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Title: Mapping for meaning. Using concept maps to integrate clinical and basic sciences in medical education
Issue Date: 2014-09-25
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 concept 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
Conclusions and discussion

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-Base 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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Conclusions and discussion


