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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, & Lernau, 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

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Concepts</th>
<th>Clusters</th>
<th>Umbrella concepts</th>
<th>Hierarchies</th>
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<tr>
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<td>clinical</td>
<td>general</td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>basic science concepts</td>
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<td>1</td>
<td></td>
<td></td>
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<td>clinical &amp; basic science</td>
<td>-.47</td>
<td>.57</td>
<td>1</td>
<td>.57</td>
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<tr>
<td>clusters</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
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<td>-.73</td>
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<tr>
<td>clinical-problem-specific</td>
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<td>.42</td>
<td>.62</td>
<td>-.61</td>
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<tr>
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<td></td>
<td></td>
<td></td>
<td></td>
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<td>links</td>
<td>.08</td>
<td>.51</td>
<td>.35</td>
<td>-.32</td>
</tr>
</tbody>
</table>

*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.
References


