Concept Maps as a Device for Learning Database Concepts

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Abstract

At the university level, a student should not just learn to memorise all the complex information he is taught. Instead, he should aim to learn, what the information means and what the connections between different pieces of information are, i.e., aim in deep learning. In order to do that, the student has to be able to organise the information into structures that are natural and understandable for him.

One method for structuring and representing information, so that deep learning is enhanced, is concept maps. Concept maps have been used in many university disciplines, e.g., biology, chemistry, engineering, history, medicine, psychology, social sciences and computer science. They have even been applied in teaching databases.

In order to enlighten the suitability of concept maps for teaching database concepts, we describe in this paper how concept maps were used as a learning and assessment tool in a course of distributed databases. The learning results of the course were good, and on the whole, concept maps showed out to be a promising tool for learning of database concepts.

Keywords

Concept maps, Distributed databases, Learning, Assessment

1. Introduction

A university student has to learn a lot of complex information [10]. The student at this level should not, however, just learn to memorise the information, but instead aim in deep learning, i.e., aim to learn to understand what the information means and how the different pieces of information are connected to each other. Teachers, of course, try to teach the information in a structured form that is natural for them, but this structure is not necessarily logical for every student. Therefore, each student has to be able to organise the information into structures that are natural and understandable from his own point of view.

There are many methods that can be used for structuring and representing information so that deep learning can be enhanced. One such method for describing concepts and their connections are concept maps [17, 18]. Concept maps are known to develop students' logical thinking and study skills [1], and they have been used in schools and universities and as well as in business and industry.

At university level, concept maps have been used successfully for teaching and assessment in many disciplines, e.g., biology, chemistry, engineering, history, medicine, psychology, social sciences, and computer science. Concept maps have even been applied in teaching databases, e.g., in teaching database design and conceptual level modeling of data [13, 14, 22]. It would, however, be interesting to study more thoroughly how concept maps could help students in learning database concepts.

In order to enlighten the suitability of concept maps for teaching database concepts, we decided to use concept maps as a learning and assessment method in a course of distributed databases [16]. The students in this course built individually a concept map of each weekly topic, and these maps were then studied and discussed together in a group. In the final task of the course, the students had to also analyse their own concept maps and compared them to another student's maps. The learning results of the course were good, and on the whole, concept maps showed to be a suitable tool for learning of database concepts.

The rest of the paper is organized as follows. First, in Section 2 we consider briefly teaching and learning of databases. Then, in Section 3 we describe what concept mapping is. After that, in Section 4 we present how our course in distributed databases was organised and how the concept maps were used as a learning and assessment tool in this course. We analyse the outcomes of the course and discuss how the use of concept maps could be improved in this course in Section 5. Section 6 is a short conclusion.

2. Learning of Databases

Computer science is usually seen as a very exact and hard science [2]. This influences the traditions of teaching and learning objectives in this discipline. Typically, computer science courses consist, on the one hand, of large entities, and, on the other hand, many small details. Characteristic for this discipline is also that the students need both the theoretical as well as practical knowledge and skills [9, 15]. The part of developing practical skills is, however, sometimes forgotten, at least in the advanced level courses. In the same way, the focus of the teaching is often in the details, not in the entities, which unfortunately has the consequence that the students end up in learning the details by heart and do not learn at all how the details are connected to the bigger picture. These general characteristics of computer science also hold for teaching databases.

In teaching of databases, there is quite clear consensus on what the basic terms and issues that should be taught [15]. This is implicated by the fact that there are many good and internationally used textbooks that cover these same topics. What, however, is not that clear is, what teaching methods should be used in teaching databases and what kind of skills we expect students to have after the given database courses. A study on what is the impact of the convergence process of the European Union universities on database teaching [15] shows that we should use more team work and project-based learning, which empower skills related to understanding of databases, and train our students to identify the main characteristics of each topic studied and even to carry out additional studies of advanced topics when needed. The same study also emphasises the importance of peer evaluation and discussion between different students as a positive technique for enhancing learning.

3. Concept Mapping

As noticed before, a university student has to learn a lot of complex information, and in order to be able to learn this information successfully, he has to be able to organise it into structures that are the natural and understandable for him. There are, of course, many ways of structuring and representing complex knowledge in a meaningful way, but one of such methods that has shown to be very effective are concept maps. Concept maps were originally proposed by Novak [17] in 1970's, and since then concept maps have been used widely in different schools and universities for enhancing learning.

Concept maps are graphical diagrams showing relationships between different concepts on a certain topic. In a concept map, each concept is connected to other concepts, and these connections between the concepts are specified with linking words or phrases [7, 10, 17, 18]. The concepts in the maps are usually presented as circles or boxes of some type, and the relationships between concepts are indicated by a connecting lines or directed arcs between the concepts. The linking words or phrases, i.e., the words or phrases on the line or arc, in turn specify what kind of relationship these two concepts have. These relationships between two or more concepts combined with the linking words or phrases presented as meaningful statements are called propositions.

Concept maps have also other characteristics. A concept map should always be constructed based on a focus question [18], i.e., based on a particular question that clearly specifies the problem or issue that the concept map should help to solve or describe. The choice of the focus question is critical in a sense that a good focus question typically leads to a much richer concept map.

Yet another characteristic of the concepts maps is the organisation structure of the concepts. The concepts in the maps can be presented in a hierarchical fashion [18], or as a network [19] or even a flowchart [5]. Different concept maps can also be linked together, and it is also possible to add examples of events and objects to clarify the meaning of a given concept [18].

Construction of a concept map begins with some kind of need for organising knowledge. Whether the domain of the concept map is known or not, the next step in this process is to define the focus question. In general, steps of constructing a good concept map according to Canãs et al. [18] are:

1. Selection of a domain for the concept map;
2. Definition of a focus question;
3. Identification of key concepts that apply to the domain;
4. Ranking of the key concepts;

5. Construction of a preliminary concept map;
6. Identification of cross-links between different parts of the map;
7. Identification of linking words.

If the domain of the concept map is not known before, Step 3, i.e., the identification of the key concepts can, of course, be only done after that the student has become acquainted with the given material.

It is important to notice that a concept map is actually never ready [10, 15]. Therefore, after the first version of the map is ready, the map should be revised. That means that one has to check whether new concepts or links are needed into the map. It might also be good to reposition concepts and try to make the overall structure of the map clearer.

Concept maps can, of course, be constructed by using pen and paper. The dynamic nature of concept maps makes it, however, difficult to revise them [4, 15]. Because this, many computer-based concept mapping systems like CmapTools [3, 6] and KMap [8] have been developed to help the students to construct and revise their concept maps more easily. These systems also make it easier for the students to share and construct concept maps collaboratively.

Concept maps can be used in different ways for enhancing learning: they can be used as a teaching, learning or assessment tool [7]. When a teacher presents the structures of the topics to be learnt as concept maps to her students, concept maps are used as a teaching tool, and they can be seen as a teacher-directed activity of learning [1]. However, if students construct the concept maps themselves, they are used as a learning tool and can be seen as a self-directed activity of learning. In this case, concept maps help students to explicitly structure their thinking [1] and helps memorising and understanding the information studied [5]. The resulting map also gives an indication on how the student sees the topic: what are the concepts and how they are related to each other [1]. This, in turn, gives the teacher a possibility for using the concept maps as an assessment tool. The teacher can, firstly, recognise misconceptions and identify other issues that have been difficult or unclear for the student. Secondly, the teacher can compare students' maps to each other, or to an expert's concept map on the same topic, and evaluate the level of learning in that way. The coverage of the essential concepts and their relationships as well as complexity of the arrangement of the map and correctness of the relationships can also be judged [1, 4, 18, 19].

4. The course of Distributed Databases

In the Department of Computer Science, at the University of Helsinki, many database courses are taught each year. At the master's level, one of the possible specialisation areas is data management, and one of the advanced level database courses that is offered to the students in this area considers distributed databases. This four credit course has with its current contents taught each spring term since 2006.

The first two times, the course Distributed databases was taught in a traditional way: each week there were two two-hour lectures and one two-hour exercise session. Because the number of students attending the course was very low in spring 2007, and the situation was expected to be the same in the following years, we decided to offer the course in spring 2008 based on study circle meetings and without any lectures [16].

Despite the structure and the teaching activities of the course, we wanted also to change the learning methods to be used in this course. As a main learning method we chose concept mapping. The choice was based on the thought that we should support the students as good as possible in their learning of a large amount of new information. The contents of this course has obvious connections to the previous database courses, and we wanted to make sure that these connections as well as the connections between the topics of this course would become clear to the students. Because of this and the fact that we wanted the students to focus on the big picture of distributed databases, concept maps seemed an appropriate device for reaching our goals. This approach is also in line with a definition of good teaching [21], which was one of our goals, too.

In the following sections, we will consider first the topics and material of the course and the background of the students attending the course. After that we give a brief description of the structure of the course and the methods used for assessing students' learning in this course.

4.1 Topics and Material of the Course

As mentioned before, the course of distributed databases covers a wide range of topics. These topics were

1. distributed data and distributed database systems;
2. distributed query processing;
3. distributed transaction management;
4. management of replicated databases and

5. architectures of distributed transaction management systems.

In the first two offerings of the course there was one additional topic, namely management of parallel databases. Because of time constraints, we had, however, to exclude this topic from our version of the course.

The material on the topics of the course that was given to the students consisted of the lecture notes of the previous offerings of the course and some textbooks covering the topics. The lecture notes were mainly based on database books by Silberschatz et al. [20] and Kifer et al. [12]. In addition to these two books, we recommended to the students Öszu's and Valduriez's book [23] on distributed databases.

The basic ideas of concept mapping were presented to the students in the first meeting. They were also given links to diverse material on concept maps. We recommended that the students would use the CmapTools software [3, 6] for constructing their concept maps on the different topics of the course. The CmapTools software is a client-server based software kit for constructing concept maps that was developed at the Institute for Human and Machine Cognition. This software was chosen as a recommended tool, because it is free and the concept maps are easy to construct and modify with it.

4.2 Students and their Background

Before attending the course of distributed databases, the students should have taken several other database courses. At the bachelor's level each students have to take three such courses: Introduction to databases, Database application (a project work) and Database design. At the master's level, the students should have taken at least the course Transaction management before attending this distributed database course.

In spring term 2008 only five students enrolled to this course. This means that our expectations on the low attendance turned out to be true. All these students had completed most of their intermediate studies, and three of them had already started writing their master's thesis. At least one of the students had attended this course during the previous offering, but had not been able to pass the course that time.

4.3 Structure of the Course

The course of distributed databases was six weeks long, and it covered five topics. The course began with an initial meeting where the topics, learning objectives, working methods and schedule of the course were explained to the students. During this meeting we also made a short questionnaire on the background of the students in order to see what they knew about distributed databases and concept mapping. It showed out that they were not familiar with neither of those issues.

After this initial meeting, the students had a weekly two-hour meeting. Before each meeting the students were supposed to read the material related to that week's topic and construct their own concept maps based on the read material and their thoughts about it. The students were not given any focus questions or central concepts to use in creating concept maps. In the meeting, the students first discussed their concept maps in pairs, and after that with the whole group and the teacher. In this phase, we usually looked at one of the students' maps in detail and the others just to notice the main differences. One of the students, for example, made a simple top-level concept map that corresponds to the main topics of the course (Figure 1), and then a more detailed map of each topic like the map in Figure 2 describing distributed data and distributed database systems. Yet, for another student it was more intuitive to include some details already to the top-level map (Figure 3). This approach together with the pair-wise discussion gave the students a possibility to see how differently the same information can be restructured, and to reflect which parts of the material they had learnt and which parts were still unclear to them. In some of these weekly meetings, we also considered few exercise tasks that had been used in the previous offerings of the course, either ex tempore or so that the students had already tried to solve them before the meeting.

In the end of the course, the students were given a final task that was also partly based on the concept maps constructed during the course, and partly on applying the learned knowledge to a given situation. The final task was in a take-home exam format, and the students had two weeks for doing it. After the final tasks were assessed, we had a final meeting where the teacher was able to given the students feedback on their final tasks as well as their learning on the whole, and the students were able to give feedback to the teacher on their learning and the suitability of learning methods used in this course.

In addition to the weekly meeting and the final task, the students did self-assessment on their own learning. After each weekly meeting they submitted a brief self-assessment on what they had learned on that week's topic, what things had been difficult or were still unclear, how they hade been able to reach their own learning objectives and those of the course, and how their learning still could be improved. As a part of the final task they also made a larger self-assessment concerning the whole course.

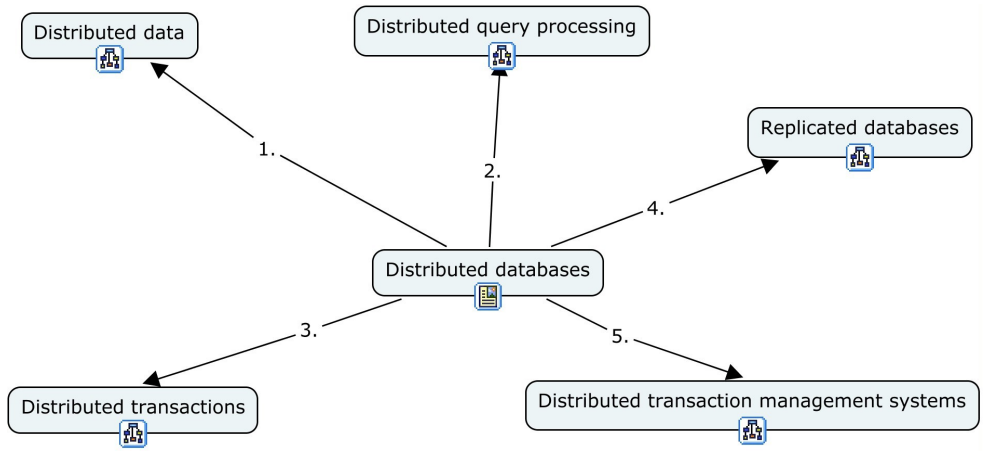

Figure 1 One of the students made a top-level concept map that corresponds directly to the topics of the course. Each of the topics has a more detailed concept map linked to it.

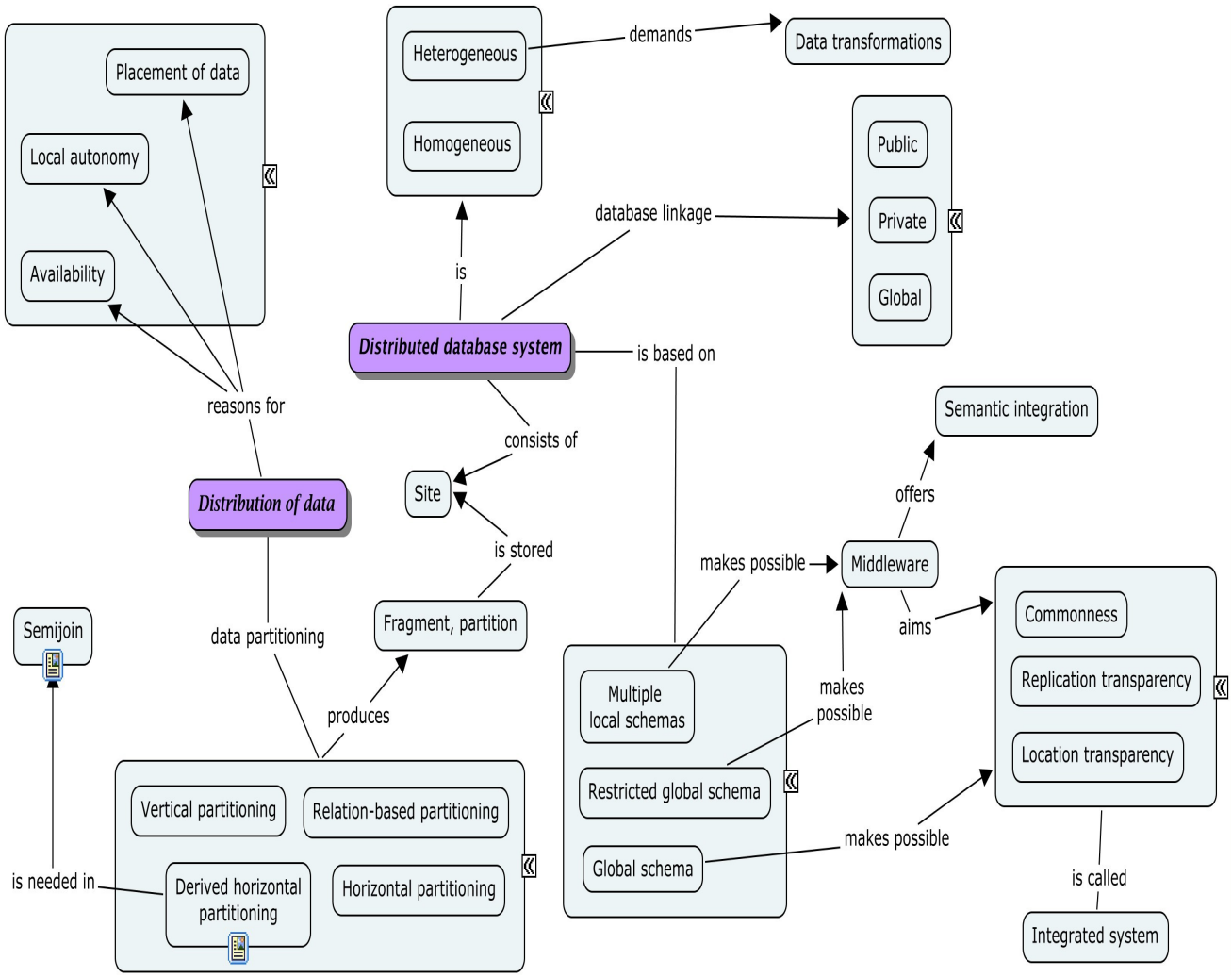

Figure 2 This detailed concept map on distributed data and distributed database systems was made by the same student that made the concept map in Figure 1.

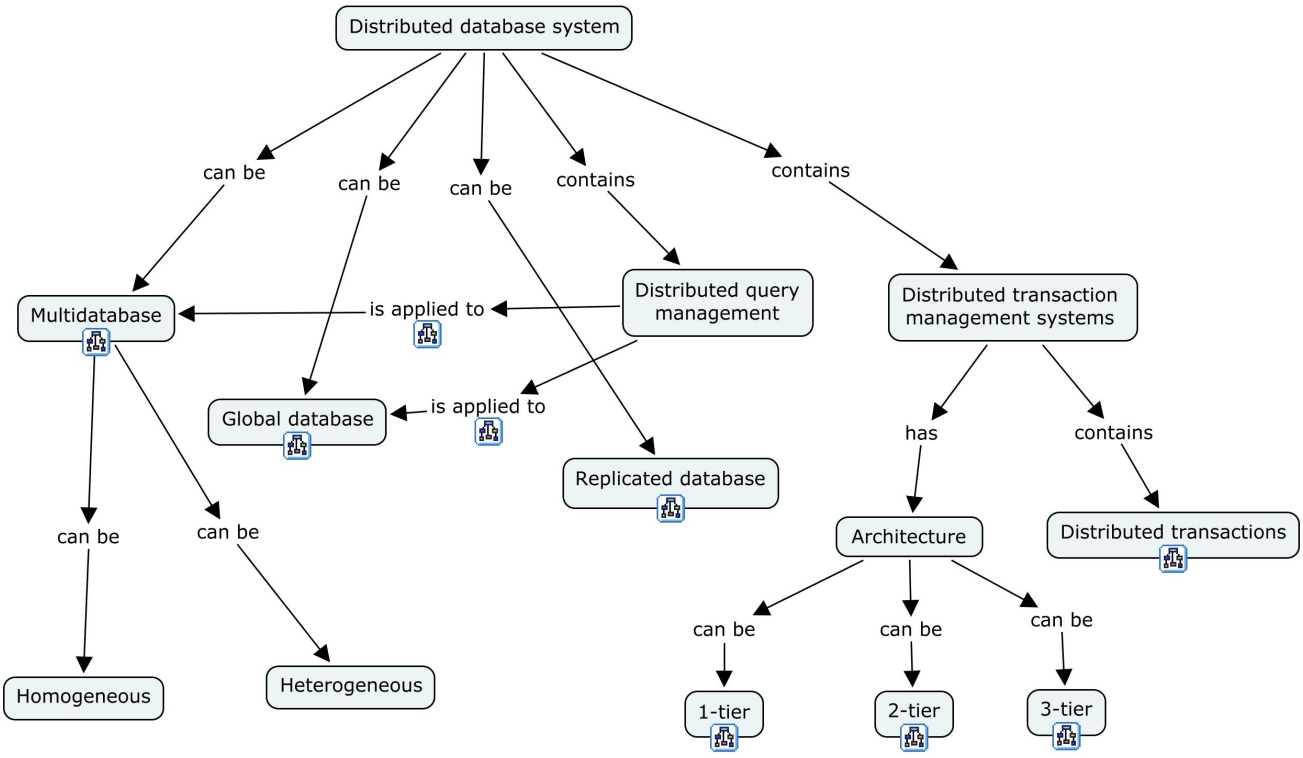

Figure 3 Another student's top-level concept map was already more detailed.

4.4 Assessment of Learning

The assessment in this course of distributed databases consisted of two parts: formative and summative assessment. The formative evaluation of learning was based on the weekly concept maps, discussions and self-assessments. We followed also how active the students were in the different discussions. Only this student activity in discussion had an effect on the students' final grades.

The summative assessment in this course was based on the final task (70%), activity in discussions and peer-assessment (20%) and self-assessments (10%). The grade scale was the standard scale of the University of Helsinki, namely, grades 1 to 5 or failed were used.

The final task that had the main effect on the final grade consisted of three subtasks. The first subtask was to represent all the concept maps that the student had done during the course and explain the contents of them briefly in the text. The students were also supposed to compare their maps with another student's concept maps and to try to analyse in which points the maps were different to each other: in which ways their maps were better than the other student's maps and what was missing in them. This task was supposed to give the students a possibility to see a different way of structuring and representing the same knowledge and, therefore, a possibility to deepen their knowledge on the topics of the course. In the second task, they were given a scenario on a distributed study attainment system and they were asked to explain what kinds of distributed database solutions would suit for this environment. The third subtask was the self-assessment of their learning during the whole course.

5. Analysis of the Course

In the previous section we described the structure of the course Distributed databases, and how concept maps were used as a learning and assessment tool in this course. Now we analyse how successful our course was and how the use of concept maps could be improved in the future.

The students attending this course of distributed databases had all passed the prerequisite bachelor-level courses. Four of the five students had also passed the advanced-level prerequisite course of transaction management, and the fifth has attended that course, but not yet passed it. Therefore, we could rely on that the students had the necessary background knowledge for this course.

The learning outcomes of the course on the whole were good: all the students passed the course and most of them even with a good grade. The students themselves felt that they had learned the basic issues and

concepts on each topic more thoroughly than they would have done with traditional methods. These results could be easily interpreted to mean that the students' learning was really enhanced by using concept maps, but the number of the students attending this course was so low that is not possible to make any statistically significant analysis of the importance of these results. Still, at least one of the students had attended the course before without passing it, and this time his learning was improved in a way that he passed the course and felt himself that he had understood the topics of the course much better than before. This might be an indication on the fact that the weaker learners benefit a lot of this kind of learning tools, because they force also these students to be active and to think and restructure the topics by themselves, which clearly enhances their learning and changes their behavior.

None of the students in our course were familiar with the concept maps before the course, and therefore, they had to first learn what the concept maps are and how they should be build. They also had to learn to use the CmapTools software [3, 6] used for constructing the concept maps. In the beginning both the idea how to construct a concept map and how to use the software caused some problems, but the students coped with them quite fast. These problems, however, indicate how important it is to give a proper introduction to concept mapping and the use of the possible tool right in the beginning of the course, if that has not been done before the course.

The students indicated in their self-assessments that concept maps had been very useful for their learning and that they would probably use them in other occasions, e.g., in writing the master's thesis. According to them, the database concepts were easy to represent in a concept map, but describing small details as well as algorithms and processes with the maps were more demanding, though it is fully possible [18]. Finding good linking words and phrases showed to be a challenge, too. The comparisons of different concept maps in weekly meetings and in the final task had also given the students insight how differently the same knowledge can be structured, and made them think why they, for example, had missed some concepts or understood them totally differently than other students had. Figures 4 and 5 depict distributed transactions, and they are good examples on how students can perceive the same topic very differently. Both the maps are basically correct and contain many similar concepts, but still they describe the topic from alternative viewpoints. Some students commented that their maps would have certainly been quite different, if they had built them after the course when all the topics had been covered and they had had a better overall picture of the whole theme.

From the perspective of learning outcomes, the use of concept maps was certainly justified. However, it showed out that constructing concept maps is very demanding and time consuming. Because the number of topics in this course was lower than in the traditional version of the course, and still the students thought that they did not have enough time to study the material and build concept maps as thoroughly as they would have wanted to, it is, on the one hand, possible that learning by constructing concept maps takes more time than learning by attending lectures and doing exercises. On the other hand, the lack of time might be due to the missing experience in building concept maps or some personal reasons.

Another factor that might diminish the usability of concept maps as a learning and assessment tool is the number of students attending a course. In our small group of students, using concept maps as an assessment tool worked well with this small group of students. In larger courses, it could, however, be quite exhausting, if one were supposed to evaluate all the maps by hand. Thus, some kind of methods for computer-aided assessment of the concept maps [4] would, thus, be essential. In this small group it was also possible to study and discuss concept maps of each student in every weekly meeting. This, too, would be impossible, if the size of the group would be much bigger: there would not simple be enough time for that.

By constructing the concept maps, the students were able to identify areas that they had understood and that were still unclear to them. They learned to look at the topics from their own perspective, and some of them had even considered how the new things they have learnt are related to what they knew before the course, or how they could be applied in their work. Some students also told how concept maps helped them to see the big picture, which was one of our goals when we decided to use concept maps as a learning method in this course.

Concept maps were also used in the final assessment of this course. There are a variety of ways how concept maps can be used as an assessment tool of learning, some of which were considered in Section 3. In our course, we decided, for the first, to let the students construct their concept maps totally by themselves, because it has been shown that requiring the students to construct maps using predefined concepts hinders them to completely express their thoughts and ideas [4].

In the assessment of the students' maps we then checked which concepts and what kind of relationships were included in the maps. We did not have any expert's map that we could have used for comparing and evaluating the students' maps. It showed out that the maps of the students were very different, but that they all had been able to identify most of the central concepts of distributed databases and even find reasonable and natural connections between them. In addition to the concept maps themselves, we evaluated how clearly the

student was able to describe his own maps and the stage of his learning. Similarly, we evaluated how deep and thorough the analysis of the similarities and differences of the student's own maps and the other student's maps was. The evaluation confirmed a former observation on how good concept maps are characterised by clear and validly linked concepts, while poor maps have less concepts and weaker linkage between the concepts [11]. In our opinion, a reason for why a student produces a poor concept map is that he has not really learned to use and construct concept maps. This kind of differences in learning stages of students should somehow be taken into account when the concept maps are evaluated [4].

6. Conclusions

In this paper we have presented how concept maps were applied as a learning and assessment tool in a course for teaching distributed databases held at the Department of Computer Science at the University of Helsinki, Finland. The learning results of the course very good which indicates that concept maps can be used as a device for learning database concepts. The number of students attending this particular course was, however, very low, and we were not able to get any statistically significant proof on how remarkable effect the use of concept mapping had on the learning of the students. Even if more research on using concept maps in learning database concepts is needed, the results were encouraging, and in our opinion, concept mapping seems to be a promising tool for database learning.

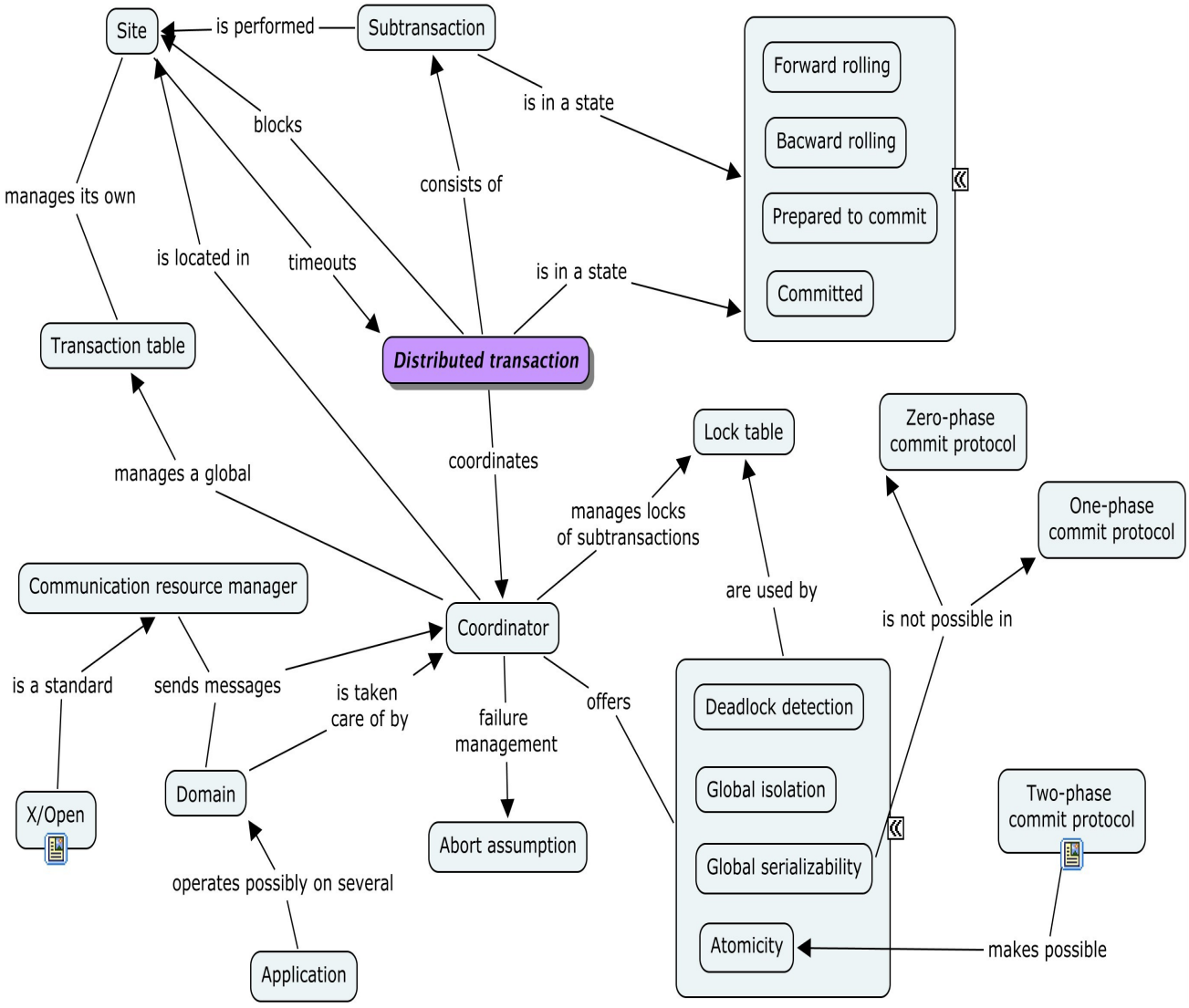

Figure 4 This concept map shows one student's way of perceiving distributed transactions.

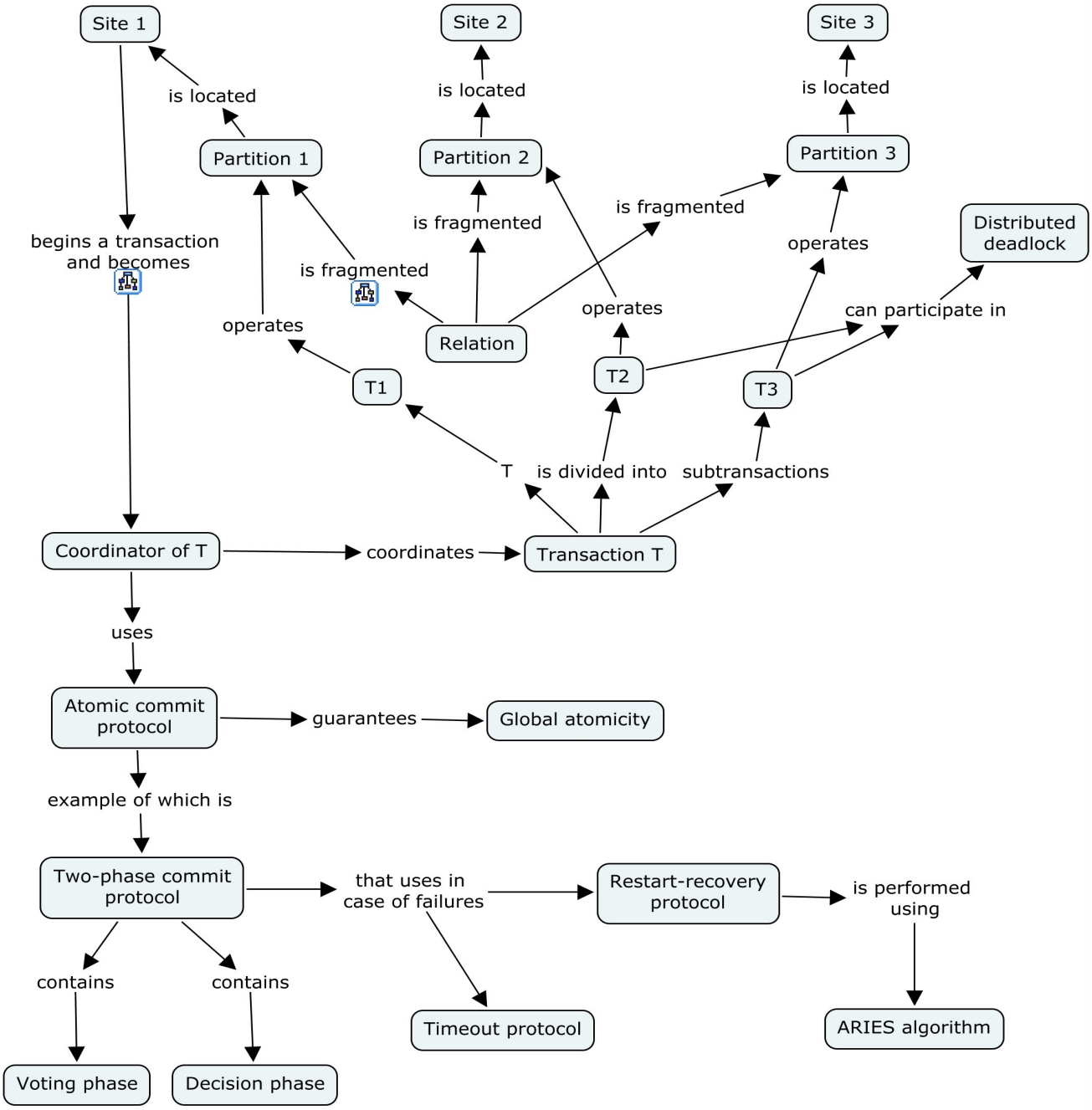

Figure 5 Another student understood distributed transactions in this way.

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