et al., 'sharing', 'constructive conflict', 'co-construction' and 'boundary crossing', are relevant for our studies. Exchange of information in our studies seems equivalent to what Decuyper calls 'sharing': experts were surprised to hear each other's point of view and accepted all contributions from the other participants. Note that in the Decuyper model 'sharing' is used in a slightly different way than how we used it in Chapter 5 and this chapter, where 'shared content' refers to content that medical teachers agreed on. In the expert groups constructive conflicts did not occur as frequently as in the groups of residents, who readily acknowledged their knowledge deficiencies. Constructive conflicts stimulated residents to ask the other constructors for clarification and explanation, and so elicited interaction. When acknowledging deficiencies, residents

related the concepts they knew to the new information they received from the other participants, which resulted in an explicit linking of concepts. The process variable 'co-construction' forces constructors to make joint decisions. Decuyper et al. do not explicitly relate co-construction and constructive conflicts, whereas we noticed that decision making elicited interaction. Boundary crossing refers to borders between team members that represent different groups, or between teams and their environment (Decuyper et al., 2010). Because the constructors in our multidisciplinary teams represented different disciplines, each with its own culture and jargon, the process variable 'boundary crossing' is certainly applicable to the process of concept mapping in our study. As stated in Chapter 4, the knowledge gaps between the experts are assumed to be bigger than those between residents. In the context of an academic hospital clinical specialists and basic scientists are highly specialized. They often perceive their knowledge domains as complementary rather than intertwined (Feltovich et al., 1993; Koens et al., 2006). This could explain why experts do exchange views - or, in terms of Decuyper, 'share' their views -, but do not easily cross boundaries. The latter implies each party being willing to accept the other's viewpoint and search for shared content. Thus, a lower level of articulated integration could be interpreted as difficulties with boundary crossing. As Table 2.1 in Chapter 2 shows, experts did cluster concepts but avoided clusters combining clinical and basic science concepts. The boundaries between residents' disciplines might be less rigid, because residents are still in a learning process, which makes it easier for them to engage in constructive conflicts and find common interests.

Our conclusions regarding the process of concept mapping aimed at the articulation of integration are in concordance with the theory of team learning as proposed by Decuyper et al. Actually, the two viewpoints are complementary. The process variable 'boundary crossing' sheds a different light on the differences between expert and resident concept maps in terms of articulated integration. Moreover, our findings suggest that process variables might be related, an issue not discussed by Decuyper et al. Just as in our studies decision making affected interaction, co-construction could raise constructive conflicts.

6.3.5 Impact of involvement on perceived usefulness

The differences between constructors and non-constructors with respect to the perceived usefulness of the concept maps may also be clarified through the theoretical discourse about team learning. In our studies concept mapping was actually a process of co-construction (Decuyper et al., 2010). Earlier, we argued that experts proved to have a harder time crossing boundaries between the disciplines than residents, and that it took them more time to establish constructive conflicts. All

non-constructors were experts and so were prone to have difficulties crossing boundaries between disciplines. From the findings reported in Chapter 5 we can deduce that boundary crossing between disciplines requires interaction and that digital exchanges do not suffice. Although all concept maps were constructed by consensus between representatives of three different disciplines, this obviously did not help non-constructors to agree with the content of the map. We therefore assume that it will not help to enlarge the group of constructors to construct concept maps based on an even broader range of consensus. We suppose that it is the activity of constructing concept maps itself and the accompanying experiences of constructive conflicts, and hence interaction, that contribute to the willingness to accept the content presented by other disciplines. Distributing the concept maps by e-mail did not turn out to be an effective way for medical teachers to appreciate the articulation of integration in the concept maps that they did not construct themselves. Viewed from the team learning perspective (Decuyper et al., 2010) constructive conflicts without interaction seem to hinder perceived usefulness, whereas constructive conflicts in team learning tasks which arouse interaction might improve the usefulness of preconstructed concept maps for non-constructors. Such a task might be adapting the preconstructed concept map in multidisciplinary groups.

6.3.6 Integration in day-to-day practice

The constructors of the concept maps were not questioned about their views on integration in their daily teaching practice. Therefore, we cannot relate their views on the usefulness of the concept maps to their need to improve integration in their program. The non-constructors, who were questioned on this issue, did not view integration of clinical and basic sciences as a major theme in their own teaching. In Chapter 5 we suggested that it was the process of concept mapping that enhanced awareness of the disciplinary view on the clinical problems, and hence of the relevance of integration of clinical and basic sciences to one's own teaching. Thus, the implementation of integration seems a matter of interaction and constructive conflicts. Improving integration in medical curricula seems primarily to require an intervention to improve interaction on the level of clinical problems. The relevance of interaction to improve integration has also been pointed out for teacher learning programs (Martimianakis et al., 2009). It is striking that on curriculum level and in research on clinical reasoning so much attention is devoted to integration (Boshuizen, 2004; Boshuizen & Schmidt, 1992; Dahle et al., 2002; Feltovich et al., 1993; Harden, 2000; Wilkerson et al., 2009), whereas teachers do not experience any urgency to improve integration in their own teaching. This discrepancy deserves further study, in

which teachers' actual behaviour in the classroom should be related to their cognitions and beliefs about integration (Janssen et al., 2013; Verloop et al., 2001).

6.4 Strengths and limitations

In this thesis we explored integration on the level of clinical problems, which has not received much attention until now. On curriculum level, the relevance of integration is widely acknowledged (Dahle et al., 2002; Harden, 2000; Wilkerson et al., 2009). The lack of attention for teachers' cognitions and behaviour with respect to integration on a more detailed level, such as clinical problems, is what constitutes the relevance of our studies. Our research not only provides insights into the construction and reception of concept maps aimed at articulating integration, but might also be a stepping stone towards further insights into what integration actually entails and how individual teachers can improve their teaching with respect to integration.

We relied on a diversity of theoretical views as a basis for both the design of concept mapping instructions and the interpretation of the data. These views stem from cognitive psychology, in particular literature on clinical reasoning and expertise development, and from educational sciences such as cooperative learning and team learning. We endeavoured to combine or, to stick to the theme of this thesis, to integrate these theoretical viewpoints. This integrated theoretical approach has enlarged our understanding of what constitutes integration and how to achieve it.

Methodologically we also combined different approaches. Qualitative research methods such as the interpretation of the concept maps and the analysis of the video tapes and field notes were combined with quantitative methods such as surveys. Moreover, we involved diverse participants: experts, residents, and teachers from different medical centres. The outcomes of three of our studies were framed by the methodology of Design-Based Research: practical outcomes such as concept mapping instructions, and the theoretical modelling of the integration achieved in multidisciplinary groups.

Any limitations of this research project concern the explorative character of the studies presented in Chapters 2, 3 and 4 and potential biases. Because educational research on integration on the level of clinical problems is scarce, the first steps in this research domain have been necessarily explorative. In this phase, research questions and methodology are not primarily directed at understanding the effects of the intervention and the underlying process of learning (Gravemeijer & Cobb, 2006), rather than measuring the effects. Coupling the concept mapping instructions and the data with a theory provides a framework for interpretation (Barab & Squire, 2004). First, we need to know what integration entails and what

concept mapping may contribute before experiments, including pretest and posttest comparisons, can be scaled up (Raudenbush, 2010). Therefore, in our study generalizability has definitely been compromised. We were able to include only a limited number of concept maps in our study in order to be able to analyse each concept map and concept mapping session. A second limitation pertains to the context of the experiments, which were not part of curriculum innovations at the Leiden University Medical Centre. We therefore engineered different contexts, to test the instructions in settings that were semi-real life rather than real life, and described these context variables in order to make generalizations of our conclusions to other contexts possible (Barab & Squire, 2004). The explorative character also holds true for the validation of the framework, as discussed previously.

Potential sources of bias lie in the theoretical founding of the concept mapping instructions, in the construction of the concept maps, and in the interpretation of the data. We derived the concept mapping instructions from the theory of knowledge encapsulation, a theory in which clinical and basic science knowledge is seen as an integrated knowledge network. Our literature search on knowledge development was not confined to this theoretical perspective, and we also took on board the theoretical discourse on expert knowledge organization in general. Nevertheless, the concept mapping instructions have been strongly inspired by the theory of knowledge encapsulation. We counteracted this predominance of the knowledge encapsulation theory in the design of the concept mapping instructions by involving other theoretical perspectives, such as models clarifying cooperative learning and team learning, for the interpretation of the data. By involving the constructors and their feedback on the instructions (Barab & Squire, 2004), we tried to correct any flawed operationalizations of these theoretical insights. The construction process, too, might have caused bias because all constructors were affiliated to the Leiden University Medical Centre. Additional analysis with the data of the study described in Chapter 5, in which non-constructors from the LUMC were compared with non-constructors affiliated to other medical centres, showed that LUMC non-constructors considered the concept maps slightly more useful than the other respondents did, but they were significantly more positive about the usefulness of the resident concept maps for curriculum development. This difference within the group of non-constructors might be due to curricular differences and to differences in experience with schematizing. Finally, the qualitative interpretation of the concept maps and the framework distilled from these concept maps might have been sensitive to bias. In order to cope with dominant views in the interpretation phase of the concept maps, we involved researchers of different disciplinary backgrounds and expertise levels : educationalists, clinicians and an undergraduate medical student. For the analysis of the qualitative data presented in of Chapter 4, i.e., the video tapes

and field notes, we endeavoured to limit biased interpretations by means of triangulation, in which the video tapes and field notes were combined with a questionnaire and the concept maps.

6.5 Implications for research and practice

The Design-Based Research methodology we adopted in this research project promotes ecological validity: experiments take place in a naturalistic context. Precise descriptions of the contexts of these experiments have to accommodate follow-up research and practical implementation (Gravemeijer & Cobb, 2006). The research project described here delivered theory-based and empirically tested concept mapping instructions, a framework of features by which to measure integration in concept maps, concept maps on different expertise levels, insights into context variables and process variables that affected the articulation of integration in concept maps, and teachers' views on the use of the concept maps and the factors that affect these views. For the near future, these products will set the research agenda regarding the role of concept maps in the articulation of integration, along three paths: developing the framework, refining the instructions, and examining student learning guided by preconstructed concept maps with varying degrees of articulated integration. We conclude with four practice points of this research project: the meaning of explication for learning, residents' role in curriculum development, the role integration plays in the interpretation of history, physical examination and lab research, and the use of concept maps as a point of reference to store shared content and to change it.

6.5.1 Further development of the framework

It is sensible to offer students a program that connects the different disciplines, in particular the clinical and basic sciences. However, research on integration in the classroom in instruction material for students and as expressed by actual teachers' behaviour is scarce. Our research project offers a theoretically and empirically grounded framework that describes integration of clinical and basic sciences in concept maps. In future research, its scope might be extended to teacher behaviour and student discussions, for it offers a more differentiated view on what integration of clinical and basic sciences actually means.

Above, we discussed the need for further validation of the framework. A first step in this direction would be to apply it in concept mapping research at other expertise levels, such as undergraduate students, and in other clinical domains and

with other clinical problems. Note that in the educational programs of other medical disciplines, such as dentistry and veterinary medicine (Edmondson & Smith, 1998), integration of clinical and basic sciences is as prominent as in the medical disciplines involved in our studies. Follow-up research in these disciplines will strengthen the validity of the framework. The cyclic process of testing in new situations and refining should be continued until saturation point has been reached.

6.5.2 Further refinement of the concept mapping instructions

The setting in which we tested the concept mapping instructions can be described as semi-natural. A real natural setting would be a setting in which teachers are intending to change their program and the multidisciplinary concept maps serve as a road maps for the development of the modules and the instruction material. This was not the case in our experiments. Follow-up research should include such natural settings.

In Chapters 2 and 4, and in this chapter, we have suggested some adaptations of the concept mapping instructions that might influence either the process of concept mapping or the resulting concept maps. We did not implement these adaptations in the experiment with the residents, because we wanted to examine differences in expertise, a variable that we expected to be informative. Future testing of the adaptations would complete the empirical and theoretical cycle, as recommended in Design-Based Research (Gravemeijer & Cobb, 2006) because that is what Design-Based Research is about: improvement of the intervention.

New research directions regarding the articulation of integration in concept maps may also be discovered when the model of team learning is used for the interpretation of the learning processes in experiments with the adapted concept mapping instructions. Do these adaptations indeed change the experts' 'sharing mode' into constructive conflicts and interaction?

6.5.3 Cognitive load and concept maps

In our research we did not investigate the effects of the use of preconstructed concept maps on student learning. It is especially the differences between expert and resident concept maps that form a challenge in this respect and that need further research. The rationale for providing students with preconstructed concept maps is that the concept map can serve as a scaffold to support student learning. This reduces cognitive load, which in turn may improve student learning (Sweller, Merrienboer, & Paas, 1998). The question arises what it is that relieves cognitive load when preconstructed concept maps are provided to students. Is it the elaborateness of residents' concept maps, or the conciseness of experts' concept maps that keeps

clinical and basic science concepts and their relations implicit? Expert concept maps look simpler than resident maps, and simplification is a strategy often adopted if maps are used for medical education (Cutrer et al., 2011; Mandin et al., 1997). Some non-constructors (cf. Chapter 5) also preferred simple schematizations, such as decision trees. However, simplification is at odds with the explication of concepts and their relations, and it is this aspect of concept maps that is put forward as scaffolding (Daley & Torre, 2010; Kinchin et al., 2008). Studies in which students' clinical reasoning is supported by means of both expert and resident concept maps may provide insights into the scaffolding power of different levels of elaborateness.

6.5.4 Explication and learning

Concept mapping is in essence an act of making knowledge explicit, and so builds on explicit learning processes (Daley & Torre, 2010; Rebuschat & Williams, 2012). This emphasis on explicitness does not entail a denial of implicit learning (Rebuschat & Williams, 2012). Making integration of clinical and basic sciences explicit seems to be an educational approach intended to encourage analytic clinical reasoning (Eva, 2005). Evidently, concept maps that articulate integration should be used in study assignments, lectures and small group sessions revolving around the analytic approach to clinical reasoning. In addition to analytic reasoning, students should also practice the non-analytic way to approach patient cases (Ark et al., 2006; Eva, 2005). We do not consider concept mapping suitable for this way of clinical reasoning, because non-analytic reasoning relies on pattern recognition and leaves basic science knowledge implicit.

The findings presented in Chapters 4 and 5 indicate that the activity of concept mapping itself and interaction in particular, contribute to experts' views on the relevance of integration in their educational program. Our conclusion underlined that interaction enhances teachers' abilities to explicate integration. We suppose that it is this ability that in turn shapes integration in educational programs. At the heart of integration in medical educational programs lies the interaction between clinicians and basic scientists. Bringing disciplines together does not automatically produce interaction, let alone integration. Constructing concept maps in multidisciplinary groups, preferably guided by instructions that focus on integration, seems to be a good instrument for teacher learning in the context of integrated curricula, in which the key word is interaction.

6.5.5 Role of residents in medical education

The development of educational programs is mainly a task of expert teachers. In medical education, the pivotal role of experienced clinicians and basic scientists in the development of programs and instruction material seems taken for granted. It is their content knowledge that is emphasized (Cutrer et al., 2011; Mandin et al., 1997). We argue that the differences between expert and resident concept maps can be deliberately used in medical education. Overall, residents' current role remains confined to supervising clerks and tutoring small groups. Our findings seem to underline the potential residents' participating in curriculum development. They can bridge the gap between students and experts, and help to determine the content of a program by their ability to explicate the concepts and relations that are crucial to understanding a clinical problem. Further research should explore the potential of residents for the development of educational programs.

6.5.6 Integration and history, physical examination and lab research

In Chapter 2 we described how diagnostic categories played a pivotal role when experts articulate integration of clinical and basic sciences in concept maps, at the expense of history, physical examination and lab. However, students should learn what data from history, physical examination and lab add to the understanding of the patient problem, and how the concurrence of these data can be explained by basic science mechanisms. Previous research has already shown that day-to-day teaching practice does not include much explication of the relations between basic sciences and data from history, physical examination, lab and interventions (Prince & Boshuizen, 2004). The framework we propose could raise teachers' consciousness about what they actually do when they teach students to relate clinical phenomena to basic science explanations. What relations do they elucidate during lectures? Do their basic science explanations remain limited to diagnoses, leaving relations with history, physical examination and lab research underexposed? The framework of features might stimulate a broader educational approach to integration of clinical and basic sciences.

6.5.7 Concept maps for changes as well as storage

Undergraduate medical education schools generally have to accommodate large cohorts of students. Consequently, many teachers are involved in the programs to teach students via lectures and small group sessions. This implies that there is not one single program, but as many programs as teachers. Module coordinators might use preconstructed concept maps to initiate discussions among teachers about the

content of the program and about what should be added to or changed in the concept map in order to establish a shared content in the teaching. The adapted concept maps can function as the stored content of a module which could guide teachers in their task. In conclusion, preconstructed concept maps that articulate integration of clinical and basic sciences might provoke changes in teachers' views on integration, and provide a means to store the content of teaching programs.

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SUMMARY

SAMENVATTING

Summary

Introduction and problem definition

This thesis revolves around the integration of clinical and basic sciences in medical education, and the role concept maps can play in the articulation of this integration. Its point of departure was the assumption that teaching programs rely on knowledge that can be made explicit. Students might learn explicitly or implicitly. However, a curriculum can only be designed by the knowledge that can be identified. This means that to help students build a sound knowledge base that comprises intertwined clinical and basic science knowledge, this integrated knowledge should be explicated.

The importance of vertical integration, that is integrating clinical and basic sciences, is widely emphasized, with the focus on the curriculum level. In this thesis we explore integration of clinical and basic sciences on the level of clinical problems. It is this level that pertains to the day-to-day practice of teaching in medical education. On the level of clinical problems, a clinician should be able to explain and predict clinical phenomena, which manifest themselves during history taking, physical examination, lab research, and clinical conclusions such as possible diagnoses, via knowledge about basic sciences such as anatomy, physiology, and biochemistry.

We have chosen concept maps as a vehicle to help teachers with this task. In a concept map a subject is depicted in a schematic way. The map contains the concepts needed in order to understand the subject, with these concepts linked in order to express the relations. There are always hierarchic relations in a concept map; an umbrella concept is explained by the concepts subsumed by the umbrella concept. The activity of concept mapping has already proved an adequate approach to evoke knowledge. It is considered a promising approach particularly for the elicitation of tacit knowledge, that is, knowledge used unconsciously.

Protagonists in the four studies presented here were teachers, because integration starts with them. They determine what and how students are taught. Not only does an integrated curriculum require teachers to explicate the clinical and basic science concepts and their relations, an integrated curriculum in which basic scientists and clinicians do not cooperate when developing an educational program is also difficult to imagine. Educational research on the articulation of clinical and basic sciences on the level of clinical problems is still in an explorative phase. Consequently, insights into the way teachers cope with this integration are needed before we turn to look at students.

Cognitive psychological research on the knowledge base of experienced clinicians, and of experts in general, has increased our understanding of how clinical and basic sciences are integrated within the mental organization of clinicians. These insights can provide a basis for educational innovations. This also applies to concept mapping instructions intended to help medical teachers to articulate integration. In the literature, concept mapping is recommended as a technique to articulate integration of clinical and basic sciences. However, the concept maps published so far have not exhibited integration of clinical and basic sciences to any great extent. Often, the emphasis is either on clinical sciences or basic sciences. Hence, it seems to make sense to endeavour to improve the articulation of basic sciences by means of instructions that harmonize with the knowledge base of experienced clinicians. These instructions might help clinical and basic science teachers to articulate integration. When medical teachers construct concept maps intended to visualize integration, their challenges lie in the comprehensiveness of the maps, in particular pertaining to the different phases of clinical reasoning, in the articulation of basic science knowledge which often belongs to clinicians' tacit knowledge, and the articulation of the different kinds of relations between clinical and basic science concepts. We designed specific concept mapping instructions, which are intended to meet these challenges.

Whether medical teachers are able to articulate integration in concept maps if they are supported by instructions actually focusing on integration is an empirical question. However, it is still unclear what precisely constitutes integration of clinical and basic sciences on the level of clinical problems. In order to measure effectiveness of instructions to articulate integration in concept maps, we needed a framework that can describe this integration on the level of clinical problems.

At the heart of integration lies communication and cooperation. Integration offers a multidisciplinary view and to attain this integration varied medical disciplines should be engaged and should give their input. In addition to adopting the cognitive psychological perspective on integration, in our research project we also set out to examine what was the impact on the articulation of integration of communication and cooperation when multidisciplinary groups of medical teachers jointly endeavour to construct a concept map.

The first three studies in this thesis can be characterized as Design-Based Research. Starting with theory-based concept mapping instructions, we conducted experiments to improve these and relate them to context variables, in order to understand why medical teachers articulated integration to the extent and in the way visualized in the concept maps and finally to improve them. What is pivotal in Design-Based Research is the linking of the concept maps (as the product of the learning

process to articulate integration) and the process of concept mapping (in which communication and cooperation are essential). This enabled us to examine what factors affect the construction of integrated concept maps by multidisciplinary groups.

Aims of the studies

The theme of the use of concept maps for the articulation of vertical integration was investigated from four different angles, each covered in a separate study. The first angle is based on the view that it is possible to describe integration and to improve the articulation of integration. This angle is covered in the first study in which we explored the articulation of integration of clinical and basic sciences in concept maps by expert groups of clinicians and basic scientists, and the way to measure this articulated integration. The groups were guided by instructions focusing on the articulation of integration. In the second study, this perspective was broadened to include differences between groups of clinicians and basic scientists of different expertise levels. The third angle was intended to shed light on the process of concept mapping, in order to understand what it is that process characteristics contribute to the articulation of integration. In addition to our investigations of the construction of concept maps and its learning effects, the fourth study focused on the usefulness of the concept maps themselves in medical educational programs as perceived by medical teachers. By comparing the views of teachers that constructed the concept maps with the views of teachers who were not engaged in the construction process, we questioned the relevance of active communication and cooperation for the articulation of integration. Chapter 6 adds to the insights gained in the previous chapters by comparing the results and conclusions of Chapters 2 and 3, so that the framework of features is further refined and the lessons learned from Chapters 2, 3 and 4 are combined in order to sharpen concept mapping instructions for the articulation of integration.

Results

Chapter 2 sets out with the first perspective on the role of concept maps for the articulation of integration of clinical and basic sciences, and focuses on the questions *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? What features describe integration in concept maps?* We derived concept mapping instructions from current insights into the knowledge base of experienced

clinicians concerning the integration of clinical and basic sciences. Our instructions were intended to turn constructors' focus to the contribution of their own discipline, to help them organize the concepts along two hierarchical devices to purposefully link clinical and basic science concepts, and to check comprehensiveness and relations between clinical and basic sciences concepts by means of two patient cases. Seven groups of three experts, both clinicians and basic scientists, each constructed a concept map about a clinical problem along these instructions.

Because there were no instruments to measure integration, either in concept maps or presented in other ways, a framework of features by which the concept maps could be described both qualitatively and quantitatively, was required. We developed such a framework, evaluated it and proposed refinements. Integration in concept maps can be measured by clinical umbrella concepts that encapsulate basic science concepts, by basic science umbrella concepts that subsume clinical concepts, and by links between clinical and basic science concepts, for which it is meaningful to distinguish the phases in clinical reasoning linked to a basic science concept. Moreover, if less than a sixth of the concepts were of basic science origin, there were hardly any features of integration visible. Umbrella concepts that indicated general clinical categories such as 'history' and 'lab research' hindered the articulation of integration, whereas umbrella concepts that were specific for the clinical problem at hand seemed to facilitate the articulation. Clusters of clinical and basic science concepts coincided with basic science umbrella concepts subsuming clinical concepts, and were therefore not informative about the articulated integration.

We concluded that the experts in our study were able to construct concept maps that articulated integration of clinical and basic sciences, as measured by the framework. They mostly articulated integration by links between basic science concepts and diagnoses, and there was a preference for clinical concepts that encapsulated basic science concepts. However, regarding the actual level of integration the concept maps showed a wide variation. We proposed some adaptations of the instructions, to improve the articulation of integration in concept maps.

The second study is reported in **Chapter 3**, and focused on expertise differences that could become apparent in concept maps. The research question was: *What consistent variations are found in concept maps constructed by groups of experts, and by groups of constructors at resident level?* Whereas in previous research on concept mapping differences in concept maps that visualized one theme were investigated, we searched for consistent differences regardless of theme - in our study, clinical problems-. Moreover, we mainly examined differences concerning the articulation of integration of clinical and basic sciences. Concept maps constructed by seven

multidisciplinary groups of experts were compared with concept maps constructed by seven groups of residents and basic scientists in training, with the same disciplinary composition as the expert groups. This enabled us to look for evidence for three hypotheses regarding the articulation of integration, derived from cognitive psychological research on expertise knowledge organization.

The first hypothesis referred to the theory of knowledge encapsulation, and stated that residents would use more basic science concepts in their concept maps, because these concepts are not encapsulated in clinical concepts to the same extent as is the case in experts' knowledge base. The comparison of the concept maps made by the two groups revealed that this hypothesis could be neither verified nor rejected: residents used more basic science concepts, but not significantly so. Overall, residents constructed concept maps that included more concepts, both basic science and clinical concepts. The second hypothesis pertained to the organization of the concepts in the map. In line with our expectations, resident concept maps contained significantly more basic science umbrella concepts that subsumed clinical concepts than experts maps and the latter contained more clinical concepts encapsulating basic science concepts although this last difference was not significant. For the third hypothesis we did not find any evidence. We expected experts, with their holistic views on clinical problems, to use more links between clinical concepts and basic science concepts than did residents. However, resident concept maps contained significantly more links between clinical and basic science concepts than did the expert maps. In addition, the residents linked basic science concepts not only to diagnoses, as was mainly the case in the expert maps, but also to patient history, physical examination and lab research. Moreover, previous concept mapping research has shown that the more expertise on the part of the constructors, the more complex their concept maps. Measuring by our set of features, which partly overlapped with the way complexity is gauged in these concept mapping studies, we found the opposite was true: the resident concept maps were more complex. This can be explained by the process: in previous research concept mapping was an individual activity whereas in our study it was a joint venture of multidisciplinary groups. We also suggest that groups of experts could be more concise in their communication with each other than residents, because they assume that their colleagues possess extensive knowledge of the clinical problem.

We conclude that resident concept maps could be valuable in medical education because of their explicitness, in particular concerning integration of clinical and basic sciences.

The process characteristics that could account for the differences between concept maps of experts and those by residents were investigated in the third study, described

in **Chapter 4**. Following the Design-Based Research approach, we endeavoured to clarify the articulation of integration by means of examination of the process of concept mapping in order to optimize the concept mapping instructions that we designed and asked: *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?* In addition to the cognitive psychological perspective in Chapters 2 and 3, a constructivist and a cooperative learning dimension was brought to bear on the integration articulated in the concept maps.

After a pilot which showed that a group size of three participants was optimal, we examined the constructivist perspective by comparing the draft and the final version of each concept map, and found that the articulation of integration can be learned. Expertise level turned out to be a relevant context variable: residents proved better to learn the articulation of integration than experts. For the cooperative learning perspective, we analysed notes taken from video tapes of the concept mapping session and field notes by means of an interpretation framework that fit conditions and communication patterns as described in the literature on cooperative learning and consisted of four interpretation categories: (1) motivation, (2) exchange of information, (3) interaction, and (4) the decision making process. This data source helped us to understand why residents articulated integration to a higher extent: their communication pattern differed from that of experts. Whereas residents interacted with each other right from the beginning of the session, i.e., asking each other questions, explaining concepts to each other, experts were more reluctant in their interaction. Compared with the communication of residents, experts' communication pattern relied more on exchange of information. They started to interact only when joint decisions had to be made. Hence, decision making and interaction were not only factors that separately affected the learning of articulation of integration as proposed in the theoretical discourse of cooperative learning, but they also seemed to be related. Moreover, we asked the participants about their views on the theory-based instructions for the construction of concept maps. The experts were more positive about the instructions than the residents and expressed more motivation, as also became clear from the analysis of the video tapes. The three data sources enabled us to combine the products, i.e., the concept maps, communication during the process of concept mapping, and participants' views, in order to understand the articulated integration. The perceived usefulness of the instructions and motivation appeared to be irrelevant factors for the articulation of integration in concept maps: experts were highly motivated, but their articulation of integration lagged behind that of the residents. However, integration turned out to be a relevant factor for the articulation of integration.

In the fourth and last study, described in **Chapter 5**, we adopted another perspective. Whereas the first three studies focused on concept maps themselves and their construction process, in this study we were concerned with the usefulness of the concept maps for educational programs as perceived by medical teachers, i.e., *Is the perceived usefulness of preconstructed concept maps, constructed collaboratively by groups of clinicians and basic scientists, affected by (1) teachers' participation in the construction of the concept map, (2) the degree to which non-constructing teachers share the content of the concept map, (3) teachers' prior experience with schematizing or concept mapping, (4) teachers' need for change to improve integration in their own teaching practice, and (5) the degree of articulated integration of clinical and basic science?* Our goal was to get an impression of the extent to which articulated integration of clinical and basic sciences in concept maps was transferable from one teacher to another. Because the concept maps were constructed by multidisciplinary groups, which implies that they were always the product of consensus, they might be suitable for use by other teachers. By means of a questionnaire whose questions were based on literature on educational use of concept maps, we asked the constructors of the concept maps, and medical teachers affiliated to all eight academic medical centres in the Netherlands, about the usefulness of both the expert concept maps and the resident concept maps.

Medical teachers who had not been involved in the construction process valued the usefulness of the concept maps significantly less than the teachers who constructed them. An explanation can be found in the degree to which they shared the content of the map. Evidently, teachers have difficulty accepting other teachers' concept maps. The fact that the concept maps were based on consensus did not contribute to their being accepted. None of the other factors affected the perceived usefulness significantly. Previous experience with concept mapping nor experienced need to improve integration in teachers' own teaching practice, nor the degree that integration was articulated in the concept maps affected the perceived usefulness. We suggested that the non-constructing teachers did not consider articulated integration in the concept maps an advantage because integration of clinical and basic sciences did not seem a major theme in their day-to-day practice, as the survey showed. This is underlined by the finding that the concept maps, which visualized integration to a greater extent, that were the resident maps, were considered to be slightly less useful for medical education than the expert maps. The concept maps valued least were those that contained the most basic science concepts. Remember that all the concept maps revolved around a clinical problem and were therefore clinically oriented. Articulated integration in concept maps did not seem to be an advantage to teachers who had had no part in the construction. We argued that the

importance teachers attach to integration in their own practice and the degree to which they value the articulated integration in concept maps seem to be a matter of actively sharing knowledge by means of communication and thus sharing content. The teachers who assessed the usefulness of preconstructed concept maps lacked this experience.

Furthermore, constructors perceived the concept maps as equally useful for curriculum development, preclinical, and clinical student learning, whereas teachers who did not construct the concept maps differentiated between various functions and targets of their usefulness: they valued them more highly for clinical student learning than for curriculum development and preclinical learning. This seems to imply that the complexity of the concept maps is not the reason why teachers are not inclined to use preconstructed concept maps of clinical and basic science. Because these complex maps could serve as a source of information for curriculum development, complexity would not be a disturbing factor. Our fourth study suggested that integration in medical education is a matter of actively sharing knowledge and communication.

Conclusions and discussion

In **Chapter 6** we have assembled the conclusions of the four studies, and discuss them along three research lines that could be distinguished throughout the research project: (1) the development of a framework of features by which to describe integration articulated in concept maps, (2) the development of instructions to support medical teachers to articulate integration in concept maps, and (3) the description of the perceived usefulness of these maps.

Ad (1). We describe the features of the framework by which to measure integration and drew conclusions about which features to include and exclude in the framework, taking into account the findings in Chapter 2 and 3. The framework as described in Chapter 2 was used again for the study described in Chapter 3, and consequently its validity increased. The framework appeared to be suitable to describe differences between the articulated integration in the expert concept maps and those of residents, which led to the conclusion that residents were able to articulate integration to a greater extent, and to relate basic science concepts to more phases in the clinical reasoning process, than experts were. We explain the difficulties inherent in establishing the concurrent validity of the framework. Moreover, we discuss some explanations of why some of our hypotheses regarding the expertise differences could be verified and another not. A possible explanation is the 'intermediate effect'. Based on this intermediate effect, we hypothesized that residents would articulate more basic science concepts in their concept maps than experts would do. However, the intermediate effect not only showed up when

residents chose their basic science concepts, but also seemed to play a role in the linking of clinical and basic science concepts.

Ad (2). The instructions intended to help clinicians and basic scientists articulate integration in concept maps are discussed against the background of the phases as distinguished in Design-Based Research, which makes it possible to present an overview of the development of the instructions. We explain how the first study generated the research questions for the second one, which in turn evoked the third study, aimed at clarifying the articulated integration in the concept maps of experts and residents. In Chapter 6, this research line ends with a proposal for concept mapping instructions and a suggested procedure for the articulation of integration of clinical and basic sciences, which are both theory-driven, and empirically grounded. In addition to generating a set of instructions that result in concept maps with the desired articulated integration, we also wanted to understand why these instructions work and under which circumstances. Hence, we set our conclusions against a theoretical perspective we have not discussed yet, i.e., the theory of team based learning, to deepen our insight into the factors that explain the degree of articulated integration. This theoretical perspective points to the information gap, which seems to be bigger between highly specialized experts than between residents.

Ad 3. Regarding the third line, we summarize our findings concerning the perceived usefulness of preconstructed concept maps and the factors to which these findings could be attributed, and discuss the findings again from the theory of team based learning. In the fourth study it became clear that disseminating preconstructed concept maps did not encourage non-constructing teachers to 'cross boundaries'. This term is used in team based learning to indicate the process of bridging the information gap between participants. Boundary crossing within the constructing group proceeded more easily than between constructors and non-constructing teachers, probably resulting in a reluctance on the part of the non-constructing teachers to accept the content of the concept map. The keyword for boundary crossing seems to be 'interaction'. We argue that interaction could be an effective way to improve the perceived usefulness of the preconstructed concept maps. Interaction might for example be evoked by the task of adapting the preconstructed concept maps in multidisciplinary groups of teachers.

This last chapter summarizes what we consider to be the strengths and limitations of the research project. As strong points in the explorative studies of this thesis we mention the variety of theoretical views (cognitive psychology, constructivism, cooperative learning, team based learning, Design Based Research), the combination of different methodologies (description and measurement of products, surveys, qualitative research on process), also within one study, and the diverse groups of participants (different expertise levels, affiliated to different

academic hospitals and curricula). Limitations are those mostly inherent in explorative studies, and concerned the generalizability of the empirical findings because of the limited number of participants, concept maps and contexts of the experiments. We further explain potential biases and how we counteracted these. We describe the research agenda resulting from this research project. Three research paths can be distinguished: further development and validation of the framework of features for describing articulated integration, refining the concept mapping instructions, and measuring the effects on student learning when students use the preconstructed concept maps. In conclusion, the educational implications are elucidated, which all revolve around the principle of explication.

Samenvatting

Inleiding en probleemstelling

Het onderwerp van dit proefschrift is integratie van klinische kennis en kennis van de basisvakken in het medisch onderwijs en de rol die concept maps kunnen spelen in het expliciet maken van deze zogenoemde verticale integratie. Klinische kennis is die kennis die zich manifesteert in de spreekkamer: de relevante gegevens tijdens anamnese en lichamelijk onderzoek, het noodzakelijk aanvullend onderzoek en hoe dat te interpreteren en de kennis over mogelijke diagnoses. Kennis over basisvakken betreft onder andere anatomische, (patho)fysiologische en biochemische kennis, dat wil zeggen die kennis die nodig is om de verzamelde klinische gegevens over de patiënt te begrijpen en te verklaren. Daarmee is ook de relevantie van het woord 'integratie' aangegeven: een ervaren arts is in staat kennis over klinische verschijnselen en kennis van basisvakken geïntegreerd te gebruiken, zodat hij de klinische verschijnselen kan duiden en voorspellen. De kennis van basisvakken dient daarbij als fundament voor het begrijpen van klinische verschijnselen. Deze vorm van integratie wordt *verticale integratie* genoemd.

Onze interesse in het expliciet maken van verticale integratie vloeit voort uit de veronderstelling dat het ontwikkelen van een onderwijsprogramma explicitering van kennis vereist. Immers, die kennis en vaardigheden die een docent niet kan benoemen, kunnen studenten weliswaar impliciet leren, bijvoorbeeld doordat de docent als rolmodel fungeert, maar deze zullen geen onderwerpen zijn op basis waarvan een onderwijsprogramma geordend is. Om het onderwijs zo in te richten dat studenten optimaal worden ondersteund bij het verwerven van geïntegreerde kennis over klinische vakken en basisvakken is het daarom zaak deze kennis te expliciteren. Dat betreft niet alleen de relevante concepten uit deze vakken, maar ook de onderlinge relaties.

Wij hebben ervoor gekozen om concept maps te gebruiken om docenten in het medisch onderwijs te helpen hun geïntegreerde kennis te expliciteren. In een concept map wordt een onderwerp op schematische wijze uitgelegd. Een concept map kan diverse verschijningsvormen hebben, maar visualiseert altijd de concepten die nodig zijn om een onderwerp te begrijpen. Deze concepten zijn in onderling verband gebracht met pijlen of lijnen. Deze zogenoemde *links* tussen de concepten kunnen allerlei relaties tot uitdrukking brengen. In een concept map zal getracht worden hiërarchische structuren aan te brengen waarbij de concepten die door een parapluconcept worden omvat, dit parapluconcept inhoudelijk verduidelijken. In

eerder onderzoek is al gebleken dat het laten construeren van dergelijke concept maps een goede aanpak is om kennis aan een expert te ontlocken. Dat geldt zowel voor kennis die de arts nodig heeft om van klinisch probleem x naar diagnose y te komen, als voor kennis die hem helpt de logica van de stappen tussen x en y te begrijpen, i.c. de kennis van de basisvakken.

Omdat de kennisbasis van artsen zich kenmerkt door geïntegreerde kennis van klinische vakken en basisvakken, wordt deze integratie ook in het onderwijs belangrijk gevonden. In het medisch onderwijs en in onderzoek naar medisch onderwijs richt men daarbij de aandacht voornamelijk op curriculumniveau. Dit proefschrift richt zich op een gedetailleerder niveau, namelijk integratie van klinische vakken en basisvakken op het niveau van klinische problemen. Voor de meeste docenten is dit immers het niveau waar zij in hun dagelijkse lespraktijk mee te maken hebben.

Onderwijskundig onderzoek dat gericht is op integratie op het niveau van klinische problemen is schaars en daarom vaak exploratief. Wij hebben ervoor gekozen de vier studies die in dit proefschrift beschreven zijn te richten op docenten. De daadwerkelijke implementatie van integratie is immers van hen afhankelijk. De docenten bepalen wat studenten onderwezen krijgen. Voor geïntegreerd onderwijs betekent dit dat de manier waarop en de mate waarin docenten integratie expliciet maken van invloed is. De klinische docenten en de docenten die onderwijs geven in de basisvakken zullen in hoge mate moeten samenwerken om een dergelijk curriculum te kunnen ontwikkelen en uit te voeren.

Er is al veel cognitief psychologisch onderzoek gedaan naar de kennis van experts, en naar die van klinische experts in het bijzonder. Daarbij is niet alleen onderzocht wat de elementen van die kennis zijn, maar ook hoe die is georganiseerd. Deze inzichten vormen een goede basis voor verbeteringen in het medisch onderwijs. In de eerste drie studies van dit proefschrift hebben wij gebruik gemaakt van deze inzichten in het kader van het expliciet maken van integratie van klinische kennis en kennis van de basisvakken door docenten.

Hoewel onderwijskundig onderzoekers concept maps aanbevelen als instrument om integratie in het klinische domein expliciet te maken, laten de concept maps die gepubliceerd zijn in medisch onderwijskundig onderzoek doorgaans weinig integratie zien. Veelal zijn zij gericht op hetzij klinische concepten, hetzij anatomische en fysiologische concepten. Dit roept de vraag op of het expliciet maken van integratie van klinische vakken en basisvakken in concept maps verbeterd kan worden. Om docenten te helpen met het zichtbaar maken van integratie in concept maps, zouden specifieke instructies, die in de pas lopen met huidige cognitief psychologische inzichten, behulpzaam kunnen zijn. Daarom hebben wij op basis van

inzichten over de kennisbasis van experts instructies ontworpen met het doel integratie van klinische vakken en basisvakken te expliciteren. Aan de hand van deze instructies hebben docenten op verschillende expertiseniveaus gepoogd hun gezamenlijke kennis te visualiseren in concept maps. Daarbij gaat het om kennis van relevante concepten uit de verschillende fasen van het diagnostisch redeneerproces: anamnese, lichamelijk onderzoek, aanvullend onderzoek en interventies en om kennis over de basisvakken die vaak tot de *tacit knowledge* van klinici behoort, dat wil zeggen: de kennis waarvan zij zich niet meer bewust zijn, maar die zij wel degelijk hebben. Instructies kunnen experts helpen juist deze *tacit knowledge* expliciet te maken. Ook voor het expliciet maken van de verschillende soorten relaties tussen klinische concepten en concepten uit de basisvakken zouden specifieke instructies effectief kunnen zijn. Of dit inderdaad het geval is, is een empirische vraag.

Voor het tot stand komen van integratie is het van belang dat de diverse medische disciplines samenwerken. Daarom is in dit onderzoeksproject niet alleen gebruik gemaakt van cognitief psychologische inzichten over de kennis van klinici, maar is ook gekeken naar de communicatie en de samenwerking tussen vertegenwoordigers van verschillende disciplines tijdens het gezamenlijk construeren van geïntegreerde concept maps.

De eerste drie studies van dit onderzoeksproject kunnen worden gekarakteriseerd als Design-Based Research. We hebben instructies ontwikkeld om docenten in medisch onderwijs te helpen hun gezamenlijke kennis expliciet te maken in concept maps. Deze op theorie gebaseerde instructies zijn in experimenten getest, hetgeen ons in staat stelde ze te verbeteren en te relateren aan de context waarin de experimenten plaatsvonden. Hierdoor kregen we inzicht in contextvariabelen die invloed hebben op de mate waarin en de wijze waarop integratie in concept maps tot uitdrukking werd gebracht. In lijn met Design-Based Research hebben we bovendien het proces van concept mapping gerelateerd aan het product van dit proces: de concept maps zelf. Zo konden wij onderzoeken welke factoren relevant zijn als docenten in de klinische vakken en in de basisvakken gezamenlijk geïntegreerde concept maps construeren.

Doelen van de vier studies

Het gebruik van concept maps ten behoeve van het expliciet maken van verticale integratie, integratie van klinische vakken en basisvakken, is in dit proefschrift vanuit vier invalshoeken beschreven. Iedere invalshoek is in een afzonderlijke studie uitgewerkt.

In de eerste studie is opgezet vanuit het idee dat het mogelijk is het expliciteren van integratie te verbeteren en integratie te beschrijven. We hebben onderzocht in welke mate en op welke manier groepen experts bestaande uit klinici en basiswetenschappers (anatomen, fysiologen, microbiologen enz.) in staat waren integratie te visualiseren in concept maps. Daarbij maakten ze gebruik van concept mapping instructies die gericht waren op het expliciteren van integratie van klinische vakken en basisvakken. Daarvoor was het noodzakelijk een raamwerk te ontwikkelen waarmee integratie in concept maps kon worden beschreven en gemeten.

In de tweede studie is het experiment van de eerste studie uitgebreid naar specialisten- en basiswetenschappers-in-opleiding, dus docenten met een vakinhoudelijk lager expertiseniveau. De focus was in dit experiment gericht op het beschrijven van expertiseverschillen.

De derde studie voegde een nieuwe invalshoek toe: het proces van concept mapping. Door naar kenmerken van het proces te kijken poogden we de gevonden resultaten van de eerste en de tweede studie, namelijk de geconstrueerde concept maps, te verklaren.

Terwijl studie een, twee en drie zich richtten op het construeren van concept maps, stonden in de vierde studie de gebruiksmogelijkheden van de concept maps centraal. We hebben onderzocht welke mogelijkheden docenten medisch onderwijs voor het gebruik van de concept maps zagen. Door de visies van de constructeurs van de concept maps te vergelijken met die van docenten die niet betrokken waren bij de constructie, kregen wij inzicht in het belang van samenwerking en communicatie voor integratie en de explicitering daarvan in concept maps. In het laatste hoofdstuk combineren we de resultaten en conclusies uit de verschillende hoofdstukken. Dat levert een voorstel op van de beschrijvingscategorieën van het raamwerk om integratie in concept maps te meten. Ook de instructies om integratie in concept maps te visualiseren kunnen daardoor worden aangepast.

Resultaten

De eerste invalshoek staat centraal in **hoofdstuk 2** waarin gerapporteerd wordt over het onderzoek naar de volgende onderzoeksvragen: *Kan integratie van klinische vakken en basisvakken in concept maps worden geëxpliciteerd en zo ja, in welke mate is dat mogelijk als specifieke instructies gericht op integratie worden gebruikt? Hoe kan integratie in concept maps worden beschreven?* De instructies, die we hebben afgeleid van de huidige inzichten over de kennisbasis van ervaren klinici, hadden als doel de aandacht van de constructeurs te richten op de volgende aspecten: (1) de relevante concepten uit hun discipline die nodig zijn om het klinische probleem van de

concept map te begrijpen, (2) het organiseren van de concepten volgens twee ordeningsprincipes, beide bedoeld om klinische concepten en concepten uit de basisvakken aan elkaar te verbinden en (3) controle of alle relevante concepten en relaties in de concept map stonden. Dit laatste gebeurde aan de hand van twee ingewikkelde patiëntencasus. Zeven groepen van drie experts, zowel clinici als basiswetenschappers, construeerden een concept map op geleide van deze instructies.

Om de data te kunnen beschrijven, hebben we eerst het raamwerk ontwikkeld om integratie in concept maps zowel kwalitatief als kwantitatief te kunnen beschrijven. Dit raamwerk is op basis van de data afkomstig uit de eerste studie geëvalueerd. We concludeerden dat de volgende beschrijvingscategorieën integratie in de concept maps van de experts adequaat beschreven: klinische parapluconcepten die concepten uit de basisvakken omvatten, parapluconcepten uit de basisvakken die klinische concepten omvatten, *links* tussen klinische concepten en concepten uit de basisvakken waarbij de klinische concepten naar fase in het klinisch redeneerproces (anamnese en lichamelijk onderzoek, aanvullend onderzoek, diagnose) worden onderscheiden. De concept maps waren allemaal klinisch georiënteerd; zij hadden immers een klinisch probleem als startpunt. Indien van het totaal aantal concepten in de map minder dan een zesde een begrip uit de basisvakken betrof, kwamen deze beschrijvingscategorieën niet of nauwelijks voor. Parapluconcepten die algemene categorieën aanduiden, zoals anamnese, lichamelijk onderzoek, en aanvullend onderzoek, bleken negatief te werken op de pogingen van de constructeurs om integratie expliciet te maken. Parapluconcepten die heel specifiek waren voor het klinische probleem van de concept map, bleken daarentegen juist een positieve invloed te hebben gehad op het expliciet maken van integratie. Clusters van klinische concepten en concepten uit de basisvakken bleken uiteindelijk vrijwel altijd hiërarchisch geordend te zijn met behulp van een parapluterminologie uit de basisvakken.

We concludeerden dat de experts in staat zijn om concept maps te maken waarin integratie geëxpliciteerd is. De experts uit onze studie bleken een grote voorkeur te hebben voor het relateren van diagnoses met concepten uit de basisvakken en het organiseren van concepten uit de basisvakken met behulp van klinische parapluconcepten. Echter, de mate waarin de concept maps integratie lieten zien, varieerde sterk. Op basis van deze bevindingen hebben wij enkele aanpassingen van de instructies voorgesteld.

De in **hoofdstuk 3** beschreven tweede studie bouwt voort op de eerste studie. Door middel van een vergelijkbaar onderzoek als in studie 1 werden expertiseverschillen in beeld gebracht die tot uitdrukking kwamen in de concept maps. De onderzoeksvraag was: *Welke consistente verschillen bestaan er tussen concept maps gemaakt door*

experts en concept maps die geconstrueerd zijn door artsen in opleiding tot specialist (AIOS) en basiswetenschappers in opleiding (promovendi)? Tot op heden is onderzoek beperkt gebleven tot het in kaart brengen van verschillen in complexiteit van de concept maps over één onderwerp. Wij voegden met deze vraagstelling twee zaken toe aan bestaand onderzoek. Ten eerste wilden we weten of verschillen tussen concept maps consistent zijn, ongeacht het onderwerp dat gevisualiseerd wordt in de concept map. Ten tweede lag onze focus bij het expliciteren van integratie van klinische vakken en basisvakken. We vergeleken de concept maps van zeven expertgroepen met die van zeven groepen van AIOS en basiswetenschappers in opleiding (we noemen deze groepen gemakshalve specialisten-in-opleiding), waarbij in de groepen op beide expertiseniveaus dezelfde vakgebieden vertegenwoordigd waren. We onderzochten drie hypothesen met betrekking tot het expliciet maken van integratie.

De eerste hypothese luidde dat specialisten-in-opleiding meer concepten uit de basisvakken expliciet maken in concept maps omdat hun kennis van de basisvakken in mindere mate dan bij experts tot hun *tacit knowledge* behoort. Deze hypothese kon noch bevestigd, noch gefalsificeerd worden: specialisten-in-opleiding lijken, zoals we verwachtten, meer concepten uit de basisvakken te gebruiken, maar het verschil met de experts was niet significant. Hun concept maps bevatten overigens ook meer klinische concepten. De tweede hypothese betrof de organisatie van de concepten in de concept maps. Op basis van cognitief psychologisch onderzoek verwachtten wij dat de experts concepten uit de klinische vakken en uit de basisvakken ordenen met behulp van klinische parapluconcepten, terwijl specialisten-in-opleiding dat doen op basis van parapluconcepten uit de basisvakken. De data bevestigden deels deze hypothese. Conform de hypothese organiseerden specialisten-in-opleiding hun concept maps voornamelijk met behulp van parapluconcepten uit de basisvakken, dit in tegenstelling tot de experts. De experts hadden inderdaad een voorkeur voor het organiseren van hun concept maps door middel van klinische parapluconcepten, maar het verschil met specialisten-in-opleiding was niet significant. De derde hypothese betrof het aantal *links* dat experts and specialisten-in-opleiding gebruiken. Omdat uit onderzoek blijkt dat experts een holistische kijk op problemen uit hun vakgebied hebben, hadden we verwacht dat de experts meer *links* zouden toevoegen tussen klinische concepten en concepten uit de basisvakken dan specialisten-in-opleiding. In tegenstelling tot deze verwachting bevatten concept maps van specialisten-in-opleiding significant meer *links* tussen klinische concepten en concepten uit de basisvakken dan de concept maps van de experts. Bovendien relateerden de specialisten-in-opleiding de concepten uit de basisvakken niet alleen met diagnoses, zoals de experts deden, maar ook met klinische gegevens uit anamnese, lichamelijk onderzoek en aanvullend onderzoek. Meer concepten, meer

parapluconcepten uit de basisvakken en meer *links* maakten de concept maps van specialisten-in-opleiding beduidend complexer dan die van experts. Deze bevinding staat haaks op bevindingen in eerdere studies over expertiseverschillen tot uitdrukking gebracht in concept maps. In deze eerdere studies blijken concept maps complexer te worden naarmate het expertiseniveau toeneemt. Men moet daarbij wel bedenken dat in deze studies uitsluitend complexiteit wordt gemeten, terwijl wij ons vooral hebben gericht op de mate van integratie. In hoofdstuk 3 zoeken we mogelijke verklaringen in het proces van concept mapping: wij hebben concept maps laten maken door multidisciplinaire groepen en niet door individuen zoals men in eerder onderzoek consequent laat doen. Experts drukten zich in hun onderlinge communicatie beknopter uit, wellicht omdat zij veronderstelden dat hun collega's uitgebreide kennis hadden van het klinische probleem: 'een goede verstaander heeft slechts een half woord nodig'.

De belangrijkste aanbeveling in hoofdstuk 3 is dat de concept maps van specialisten-in-opleiding een belangrijk instrument kunnen zijn bij de ontwikkeling van geïntegreerde curricula, omdat zij veel explicieter de relaties tussen klinische concepten en concepten uit de basisvakken tot uitdrukking brengen dan de concept maps van hun meer ervaren collega's.

Hoofdstuk 4 bouwt voort op het onderzoek dat in hoofdstuk 3 centraal staat en beschrijft het onderzoek naar het proces van concept mapping. We hebben in deze studie getracht de integratie die geëxpliciteerd is in de concept maps te verklaren aan de hand van dit proces om zo ook relevante aanpassingen van de instructies op het spoor te komen, een werkwijze die past binnen Design-Based Research. De centrale onderzoeksvraag die richting gaf aan de studie die in dit hoofdstuk wordt beschreven was: *Welke factoren beïnvloeden het leerproces van interdisciplinaire groepen klinici en basiswetenschappers op verschillende expertiseniveaus wanneer zij integratie expliciteren in concept maps?* In hoofdstuk 2 en 3 hebben we cognitief psychologische inzichten uitgewerkt in instructies en hypothesen. Bij de dataverzameling en -analyse in hoofdstuk 4 zijn we uitgegaan van het *leren* expliciteren van integratie in groepsverband en hebben daarom gebruik gemaakt van het theoretisch kader van het constructivisme en dat van coöperatief leren.

Een pilot leerde ons dat groepen van drie constructeurs optimaal zijn om concept maps te maken. Van de experimenten die op de pilot volgden zijn video-opnamen en aantekeningen gemaakt. Deze hebben we geanalyseerd met behulp van vier interpretatiecategorieën gebaseerd op kenmerken van coöperatief leren, namelijk (1) motivatie, (2) uitwisselen van informatie, (3) interactie en (4) het nemen van gezamenlijke beslissingen. Daarnaast hebben we de draft versies en de uiteindelijke versies van de concept maps vergeleken om te meten in welke mate het

expliciteren van integratie gedurende de concept mapping sessies werd geleerd. Uit deze vergelijking bleek dat specialisten-in-opleiding niet alleen beter dan experts integratie expliciet maken in concept maps, zoals in hoofdstuk 3 bleek, maar ze leren dit ook beter te doen gedurende de concept mapping sessies. De analyse van de video-opnamen en de aantekeningen gaf aanwijzingen dat een mogelijke verklaring te vinden is in de interactie. De specialisten-in-opleiding gingen direct met elkaar in interactie (interpretatiecategorie 3), dat wil zeggen ze stelden vragen aan elkaar over zaken die zij niet begrepen, legden concepten aan elkaar uit en raadpleegden samen internet. Experts wisselden wel informatie uit, in de zin dat zij hun bijdragen aan de concept map motiveerden (interpretatiecategorie 2), maar ze stelden elkaar minder vragen, en vroegen elkaar minder vaak om verduidelijking. Ze gaven elkaar alleen uitleg (interpretatiecategorie 3) op het moment dat zij gezamenlijke beslissingen moesten nemen over bijvoorbeeld de organisatie van de concept map (interpretatiecategorie 4). In de theorie over coöperatief leren worden interactie en het nemen van gezamenlijke beslissingen als twee afzonderlijke factoren gezien die bijdragen aan het leereffect. De derde studie toonde echter aan dat deze twee proceskenmerken gerelateerd zijn. Daarnaast hebben we de constructeurs van de concept maps aan de hand van een vragenlijst bevraagd over de bruikbaarheid van de instructies. De experts waren beduidend positiever over de instructies en de gehele procedure dan de specialisten-in-opleiding. Bovendien waren zij gemotiveerder dan hun minder ervaren collega's en nam hun motivatie gedurende de sessies significant toe, hetgeen ook bleek uit de video-opnamen (interpretatiecategorie 1). Als we de drie databronnen in hoofdstuk 4, de concept maps, de vragenlijsten en de video-opnamen en aantekeningen, in samenhang bekijken, dan zien we dat de mening over de instructies en motivatie minder belangrijk is voor de mate waarin integratie in concept maps tot uitdrukking komt, dan de mate van interactie.

In **hoofdstuk 5** wordt een ander perspectief gerapporteerd. In dit hoofdstuk gaat het niet om de concept maps en de constructie ervan, maar om de bruikbaarheid voor het medisch onderwijs van de concept maps die in de eerste drie studies zijn ontwikkeld. In deze studie wilden wij weten of *naar de mening van docenten medisch onderwijs de bruikbaarheid van concept maps beïnvloed wordt door (1) of de medisch docenten al dan niet betrokken waren bij de constructie ervan, (2) de mate waarin de docenten het eens waren met de inhoud van de concept map, (3) hun ervaring met concept mapping of andere vormen van schematiseren, (4) de noodzaak die zij voelden om hun onderwijs te verbeteren op het punt van integratie en (5) de mate waarin integratie in de concept map tot uitdrukking kwam*. Door zowel constructeurs als docenten in het medisch onderwijs die niet betrokken waren geweest bij het maken van de concept maps te bevragen, konden wij ons een beeld vormen van de bruikbaarheid van

geëxpliciteerde kennis in concept maps voor niet-construerende docenten. Omdat de concept maps het product waren van consensus binnen een multidisciplinaire groep en niet van een individu, verwachtten wij dat de inhoud ervan acceptabel zou zijn voor deze docenten. Wij gebruikten een vragenlijst waarvan de vragen gebaseerd waren op literatuur over het gebruik van concept maps in het onderwijs.

De docenten die niet betrokken waren bij de constructie, waren in alle acht academische ziekenhuizen in Nederland en enkele opleidingsziekenhuizen werkzaam. Zij waardeerden de bruikbaarheid van de concept maps significant lager dan de constructeurs. De data suggereerden dat dit vooral kwam omdat ze moeite hadden met de inhoud van de concept maps. Kennelijk was het feit dat de concept maps het resultaat waren van consensus in multidisciplinaire groepen, niet voldoende om ze even acceptabel te maken voor andere docenten als voor de constructeurs zelf. Dit leidden we af uit de zeer hoge samenhang tussen hun visie op enerzijds de inhoud van de concept maps en anderzijds de bruikbaarheid. Geen van de andere factoren bepaalden zo sterk de bruikbaarheid van de concept maps in de ogen van de docenten. Zo bleken eerdere ervaring met concept mapping en de noodzaak die docenten voelden om in hun onderwijs studenten beter te ondersteunen bij het opbouwen van een geïntegreerde kennisbasis, hun mening over de bruikbaarheid van de concept maps niet sterk te beïnvloeden. Ook de mate waarin integratie in de concept maps was geëxpliciteerd, hing weinig samen met de gepercipieerde bruikbaarheid. We suggereerden dat dit laatste samenhang met de bevinding dat de docenten integratie van klinische vakken en basisvakken niet als een belangrijk probleem in de dagelijkse lespraktijk ervoeren waardoor ze geëxpliciteerde integratie in kant-en-klare concept maps waarschijnlijk ook niet hoog waardeerden. Zo werden concept maps die relatief het meest integratie tot uitdrukking brachten, namelijk de concept maps van specialisten-in-opleiding, als minder bruikbaar gepercipieerd dan de expert concept maps. Dit verschil was echter niet significant. In hoofdstuk 5 veronderstellen wij dat het zelf construeren van multidisciplinaire concept maps bijdraagt aan het waarderen van geëxpliciteerde integratie van klinische vakken en basisvakken in concept maps. Het construeren van concept maps lijkt discipline verschillen in benadering van een klinisch probleem zichtbaar te maken voor de constructeurs en dat kan mogelijk ertoe leiden dat docenten meer belang hechten aan integratie in de eigen lespraktijk. De docenten die de kant-en-klare concept maps hebben beoordeeld, hebben zelf niet ervaren dat explicitering van integratie op het niveau van klinische problemen verhelderend kan zijn.

Voorts differentieerden docenten die de concept maps niet zelf hadden gemaakt, tussen de gebruiksmogelijkheden: zij zagen vooral voor het klinisch onderwijs mogelijkheden om de concept maps te gebruiken en in mindere mate voor pre-klinisch onderwijs en voor curriculumontwikkeling. Hoewel de docenten zelf nogal

eens de complexiteit van de concept maps opvoerden als reden, lijkt complexiteit toch niet bepalend te zijn voor de gepercipieerde bruikbaarheid. Immers, voor curriculum-ontwikkeling hoeft complexiteit niet per se belemmerend te zijn voor de bruikbaarheid: de concept maps dienen dan als inspiratiebron.

Conclusies en discussie

In **hoofdstuk 6** brengen we de conclusies uit de hoofdstukken 2 tot en met 5 bijeen en bediscussiëren deze vanuit drie onderzoekslijnen: (1) de ontwikkeling van de beschrijvingscategorieën om integratie in concept maps te beschrijven en te meten, (2) de ontwikkeling van instructies om docenten medisch onderwijs te helpen integratie van klinische vakken en basisvakken in concept maps expliciet te maken en (3) de bruikbaarheid van de concept maps volgens constructeurs en docenten die niet betrokken waren bij de constructie van de concept maps.

Ad 1. In deze onderzoekslijn onderzoeken we de beschrijvingscategorieën om integratie te meten en trekken conclusies over deze beschrijvingscategorieën op basis van bevindingen in hoofdstuk 2 en 3. In de studie naar expertiseverschillen die in concept maps tot uitdrukking worden gebracht hebben we dezelfde beschrijvingscategorieën als in hoofdstuk 2 gebruikt, waardoor er een beter beeld is ontstaan over de accuraatheid ervan. Immers, met deze beschrijvingscategorieën bleek het mogelijk verschillen tussen concept maps die ontwikkeld waren door enerzijds experts en anderzijds specialisten-in-opleiding in kaart te brengen. Concept maps van specialisten-in-opleiding bleken significant meer integratie tussen klinische vakken en basisvakken te visualiseren en deden dit gevarieerder: concepten uit de basisvakken werden niet alleen gecombineerd met diagnoses, zoals in het geval van concept maps van experts, maar ook met klinische concepten die anamnese, lichamelijk onderzoek en aanvullend onderzoek betreffen. In hoofdstuk 6 gaan wij in op de validiteit van ons raamwerk van beschrijvingscategorieën en de problemen om de concurrerende validiteit te vergroten. Ook zetten wij in hoofdstuk 6 uiteen welke alternatieve verklaringen er zijn voor het feit dat een aantal hypothesen met betrekking tot expertiseverschillen in concept maps niet konden worden geverifieerd. Een verklaring is het zogenaamde '*intermediate effect*' op basis waarvan wij voorspelden dat specialisten-in-opleiding, als *intermediates*, meer concepten uit de basisvakken zouden opnemen in hun concept map. Het lijkt of dit *intermediate effect* ook een rol speelt bij het relateren van concepten van klinische vakken en basisvakken.

Ad 2. In deze onderzoekslijn verzamelen we de bevindingen over de concept mapping instructies uit de verschillende hoofdstukken en bediscussiëren we deze

langs de fasen zoals die in Design-Based Research worden onderscheiden om tot de ontwikkeling van een finale set instructies te komen. We leggen uit hoe de eerste studie onderzoeksvragen voor de tweede studie heeft gegenereerd, en deze tweede studie leidde op haar beurt weer tot vragen over verklaringen van verschillen tussen concept maps van experts en die van specialisten-in-opleiding. In hoofdstuk 6 stellen we een uiteindelijke set instructies voor die niet alleen is gebaseerd op cognitief psychologisch onderzoek, maar ook op interpretatie van empirische data vanuit een theoretisch kader van constructivisme en coöperatief leren. Vervolgens interpreteren we de conclusies vanuit een nog niet besproken theoretisch perspectief. Door middel van de theorie van *team based learning* verdiepen we onze inzichten over de factoren die van invloed zijn op hoe groepen docenten integratie in concept maps expliciteren. De informatiekloof tussen experts lijkt groter dan die tussen specialisten-in-opleiding waardoor de verschillen tussen de vakgebieden lastiger lijken te overbruggen.

Ad 3. De derde onderzoekslijn betreft de bevindingen over de bruikbaarheid van de concept maps zoals deze door docenten wordt gepercipieerd en de factoren die deze gepercipieerde bruikbaarheid beïnvloeden. Eveneens kunnen deze bevindingen geïnterpreteerd worden vanuit de theorie van *team based learning*. Uit onze vierde studie bleek dat het distribueren van de concept maps niet leidde tot wat in *team based learning* aangeduid wordt met *boundary crossing*: het overbruggen van de informatiekloof tussen de verschillende participanten, in casu constructeurs en de niet-construerende docenten. De docenten die zelf geen concept map hebben geconstrueerd, bleken kritisch over de inhoud van de concept maps. In termen van *team based learning*: bij deze docenten was *boundary crossing* aanmerkelijk lastiger dan tussen de participanten van verschillende disciplines binnen de construerende groepen. In de construerende groepen bleek interactie het sleutelwoord. Interactie lijkt een voorwaarde voor *boundary crossing* en lijkt daarmee de waardering voor de bruikbaarheid van de geïntegreerde concept maps positief te beïnvloeden. De waardering voor de bruikbaarheid van de concept maps kan wellicht vergroot worden door het uitlokken van interactie, bijvoorbeeld door docenten in multidisciplinaire groepen de kant-en-klare concept maps te laten aanpassen naar hun wensen.

Het zesde hoofdstuk beschrijft de sterke punten van dit proefschrift die ons inziens liggen in het gebruiken van meerdere theoretische invalshoeken (cognitieve psychologie, constructivisme, Design-Based Research, coöperatief leren en team based leren), meerdere methodologische aanpakken (beschrijven en meten van producten, vragenlijstonderzoek en kwalitatief onderzoek) en diverse groepenparticipanten (diverse expertiseniveaus en participanten van diverse academische centra). De beperkingen zijn met name gerelateerd aan het feit dat het hier om exploratief onderzoek gaat: kleine aantallen concept maps, contexten en participanten drukken de generaliseerbaarheid van de bevindingen. Ook wordt er

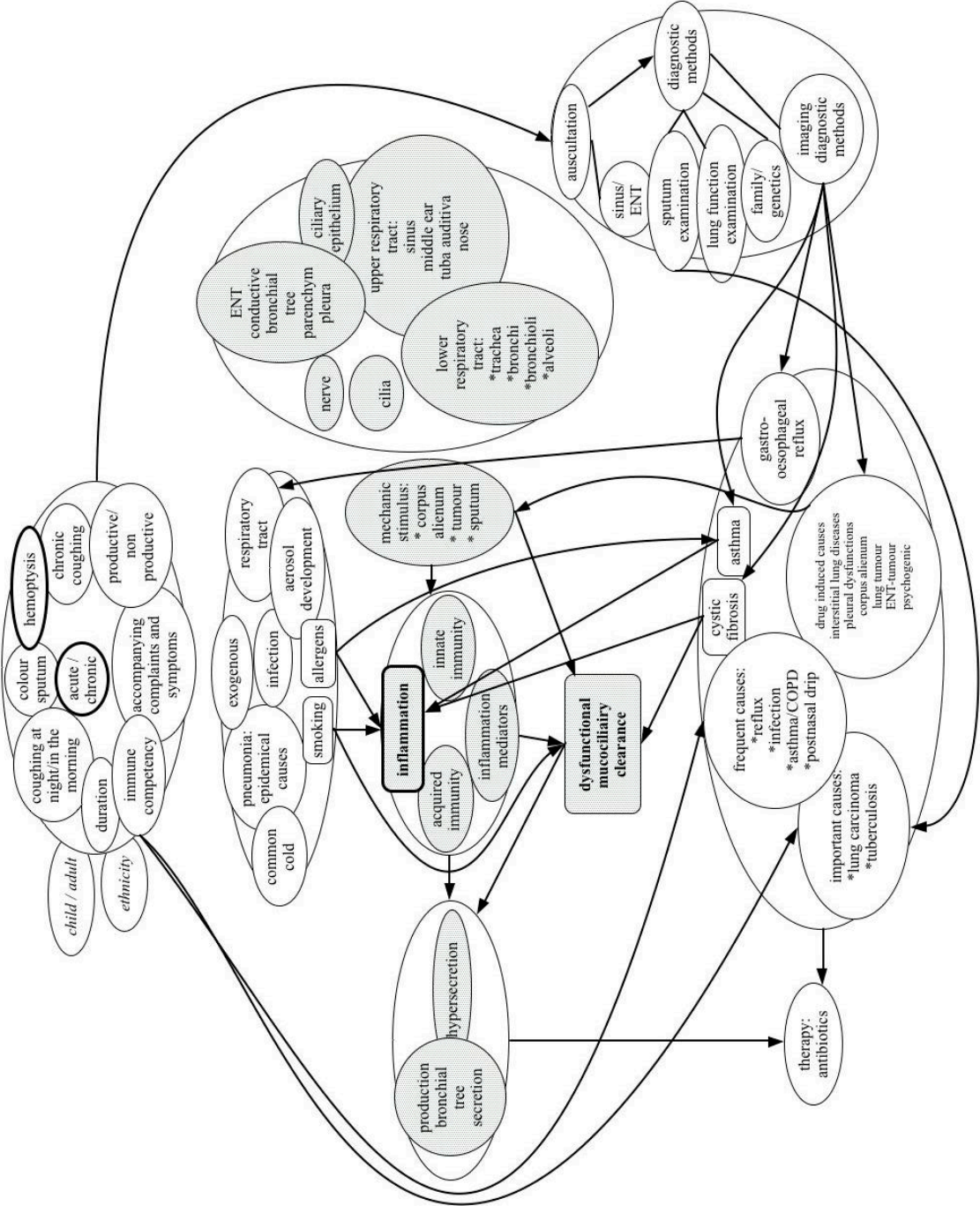
ingegaan op potentiële oorzaken van bias en welke maatregelen er zijn getroffen om de bias te reduceren.

De onderzoekagenda die voortvloeit uit dit proefschrift betreft het verder verfijnen en valideren van de beschrijvingscategorieën van het raamwerk om integratie te meten, het verbeteren van de concept mapping instructies en het meten van de effecten op het leren van studenten als deze met de kant-en-klare concept maps onderwijs krijgen. Het proefschrift besluit met implicaties en aanbevelingen voor het medisch onderwijs. Centraal bij alle aanbevelingen staat het principe van het expliciet maken van kennis.

APPENDICES

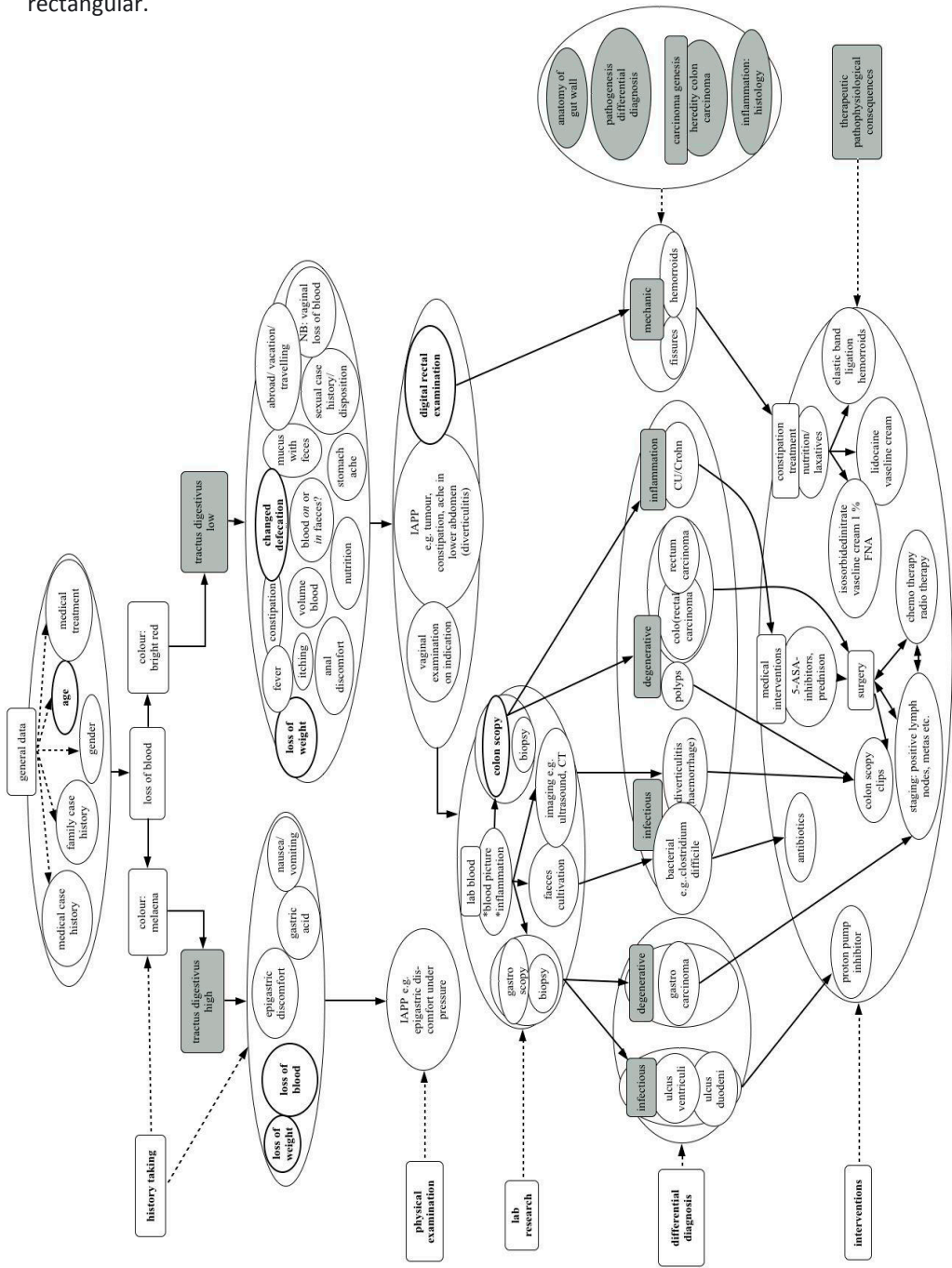
Appendix 1

Concept map about cough made by a specialist in lung diseases, a specialist in infectious diseases and an immunologist. Grey coloured concepts are interpreted as basic science concepts.



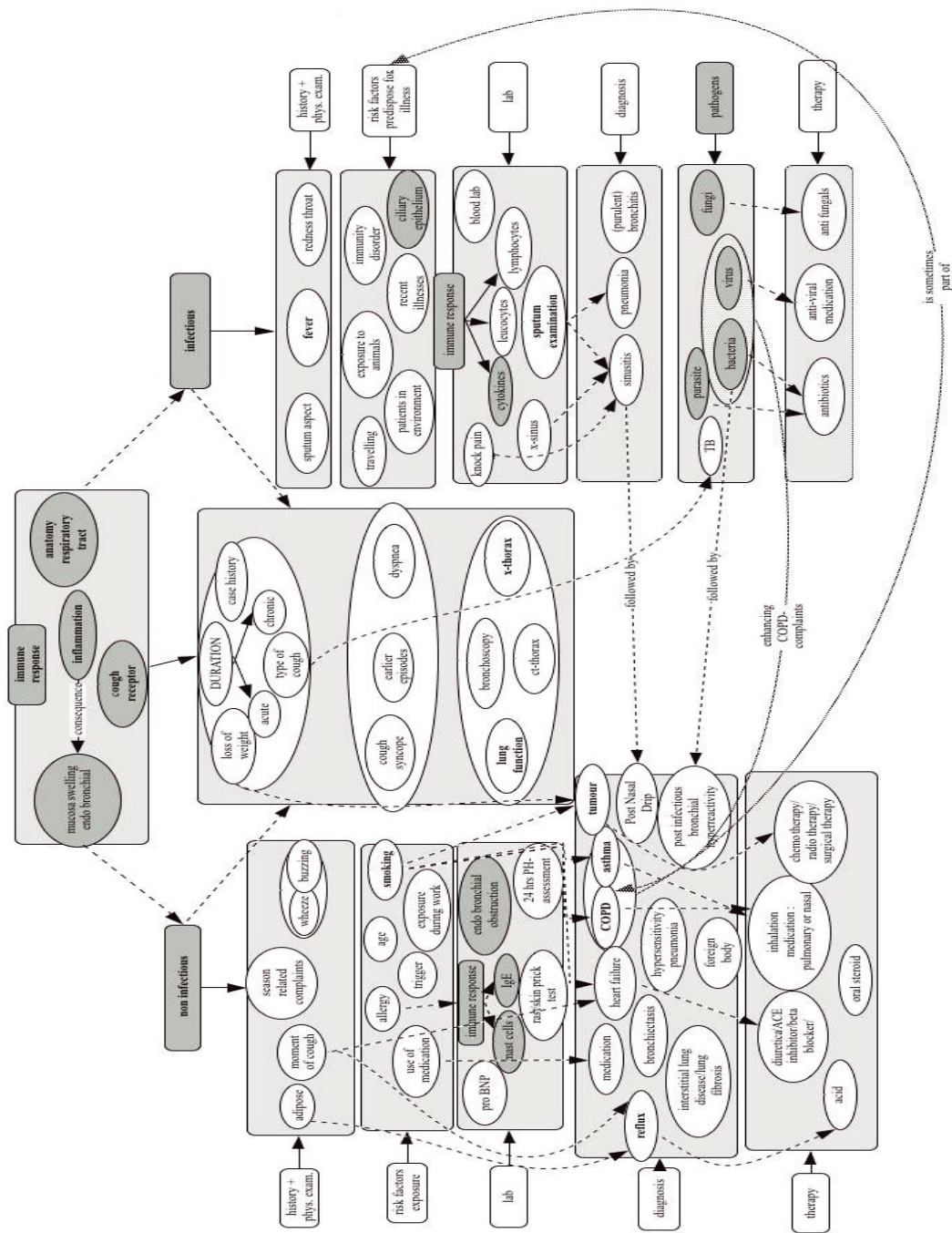
Appendix 2

Resident concept map about blood in faeces, constructed by a GP, a surgeon and a pathologist. Basic science concepts are grey coloured. Umbrella concepts are rectangular.



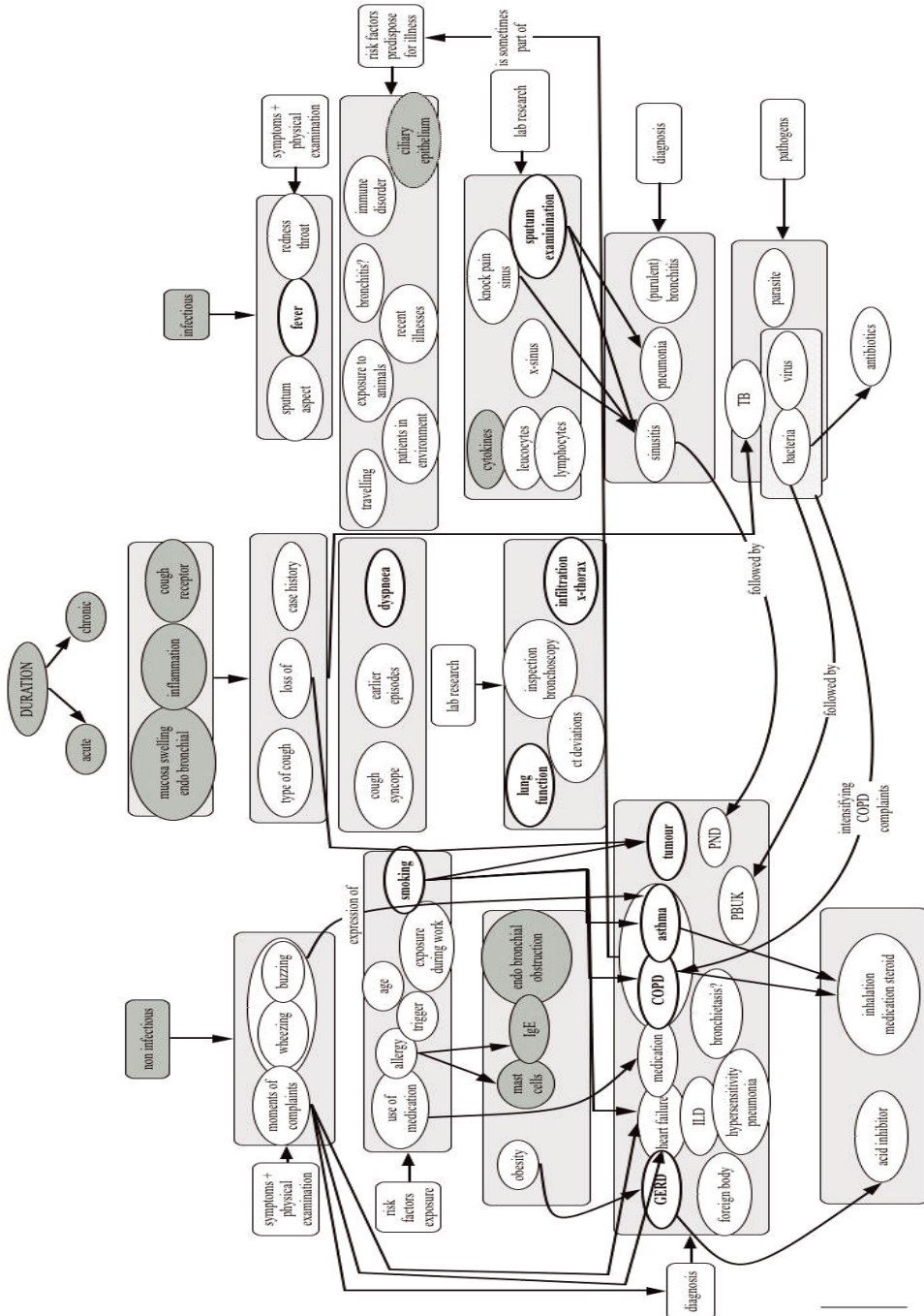
Appendix 3

Resident concept map about cough, constructed by a resident lung diseases, a resident in infectious diseases and an immunologist in training. Basic science concepts are grey coloured. Umbrella concepts are rectangular.



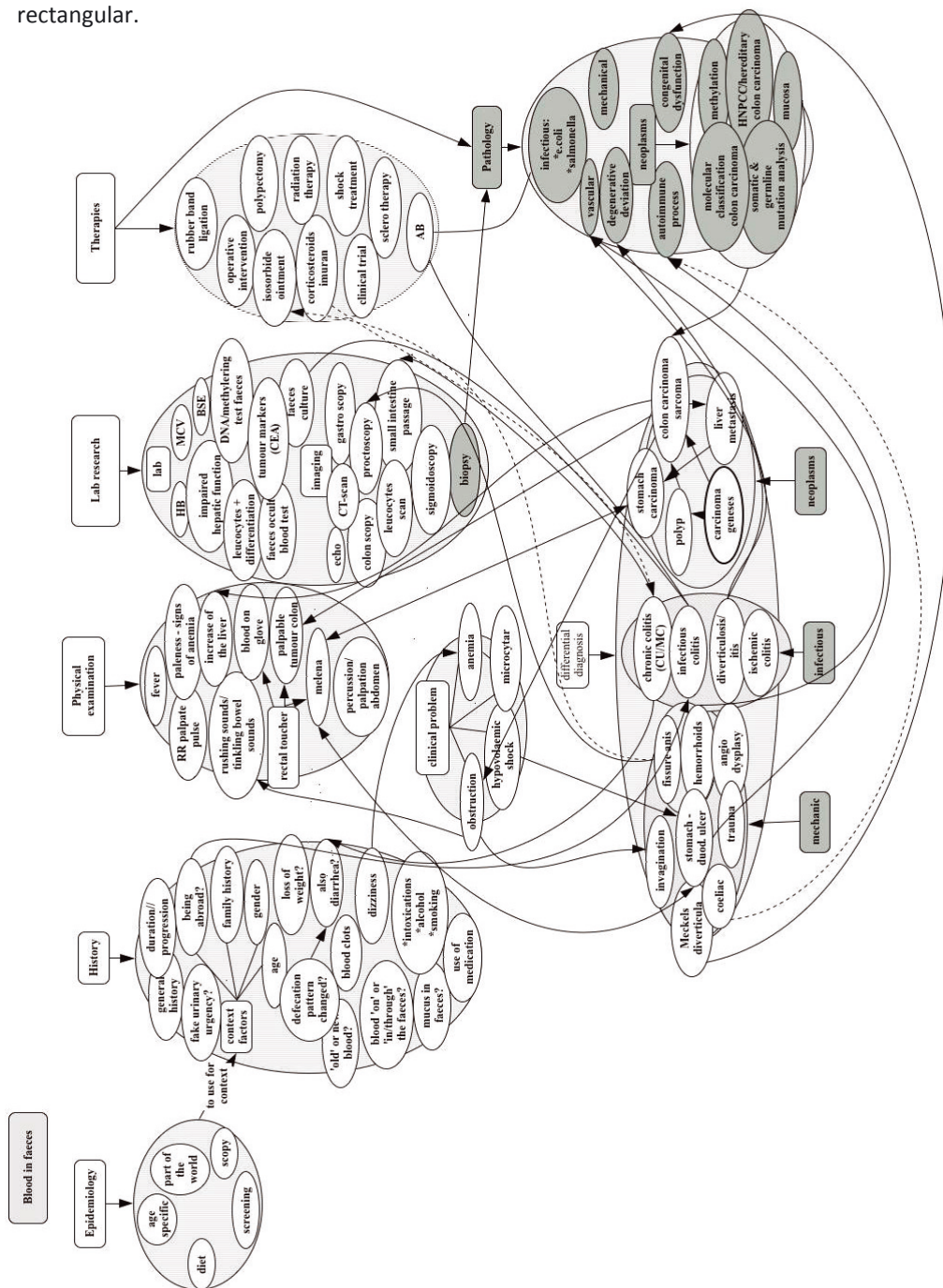
Appendix 4

Draft version of resident concept map about cough, constructed by a resident lung diseases, a resident in infectious diseases and an immunologist in training. Basic science concepts are grey coloured. Umbrella concepts are rectangular.



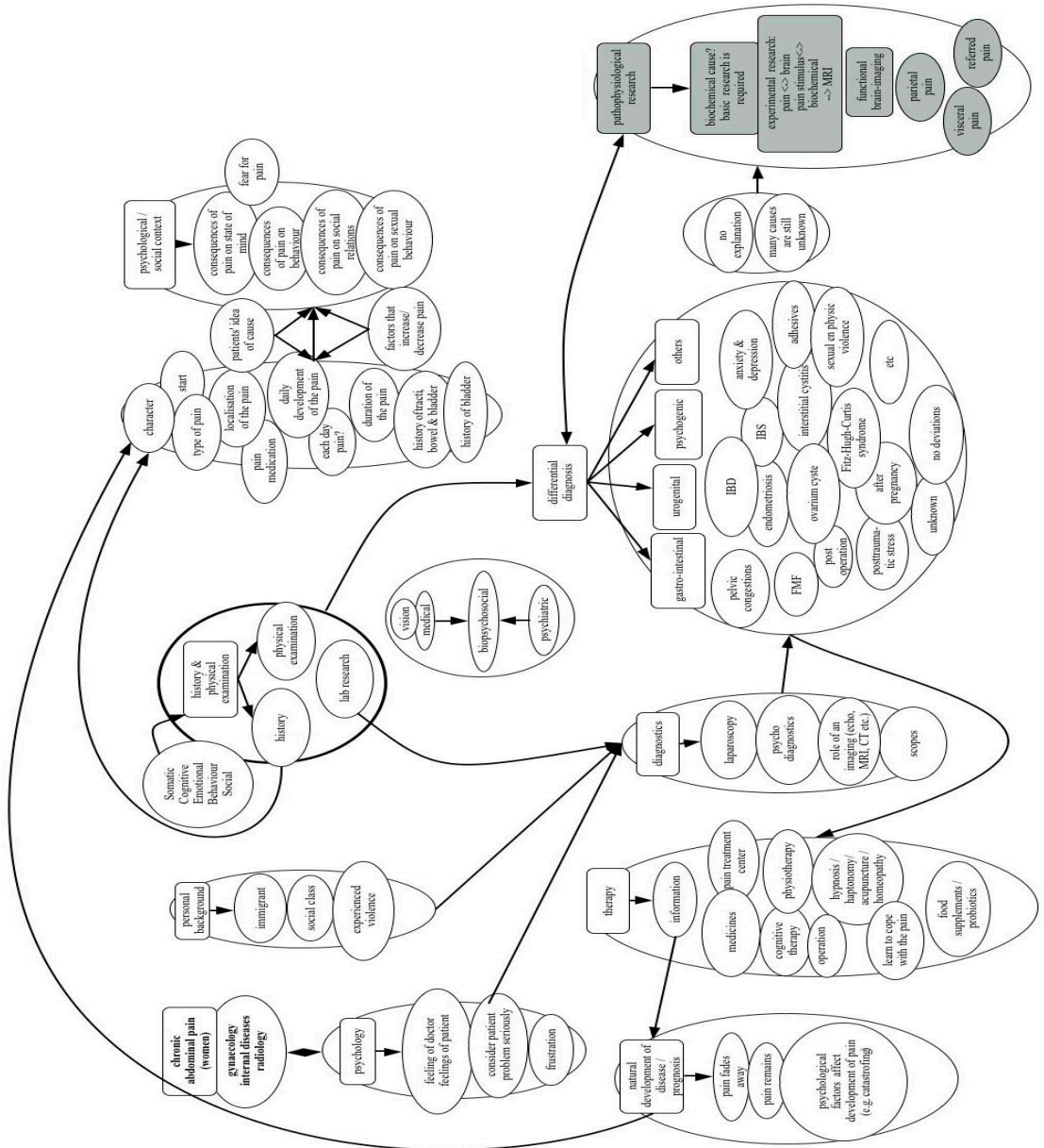
Appendix 5

Concept map about blood in faeces, constructed by specialists: a GP, a surgeon and a pathologist. Basic science concepts are grey coloured. Umbrella concepts are rectangular.



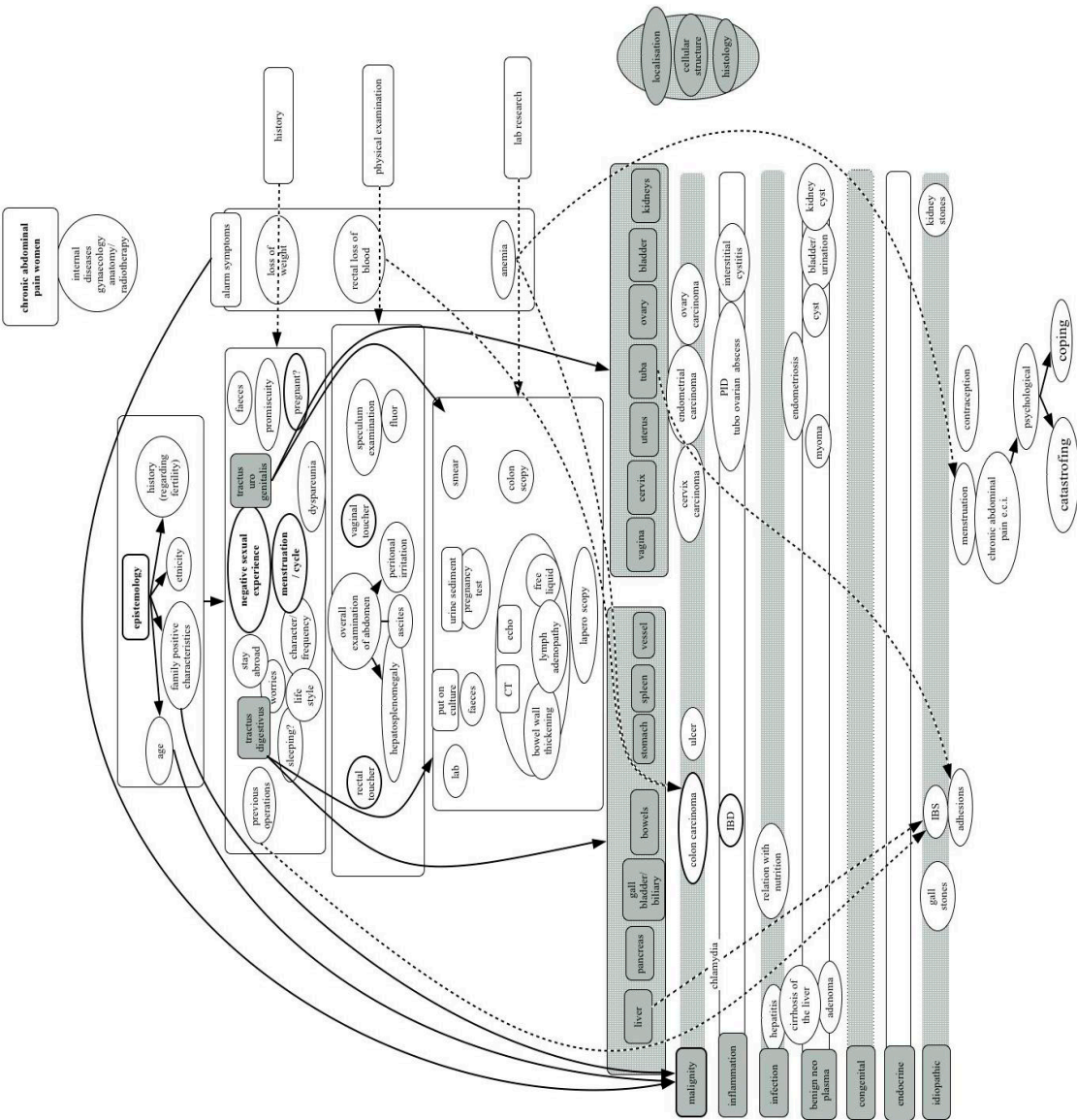
Appendix 6

Concept map about chronic abdominal pain, constructed by specialists: a specialist internal diseases, a gynaecologist, a teacher anatomy/radiology. Basic science concepts are grey coloured. Umbrella concepts are rectangular.



Appendix 7

Resident concept map about chronic abdominal pain, constructed by a specialist internal diseases, a gynaecologist and a radiologist/anatomical specialist. Basic science concepts are grey coloured. Umbrella concepts are rectangular.



DANKWOORD
CURRICULUM VITAE
LIST OF ICLOM PHD DISSERTATIONS

Dankwoord

Een proefschrift schrijven naast een baan is een tour de force. Twee mensen hebben mij gestimuleerd deze tour de force aan te gaan. Jan Vermunt overtuigde mij ervan dat ik eindelijk kon doen waar ik zo'n behoefte aan had: een tijd gefocust met een onderwerp bezig zijn. Nico Verloop heeft mij uitgedaagd door mij te vragen: 'Kun je dat eigenlijk wel, promoveren?' Ik reageerde verbolgen. Waarom zou ik dat niet kunnen? Nico doelde echter niet op 'intellectueel kunnen' maar op 'sociaal kunnen'. Het is moeilijk om me niet te laten verleiden de werkgerelateerde vragen, die vaak op korte termijn gerealiseerd kunnen worden, voortdurend voorrang te geven. Een proefschrift schrijven is immers een kwestie van een lange adem.

Dit proefschrift bleek inderdaad een kwestie van een heel lange adem. Dankzij Nico en Jan van Tartwijk ben in niet in ademnood geraakt. Nico, dank voor de vele bemoedigende woorden en relativeringen, maar vooral voor je kritische vragen en scherpe analyses van het werk dat ik je voorlegde. Dank ook dat je de vraag waarmee je me hebt uitgedaagd aan dit onderzoek te beginnen, niet meer hebt herhaald. Je bleek het gelijk aan je kant te hebben: ik kon me vaak moeilijk los maken van mijn dagelijkse werk. Jan, mijn lange traject bood je volop de tijd om carrière te maken: van dagelijks begeleider tot promotor. Naast de kundigheid van je begeleiding had deze een zekere luchtigheid waarmee je tegenwicht bood aan mijn soms wat zwaarmoedige houding ten opzichte van mijn onderzoek. Deze combinatie bleek voor mij effectief. Veel dank daarvoor.

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Tot slot is er mijn familie. Het gezin waar ik in ben opgegroeid, heeft me gemaakt tot wie ik ben geworden. Pap, ontzettend jammer dat je nu niet bij mijn promotie kan zijn. Van slagersjongen tot meubelfabrikant, jouw carrière inspireerde mij. En dan is er mijn eigen bijzondere gezin: mijn geleende meiden Floor, Julia en Sophie en onze boy, Camiel. Lieverds, een kus voor jullie geduld.

Curriculum Vitae

Sylvia Vink was born in Krommenie, the Netherlands on 2 June 1962. There, she attended the Bertrand Russell *Scholengemeenschap* for secondary education, where she graduated in 1980. In the same year she started her studies in Dutch Language and Literature at the University of Amsterdam, specializing in Dutch as a Second Language (Linguistics). She graduated with honours in 1986. While studying for her Master degree, Sylvia worked as a teacher of Dutch as a second language for foreign students at the department of Dutch Linguistics of the University of Amsterdam (UvA). After graduation, she worked at the Institute for Dutch as a Second Language at this university, where she developed curricula for foreign students who intended to study, or were already studying, at the UvA, and was a lecturer for exchange students. From 1996 to 2006 she also worked as a member of the State Committee for Examinations for Dutch as a second language.

Since 1999 Sylvia has been employed at ICLON (Leiden University Graduate School of Teaching) as a teacher trainer and educational consultant. Her main focus has been on medical education. At the Leiden University Medical Center (LUMC) she set up the quality system for testing, developed and executed training programmes for both preclinical and clinical teachers, and advised about the improvement of educational programmes. She also conducted projects at other faculties and for the Education Council of the Netherlands.

In 2006, she started her PhD project at ICLON and LUMC, while working as a trainer and an educational advisor. The project aimed at visualizing the integration of clinical and basic sciences in schematizations, and understanding what exactly integration of clinical and basic sciences means if this integration was visualized. She organized workshops on concept mapping with the focus on integration, and presented her research at national (NVMO) and international conferences (AMEE).

Currently, Sylvia's main focus is on renewing medical BSc programme at LUMC. One of the objectives of this innovation project is to improve the integration of clinical and basic sciences.

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Disciplines	Proteinuria		Cough		Chronic		Diarrhoea		Diarrhoea		Painful joints		Blood in	
	gynaecology	nephrology	lung dis.	internal dis.	infectious dis	gynaecology	infectious dis	gastroint.dis	gastroint.dis	gastroint.dis	gastroint.dis	gastroint.dis	gastroint.dis	gastroint.dis
	pathology	immunology	immunology	immunology	immunology	immunology	immunology	immunology	immunology	immunology	immunology	immunology	immunology	immunology
Concepts	N (%)	N (%)	N (%)	N (%)	N (%)	N (%)	N (%)	N (%)	N (%)	N (%)	N (%)	N (%)	N (%)	SD
Total concepts	72	76	0 (0)	97	19	19	88	84	23	20	115	89.9	14.6	
clinical	42 (58)	48 (63)		87 (90)	0 (0)	0 (0)	72 (82)	72 (86)	3 (13)	2.3	97 (84)	70.7 (79)	19.7	
basic science	30 (42)	28 (37)		10 (10)	15	12	16 (18)	12 (14)	19	14.6	18 (16)	19.1 (21)	7.6	
Organization														
Total clusters	19	18		19	19	19	19	23	23	20	23	20	2.1	
clinical & basic science clusters	10 (53)	0 (0)		0 (0)	0 (0)	0 (0)	3 (16)	0 (0)	0 (0)	2.3	3 (13)	2.3	3.7	
Total umbrella concepts	15	11		15	15	12	13	19	19	14.6	19	14.6	3.6	
general umbrella concepts	0	4		9	9	1	6	7	10	5.3	10	5.3	3.8	
specific umbrella concepts	15	7		6	6	11	7	12	9	9.6	9	9.6	3.3	
Total hierarchies combining clinical and basic sciences	15	4		1	1	11	3	0	4	5.4	4	5.4	5.5	
clinical concepts encapsulating basic science concepts	3	4		1	1	11	0	0	1	2.9	1	2.9	3.9	
basic science concepts subsuming clinical concepts	12	0		0	0	0	3	0	3	2.6	3	2.6	4.4	
Links														
Total links	9	6		1	1	12	6	1	13	6.9	13	6.9	4.8	
history, physical examination- basic science	2	0		0	0	1	3	0	0	0.9	0	0.9	1.2	
lab research- basic science	1	0		0	0	0	0	0	1	0.3	1	0.3	0.5	
diagnoses – basic science	6	5		1	1	11	3	0	10	5.1	10	5.1	4.2	
interventions - basic science	0	1		0	0	0	0	1	2	0.6	2	0.6	0.8	

Erratum: on page 41, Table 2.1 is missing

Table 2.1 Characteristics of concept maps constructed by experts: number of clinical and basic science concepts and features describing integration of clinical and basic science concepts (number, means, standard deviations and, if relevant, percentages