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KNOWLEDGE ORGANIZATION IN PHYSICS TEXTBOOKS: A CASE STUDY OF MAGNETOSTATICS

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Abstract. *Textbooks often provide teachers and students a conception of how scientific knowledge is organized. Therefore, it is of interest to recognize what is the picture of knowledge conveyed by the textbooks. In this study, the knowledge organization in three university physics textbooks is analyzed from the viewpoint of how the basic elements in the topics of Biot-Savart and Ampère's law are structurally linked. The method of analysis is based on the interpretative analysis, which (a) recognizes basic elements of knowledge and (b) identifies the categories of links that connect basic elements. Concept maps are used to represent knowledge organization of textbooks. The results indicate that content knowledge of textbooks consist of somehow identical basic elements but different categories of links and thus different knowledge organizations. The possibility to recognize these differences in the curriculum materials is a first step towards developing more effective teaching and learning solutions and curriculum plans.*

Key words: *Ampère's law, Biot-Savart law, concept maps, knowledge organization, science textbooks.*

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Introduction

The way the knowledge is organized in study materials and in textbooks is one important component affecting learning and teaching. The crucial role of science textbooks on student's learning has been highlighted in many studies. For example, in National Educational Goal Panel (1998) there are some recommendations regarding the implementation of standards such as *linking instructional material to standards*. It states, "Textbooks are where students meet the standards," and recommends that students and teachers should have instructional materials such as textbooks that could help them to meet academic standards. In particular, the picture the textbook gives of the ways the concepts are related provides for a teacher a certain model of organization of scientific knowledge. However, this organization is always rather a result of the choices of the writer of the textbook rather than some inherent and unavoidable property of the scientific knowledge itself (which can be no doubt organized in many ways).

In planning teaching, teachers try to organize their knowledge in order to improve their teaching, and students try to organize their own knowledge in a coherent way to achieve better learning. As many researchers (see e.g. Novak, 1990; Van Heuvelen, 1991; diSessa, 1993; Kinchin et al., 2000) have pointed out, gaining an organized and integrated knowledge is a basis for effective cognitive processing needed in problem solving or com-

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plex reasoning. Ainsworth and Burcham (2007) showed that maximally coherent text-based materials, which are well structured and explicit, have a major impact on the learning of students. Therefore, the high quality textbooks with well-organized knowledge substantially help students to organize their new knowledge into more comprehensive patterns. Teachers benefit considerably from textbooks when they recognize and use such effective patterns of knowledge organization in their own teaching (Ball & Cohen, 1996; Davis & Krajcik, 2005). Koulaidis and Tsatsaroni (1996) investigated the science textbooks with emphasis on the process of knowledge organization. They concluded that science textbooks, as supplementary sources for learning facts and concepts, help students and teachers to organize their knowledge more effectively. Therefore, the in-depth understanding of the knowledge organization assists teachers to recognize different possibilities for organizing conceptual knowledge and, consequently, to arrange the teaching materials during their teaching. In order to find out how textbooks and study materials contribute to teaching and learning we need to analyse their content knowledge and thus recognize and discern different ways of knowledge organization.

There are many studies, which concentrate on analyzing the content of science textbooks. Orpwood (1984) examined science textbooks by using a method, which is concentrated on themes such as science, technology, and society (STS); scientific skills; and the image of science. Strube (1989) analysed the content of physics textbooks. He studied the textbook for prose structure and literacy characteristics. Chiappetta, Sethna and Fillman (1993) studied the content of science textbooks of life sciences, earth sciences, and physics, with the emphasis on four themes of scientific literacy, including science as a body of knowledge; science as a way of thinking; science as a way of investigating; and the interaction among science, technology, and society (STS). They argued that among all science textbooks, the physics textbooks fulfil the educational goals best. Wilkinson, (1999), studied the content of physics textbooks of Victorian Certificate of Education (VCE) Physics course and used same themes than Chiappetta et al. (1993) applied in their analysis. Wilkinson showed that physics textbooks devote attention on a considerable portion of all themes, especially on STS. Roseman, Stern and Koppal (2010) analyzed the contents of four biology textbooks in order to examine their coherency. They specified the key ideas as well as other ideas within the textbooks and the alignments and connections among them. They reported that the judgments of their review team about the connections among key ideas were less consistent than the judgements about connections among key ideas and other ideas. Moreover, they noted that guidelines that were provided for making judgments about alignments were more explicit than guidelines about connections. In summary, although the impacts of textbooks on students and teachers knowledge organizing have been analysed from several perspectives but there is little research of textbooks' content knowledge organization.

In this study, the content knowledge of textbooks are analysed from the perspective of the knowledge organization. A basic assumption behind the recognition and analysis of knowledge organization in physics textbooks is that the knowledge in physics can be analyzed in terms of some basic elements (e.g. concepts, laws, entities, and principles) which are connected to each other via different categories of links and thus form different patterns (Koponen & Pehkonen, 2010). Here the knowledge organization of the content of the textbooks are analyzed qualitatively, the analysis method introduced here is based on the idea that the connections between conceptual knowledge can be represented in form of a concept map, where the nodes of the maps are conceptual elements and the links represent the existence and the nature of the connection. Such a method founds support from a study by Kinchin, Hay and Adams (2000), which introduces a qualitative approach to analyze student's knowledge organization from their concept maps. Kinchin et al. analyzed students' concept maps in terms of some structural components such as hierarchy and interactive processes. Hierarchy showed the justifiable levels of knowledge organization; interactive processes showed the association and interaction of different levels of knowledge organization. In this research, in order to examine and interpret the structural features of textbooks' concept maps, approaches resembling approaches of Kinchin et al. (2000) have been used for classifying students' concept maps.

In order to examine this knowledge organization, a method, which makes explicit the structures and organizations of the content knowledge of the studied textbooks, has to be developed. Therefore, the following research questions were established:

1. What are the characteristics of basic elements and links, which form the basis of the knowledge organization in different textbooks?
2. What kinds of differences there are between the textbooks in terms of their knowledge organization?

The first question addresses the "building blocks" of knowledge organization: basic elements and links between them, and what they tell about the way how the knowledge is organized in a textbook. The second question helps to examine the knowledge organization as a whole and makes possible to compare the similarities and differences between textbooks.

Methodology of Research

The purpose of this study is to find a way to present and analyze how the knowledge in a textbook is organized. The first task is to develop a method for analysing the units forming the knowledge organization; this includes a) the recognition of the basic elements in the textbooks and b) the recognition of links between the basic elements and their categorization.

The basic elements in the textbooks are recognized on the basis of the classification of elements suggested by Koponen and Pehkonen (2010). Basic elements include concepts, particular laws, and principles. The laws can be experimental laws that are formed through measurements (e.g. Biot-Savart law) or they can be deduced from theory (e.g. Ampère's law). Principles are higher level "laws" (e.g. superposition principle). Concepts in physics are the building blocks of knowledge structures and they describe basic properties and physical reality (e.g. properties of matter and interactions).

After recognizing the basic elements, the categories of links between the basic elements in the textbooks are identified. Only those connections, which are based on experiments and modelling in the construction of knowledge, are taken into account (compare with Koponen & Pehkonen, 2010)**.** This choice is motivated by the notion that experiments and models are important in physical knowledge construction (Mäntylä, 2011), and that most of the physics textbooks introduce very similar experiments and models. Consequently, the knowledge organization structures are featured out mostly on basis of model-related links. This is also motivated by the notion, that models and modelling have a prominent role to construct and justify the knowledge in science education.

There are different possible classifications to recognize important classes of models. Harrison and Treagust (1998) investigated the textbooks stressing the use of models in science lessons. They developed a typology of science models to classify the models in the textbooks. This typology consists of mathematical and theoretical models, analogical models, and models depicting multiple concepts such as maps and diagrams. They claimed that the cognitive ability of students would be enhanced if teachers apply these models in their teaching. Van Heuvelen (1991) classified physics knowledge into four main categories including words, pictorial representation, physical representation, and mathematical representation. His classification scheme emphasises models that help students to construct representation of a physical process, reason about the process, construct mathematical representations, and finally solve physics problems qualitatively. Concerning models depicting different concepts and pictorial representation, Gilbert (2005) posited that in the perspective of learning, a text with linear structure supports exiguous the development of visualization, whereas diagrams, figures and photos (two-dimensional structure) have more capability to develop the visualization. In addition, it has been argued that successful knowledge should include comprehensive representation and effective reasoning (Brachman & Levesque, 2004). Glynn and Takahashi (1998) have stated that if texts of textbooks are discussed through analogical models are more capable of promoting students' learning. The classifications suggested by Harrison and Treagust (1998) and on the other hand, by van Heuvelen (1991) are adopted here as a basis first, to recognize different types of models in the examined textbooks, and second, to categorize the link types. In addition, in the categorization of links, the other aspects discussed above, i.e. meaning of visualization, effective reasoning and analogical models for learning, were taken into account.

In this study, the knowledge organizations of textbooks are represented as concept maps. Concept maps are tools to represent knowledge in all levels of science education, teaching, and learning,

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and they are particularly suitable for representing of how concepts are related (Novak, 1990) or also for evaluating knowledge organization (Mintzes et al., 2000).

Selection of Textbooks and Topics

For examining the knowledge organization in textbooks, three introductory (first and second year) university physics textbooks were chosen. The chosen books were: two widely used introductory university physics textbooks *Fundamentals of Physics* (referred as FP in what follows) (Walker et al. 2008) and *Physics for Scientists and Engineers* (referred as PSE) (Knight, 2008); and one well-known introductory textbook *The Feynman Lectures on Physics* (referred as FLP) (Feynman et al. 1964). Because it is impossible to analyze the structure of knowledge covering all the topics in the textbooks, two specific sub-topics were chosen. The subject context of this study was magnetostatics with the specific topics of Biot-Savart law and Ampère's law.The decision to concentrate on at the university level textbooks was made for following reasons: the interest was to find books with suitably rich content, which is expected also to reflect in more diversified knowledge organizations; these books are international, thereby the other researchers have a better possibility to replicate or evaluate the findings of this research. The topic of magnetostatics and its basic laws were chosen, because these topics are known to be challenging for students, e.g. Manogue, Browne, Dray and Edwards (2006) stated that learning the topics of Biot-Savart law and Ampère's law is challenging for students at the transition level from the calculus-based introductory physics courses to upper-division courses. This means that there are good reasons to investigate this topic more, here it is done from the perspective of the textbooks' knowledge organization.

Procedures

First, basic elements from the textbooks were identified. In most cases, basic elements were easy to recognize, because they are the quantities, laws and principles in physics. Here the concepts that were are attached to the more complex knowledge structures such as laws and principles in an essential way, were included in basic elements (e.g. magnetic field and current length element). In Table of Appendix I, there is in the second column an excerpt from a text book, and then in the third column, also in the fourth column, the recognized basic elements are presented.

Second, the way how these basic elements were connected – linked – was examined. First these links were recognized from the textbooks and marked. Then the descriptions of their nature were written down (e.g. analogy, mathematical relation) and the links and their descriptions were compared in order to form categories for the links. Through this qualitative interpretative analysis of the links between basic elements, the categorization of links was established. In Table of Appendix I, examples of the analysis (third column) and categorization (fourth column) are given. It has to be noted, that this categorization is based only on the connections in the textbooks concerning the chosen topics, e.g. no experiment-based connections were presented in those examined topics.

Finally, the concept maps that depict the knowledge organization of textbooks were drawn. As can be seen from the fourth column Table of Appendix I, there is the simplest possible structure element of a concept map. When drawing the overall concept map, these structure elements are put together: basic elements as nodes and the categorized connections as links between nodes. Here the application of concept maps differs from the traditional way: in a link of the map there is, instead a verb, a procedure – model – that connects the basic elements to each other (compare with Koponen & Pehkonen, 2010). Then the features of the knowledge organizations of textbooks and their structural patterns made visible through the concept maps were qualitatively interpreted, analyzed, and compared. This was done through examining the hierarchy and interconnectivity (i.e. interactive process) (compare with Kinchin et al. (2000)) made visible by the concept maps.

Validating the Categorization of Links

Before drawing the concept maps, the categorization of links between basic elements were validated in order to guarantee to trustworthiness of it. In this, four external expert reviewers were asked to judge the validity of the categorization by means of questionnaires. The expert reviewers were university lecturers with Ph. D. in physics, and they were experienced teachers of the first year university physics courses. There were altogether six questionnaires (two topics and three textbooks). The structure of a questionnaire is described in the beginning of Appendix II. Basically, the reviewers evaluated if they agree with the categorization of a link through five-level Likert scale (Appendix II). The reviewers completed their answers to the questionnaires in four weeks in spring 2010. In this research two parametric tests were applied to Likert-scale and mean values and standard deviations of reviewer's agreement with the categorization in the studied cases were used to judge the validity of the categorization of links. This choice, although somewhat uncommon, is justified and for example Carifio and Perla (2008) have discussed the ways of using Likert scales and they strongly agreed with utilizing parametric tests.

The overall agreement of the reviewers with the proposed categorizations was remarkably good (as an example, the agreement results in case of the textbook FLP are presented in the Appendix II). The results from the questionnaires verify the appropriation of the proposed method of recognizing basic elements and identifying links and connection between basic elements.

Results of Research

In examining knowledge organization of textbooks the first step was to recognize basic elements; the second step was to categorize links; the last step was to represent the knowledge organization of textbooks by concept maps using the recognized basic elements and categorized links. Finally, the characteristics of those knowledge organizations are examined and interpreted.

Recognition of Basic Elements

The basic elements recognised in Biot-Savart law and Ampère's law from the examined textbooks are presented in Table 1.

All three textbooks have five basic elements in common (Bold concepts in Table 1): *magnetic field* and *electric field* in the domain of Biot-Savart law; *Gauss's law*, *magnetic field*, *magnetic field of long straight wire*, and *magnetic field of solenoid* in the domain of Ampère's law. On the other hand, FP and PSE share even more basic elements (Table 1): *superposition principle* (C3 of FP, C6 of PSE), and *magnetic field of coil/current loop* (C9 of FP, C10 of PSE) in both domains; *magnetic field inside wire* (C14 of FP, C13 of PSE) is used as a mutual element in the domain of Ampère's law.

The textbook of FLP has less basic elements than the other two textbooks (eleven basic elements. see Table 1). This textbook includes some more advanced basic elements (e.g. *Vector potential* (C10), *Stokes theorem* (C3), and *Maxwell equation* (C2)). There are sixteen basic elements in FP and fourteen elements in PSE. In contrast to FLP, the basic elements of FP and PSE include more examples of Biot-Savart law and Ampère's law. For example, FP consists of four examples of Biot-Savart law (C6, C7, C8, and C9 in domain of Biot-Savart law of Table 1) as well as six examples of Ampère's law (C6, C9, C13, C14, C15, and C16 in domain of Ampére's law of Table 1). Moreover, PSE consists of three examples of Biot-Savart law (C8, C9, C10 in domain of Ampére's law of Table 1) as well as five examples of Ampère's law (C8, C9, C10, C13, and C14 in domain of Ampére's law of Table 1).

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Table 1. The recognised basic elements for each textbook and each domain are presented (basic elements are tagged with numbered C, which refer to Figures 2-4).

	FLP	FP	PSE
Domain of Biot-Savart law	**C1 Magnetic field** C4 Electric current **C9 Electric field of charge distribution*** C10 Vector potential C11 Biot-Savart law	C1 Current length element **C2 Magnetic field** C3 Superposition principle **C4 Electric field** C5 Biot-Savart law C6 Magnetic field of long straight wire C7 Magnetic field of current in arc of wire C8 Magnetic field of brain activity C9 Magnetic field of coil**	C1 Charge **C2 Magnetic field** **C3 Electric field** C4 Coulomb's law C5 Magnetic field lines C6 Superposition principle C7 Biot-Savart law C8 Magnetic field of current C9 Magnetic field of long wire C10 Magnetic field of current loop
Domain of Ampère's law	**C1 Magnetic field** C2 Maxwell equation C3 Stokes theorem C4 Electric current **C5 Gauss's law** C6 Ampère's law **C7 Magnetic field of straight wire** **C8 Magnetic field of solenoid**	C4 Electric field C5 Biot-Savart law **C11 Gauss's law** **C2 Magnetic field** C10 Ampère's law C12 Amperian loop C13 Magnetic field outside wire C14 Magnetic field inside wire **C15 Magnetic field of solenoid** C9 Magnetic field of coil C3 Superposition principle **C6 Magnetic field of long straight wire** C16 Magnetic field of toroid	**C9 Magnetic field of long wire** C1 Charge **C11 Gauss's law** C12 Ampère's law C5 Magnetic field line **C2 Magnetic field** C8 Magnetic field of current C7 Biot-Savart law C13 Magnetic field inside wire C10 Magnetic field of current loop C6 Superposition principle **C14 Magnetic field of solenoid**

*The order of presenting elements follows the chronological order in the studied textbooks. Mutual basic elements are indicated in Bold. *The concept of electric field of charge distribution in FLP corresponds to concept of electric field in FP and PSE. **Magnetic field of coil in FP corresponds to magnetic field of current loop in PSE.*

These results show that although introductory university physics textbooks differ in using examples and advanced elements, they use almost identical basic elements in their content knowledge for the studied topics of Biot-Savart and Ampère's law.

Categories of Links in Textbooks

The method of analysis and categorization of links needs consistently to specify the nature of links and to show how they connect the basic elements. In examining how the basic elements were connected, the links were categorized as follows (an example from textbook of each category is presented in Appendix I):

1. Descriptive model (DM): A mathematical model that connects basic elements through mathematical relations or equations. In general, descriptive model links basic elements with mathematical format to new laws with mathematical expressions.
2. Explanatory model (EM): A mathematical model, which links basic elements through mathematical expressions. Usually the explanatory model connects the applications or implementations of laws (with mathematical format) to the closely related laws. In contrast to descriptive model, which describes new laws, explanatory models explain the applications and implications of the defined laws.
3. Visual model (VM): This model applies for visual perceptions. Visual model connects different basic elements through the diagrams, photos, and figures.
4. Statement of fact (SF*):* Concerns declarative knowledge. This knowledge gives information about the facts such as observations, discoveries, and phenomena.
5. Reasoning (R): A mode of presentation, which can be considered also as a model that gives reasons or arguments to justify the connections between basic elements. Reasoning might

be inductive reasoning (reasons are based on the previous experiences or observations or laws) or deductive reasoning (reasons follow a set of premises).

6. Reference to previous knowledge (RPK): A model, which refers to previous knowledge. This is often done in a form of analogy.

The result of this section reveals that basic elements in the content knowledge of studied textbooks are connected via different categories of links including descriptive/explanatory mathematical models and visual models, analogies, statements, and reasoning. The content knowledge of textbooks are different from the viewpoint of using these categories, which means in one textbook the category of mathematical model is probably the dominant category while in other textbook the category of reasoning is the central category of link. The textbooks' frequencies of using different categories of links are presented in Figure 1.

As Figure 1 shows (the dashed bars), the textbook of FLP applies many links to describe core concepts with mathematical relations or equations (DM, 3). As a result, FLP puts a particular emphasis on descriptive models. The most frequent types of links in FP (the grey bars in Figure 1) are visual models (VM, 6) and explanatory models (EM, 2). It appears that FP puts a particular emphasis on the explanatory models. It means that this textbook applies many examples in order to explain the mathematical applications of Biot-Savart law and Ampère's law. Accordingly, the majority of links in FP have mathematical and visual characteristics. PSE (the black bars in Figure 1) put a particular emphasis on the categories of reasoning (R, 4), visual models (VM, 6), and explanatory models (EM, 2). In addition, this textbook applies the category of statement of fact (SF, 1) more than other textbooks.

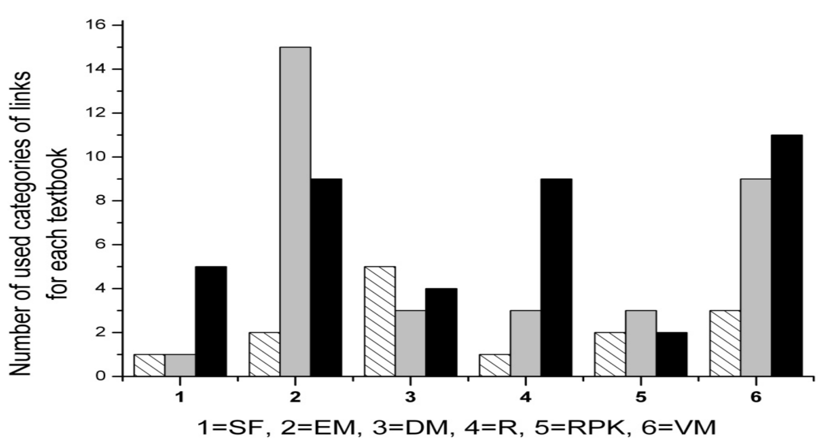

Figure 1: The number of categories of links. Used categories of links in FLP are shown by dashed bars, in FP by gray bars and in PSE by black bars.

Concept Maps Representing Knowledge Organization

Next, knowledge organization of each textbook is presented as a concept map (Figures 2 to 4). The domains of subject content in the concept maps are: 1) domain of Ampère's law and 2) domain of Biot-Savart law, where Ampère's law and Biot-Savart law are the cores of these domains. There are incoming and outgoing links in each domain that connect the core concepts to the related neighbouring concepts. Incoming link means that it starts from neighbouring concept and end to core concept. Outgoing link whereas mean that it starts from core concept and ends to neighbouring concept. In addition, concept maps contain cross-links that connect neighbouring concepts of the core concepts to each other. In Figures 2 to 4, all links are directional. These directions show the order of introducing concepts in the textbooks. The abbreviations in the links refer to previous section about the categories of links. The links

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follow the sequence of steps in the construction of the concept maps. In what follows, concept maps representing the knowledge organization are discussed separately in each case.

Concept map of FLP

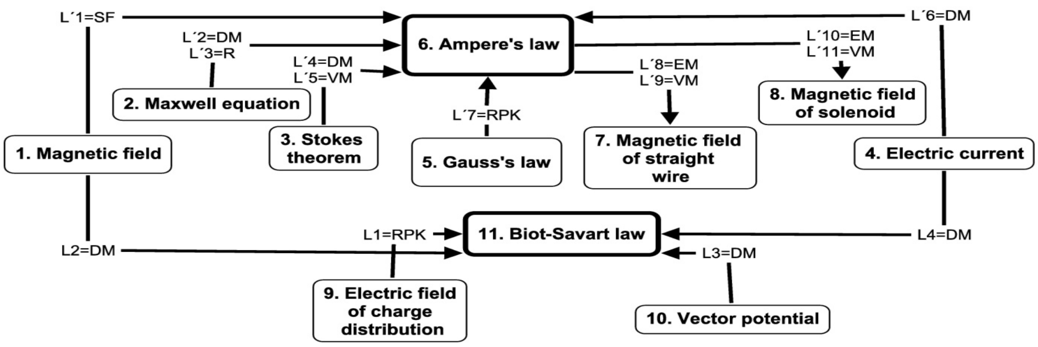

Figure 2: **Concept map representing the knowledge organization of the FLP. L and L´ present links that are associated to domains of Biot-Savart and Ampère's law respectively.**

In the concept map of FLP, first Ampère's law (C6) and then Biot-Savart law (C11) are represented (Figure 2). The concept map of FLP consists of eleven concepts. The basic elements that are used to describe Biot-Savart law and Ampère's law are given in Table 1. *Magnetic field* (C1) and *Electric current* (C4) are mutual concepts that are used in two domains.

As Figure 2 shows, all the links connect either to Biot-Savart law or to Ampère's law (core concepts). There are no cross-links between other concepts. Most of the concepts (except *magnetic field*, *electric current*, and core concepts) are disjointed. In the concept map of FLP most of the links are incoming. For instance, as Figure 2 shows L 2=DM (descriptive model) is an incoming link in the domain of Biot-Savart law. *Magnetic field* is applied to describe Biot-Savart law mathematically via L 2. There are only few outgoing links in the concept map of FLP. One example of an outgoing link is L´9=VM (visual model), which *magnetic field of a solenoid* and its relation with Ampère's law is visualized in FLP. Thereby these two basic elements are connected via visual model (L´9).

Concept map of FP

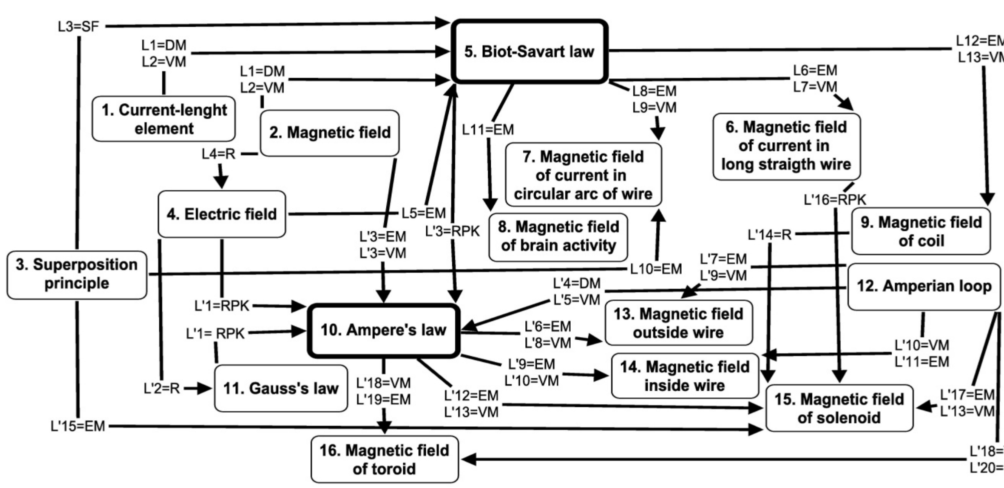

Figure 3: **Concept map representing the knowledge organization of the FP. L and L´ present links that are associated to domains of Biot-Savart and Ampère's law respectively.**

In contrast to FLP, Biot-Savart law (C5) is presented earlier than Ampère's law (C10) in FP (Figure 3). Some links appear twice in the concept map of FP, e.g. L1, L2, L´9, and L´10 (see Figure 3). It means that according to the context of FP some concepts link to some others simultaneously. For instance, in the case of L1 the concepts of *current length element* and *magnetic field* at the same time describe mathematically Biot-Savart law regarding the context of the textbook.

Concept map of FP consists of sixteen concepts. These concepts are also presented in Table 1. *Magnetic field* (C2), *superposition principle* (C3), *electric field* (C4), *magnetic field of current in long straight wire* (C6), and *magnetic field of coil* (C9) are five mutual basic elements that are repeated in two domains of Biot-Savart law and Ampere´s law in FP(see Figure 3 and Table 1). This means that FP put a great emphasize on these concepts to present the studied topics.

As Figure 3 shows, many incoming and outgoing links are associated with core concepts (Biot-Savart law and Ampère's law). There are some cross-links between other concepts as well. For instance, as L´14=R in Figure 3 shows, the reasons for connecting two concepts of *magnetic field of a coil* and *magnetic field of a solenoid* are discussed in FP and therefore these concepts are linked via reasoning.

The concepts of *current-length element* (C1) and *magnetic field of brain activity* (C8) include some limited number of links (one or two links) that are either incoming links or outgoing links; therefore, they are regarded as disjointed concepts.

Concept map of PSE

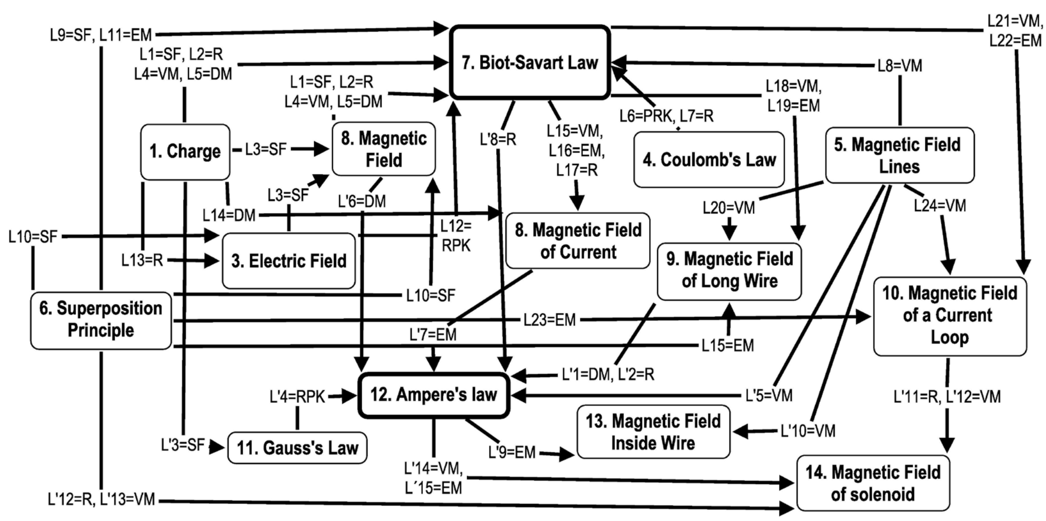

Figure 4: Concept map representing the KO of the PSE. L and L´ present links that are associated to Biot-Savart and Ampère's law respectively.

The PSE first presents first Biot-Savart law and then describes Ampère's law. There are fourteen concepts in the concept map of PSE. These concepts are introduced in Table 1. *Charge* (C1), *magnetic field* (C2), *magnetic field line* (C5), *superposition principle* (C6), *magnetic field of current* (C8), *magnetic field of long wire* (C9), and *magnetic field of current loop* (C10) are seven mutual basic elements that are used in two domains (see Figure 4 and Table 1). This means that PSE stresses these concepts to present the studied topics.

As Figure 4 indicates, many incoming and outgoing links are attached to core concepts. Besides, there are some cross-links in the concept map of PSE. The only concept of PSE, which is disjointed, is *Coulomb's law* (C4).

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Hierarchy and Interconnectivity in Knowledge Organization of Textbooks

As the concept maps (Figures 2 to 4) indicate, some concepts are connected to each other via more than one type of links. Thereby, it is expected that the connection between these concepts is stronger, in other words, these links may possess more weight. In this study, the weight of the links is not stressed and the knowledge organizations are presented without considering the weight of links. However, from the perspective of learning, it is more probable that when the basic elements are multiply connected, also the learners establish the connection between these elements. The introduced concept maps (Figures 2 to 4) reveal clearly some fundamental features and differences in the knowledge organization of the textbooks.

As Figure 2 shows, the knowledge organization of FLP has limited hierarchical levels, which means there are only few justifiable levels in the knowledge organization of FLP. The most dominant links in FLP are incoming links. Moreover, FLP includes only two cross-links so its knowledge organization is not an interactive process. Ultimately, the knowledge organization of FLP can be interpreted as a simple structure that excludes interconnectedness and cross-links but includes many disjointed concepts.

As Figure 3 shows, knowledge organization of FP includes many hierarchical levels. FP describes high interactive process that includes some cross-links. Besides, the knowledge organization of FP consists of many incoming and outgoing links. FP includes only two disjointed concepts. Therefore, the knowledge organization of FP is flexible and interconnected.

As Figure 4 shows, knowledge organization of PSE contains many hierarchical levels. Moreover, the knowledge organization of PSE is an interactive process that includes some cross-links. The knowledge organization of PSE includes many incoming as well as outgoing links. There is only one disjointed concept in the knowledge organization of PSE. Such an organization has flexible and interconnected structure. The knowledge organizations that are hierarchical and include interactive processes are more flexible and interconnected and therefore they are more beneficial for learning than simple structures.

Discussion

The textbooks analysis have most often concentrated on the content knowledge of textbooks from the viewpoint of textual features (Strube, 1989), educational goals (Orpwood, 1984; Chiappetta et al. 1993; Wilkinson; 1999), or coherency of texts (Roseman et al, 2010). Other analysis have been emphasized the impact of textbooks on student and teachers' knowledge organization (Ainsworth & Burcham, 2007). This study puts effort into detailing the characteristics of knowledge organization of textbooks and developing a method of doing this. This is of importance because the organization of knowledge within the textbooks affects learning and teaching (Ball & Cohen, 1996; Davis & Krajcik, 2005). Before the effect of textbooks' knowledge organization in learning and teaching can be evaluated, there has to be methods of visualizing and evaluating the knowledge organization of the curricular materials. This study is a contribution for making the knowledge organization in textbooks explicit, and the results show that the method proposed here is applicable doing it. This was done in the form on concept maps. An important element in this was that the connections were links. The traditional way of producing concepts maps (Novak, 1990), where links are verbs (propositions) between nodes (concepts), was not possible: the concepts maps covering these chosen topics would have been so massive that it would have been impossible to analyse them. It would not have told about the procedural nature of the knowledge organization either.

The basic elements (quantities, laws and principles) are in the core of learning and in that, the way how they are connected to each other has an important role; they tell about the ways how knowledge is organized (compare with Mäntylä, 2011; Koponen & Pehkonen, 2010). Thereby the learning of the content knowledge includes the learning of the concepts, the ways they are constructed or derived, and the knowledge structures that form during knowledge construction. The textbooks are important sources that teach these aspects more or less explicitly. When the basic elements are compared in different textbooks, there is a consensus of the important basic concepts. However, FLP emphasises more advanced concepts like Stokes theorem and Maxwell equation, while the other books emphasise more different examples of applying the examined laws like magnetic field in different systems.

Harrison and Treagust (1998) and van Heuvelen (1991) have discussed different models in science education, including mathematical models (or representation). In the categorization of links, two different categories of mathematical models were identified: descriptive models (new laws are obtained through mathematical formulation) and explanatory models (applications or implications of defined laws are mathematically explained). Mathematical models are widely used in connecting the basic elements in the textbooks, descriptive models in FLP and explanatory models in FP and PSE. Gilbert (2005) has stressed the importance of visualization in science education; also all three textbooks make much use of visual models in linking basic elements. PSE also utilizes a lot of reasoning in its connections; its importance in formation of knowledge has also been highlighted (Brachman & Levesque, 2004). Also analogies (or more general reference to previous knowledge) play a role in learning as mapping tools (Glynn and Takahashi, 1998), and this can be seen also in the textbooks. Surprisingly, the textbooks did not apply any descriptions of real experiments in linking the basic elements. This could be due to the nature of the selected topics, e.g. at least PSE applied experiments in case of other topics.

The previous studies have shown that the way how knowledge is presented and organized in textbooks have important effects on students' learning (Koulaidis & Tsatsaroni, 1996). The scientific knowledge can be organized in many ways and in the textbook the choice of organization is made by the author(s). This choice has consequences in the ways how the learners can learn or understand the contents. In the examined textbooks, FLP had a clear and quite simple structure, this means that there are very limited number of ways of understand and organize the content from the learner's perspective. This could also mean lead to situation that if the learner fails to understand one concept, it hinders the understanding the concepts following this concept (e.g. as if one node is removed from the concept map in Figure 2). FP and PSE on the other half had flexible and interconnected structures, which means that the learner studying from these books have several options of organizing her/his own knowledge. Also if one concept is not understood, the consequences are not so drastic, because the following concepts can be understood different ways (if one node is removed from the concept map on Figure 3 or 4, it is possible to find another route going to the following node). According to Ainsworth and Burcham (2007) well structured and explicit text-based materials (like textbooks), have a major impact on students' learning. The example above shows that perhaps it is not always the case; FLP was never quite popular in introductory physics education although it is well-structured and explicit, the other two books are currently widely used in introductory courses of physics, although they are not so explicitly structured as FLP. The popularity could be due to their flexible structure, they can be used various ways in teaching and learning. But there are of course other reasons also, FLP makes also much use of the more advanced concepts, which makes the learning more demanding.

Conclusion

In this study, a method of making knowledge organization of textbooks visible and analyzable through concept maps was developed. This required the recognition of basic elements and the way how they were connected, categorizing the links between basic elements. The examined introductory physics textbooks contained similar main basic elements. There were, however, differences between the textbooks, in FLP more advanced basic elements were applied and in FP and PSE made much use of examples and implications. In case of Biot-Savart law and Ampère's law, the textbooks applied mainly model-based links. In FLP there were relatively little links, although the number of basic elements in that book was also smaller compared to the other books. All books applied the different type links categorized in this study. However, FLP emphasized descriptive models, FP explanatory and visual models, and PSE was most versatile: it emphasized explanatory and visual models and reasoning. When examining the structures and connections in the concept maps, the links are mainly connected to the core concepts: Biot-Savart law and Ampère's law. The knowledge organization of FLP has simple structure. As for knowledge organizations of FP and PSE have flexible and interconnected structures. In conclusion, the knowledge organization of FP and PSE are in many respects similar what comes to hierarchy and inter-

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active process, and they are very different from the knowledge organization of FLP. Such fundamental differences in knowledge organization are bound to affect the views of the knowledge organization of physics that teachers and students obtain from the textbooks.

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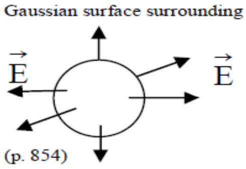
Appendix I

Table I. The characteristics of categorizing links are summarized below. The examples are from PSE.

Link	Excerpt from the textbook	Basic elements	Interpretation
1. Descriptive model (DM)	By definition the net flux is $\varphi_e = \oint \vec{E}.d\vec{A}$. For any closed surface enclosing total charge Q_{in}, the net electric flux through the surface is $\varphi_e = \oint \vec{E}.d\vec{A} = \frac{Q_{in}}{\varepsilon_0}$ (28.18). This result for the electric flux is known as **Gauss's law.** (p. 864)	a. Flux $\varphi_e = \oint \vec{E}.d\vec{A}$ is a concept with mathematical format. b. Gauss's law $\varphi_e = \oint \vec{E}.d\vec{A} = \frac{Q_{in}}{\varepsilon_0}$ is a law.	Flux → DM → Gauss's law
2. Explanatory model (EM)	**Finding the electric field of a long, charged wire.** Gauss's law is $\varphi_e = \oint \vec{E}.d\vec{A} = \frac{Q_{in}}{\varepsilon_0}$ [...] Thus the electric field at distance *r* from a long, charged wire is $E_{Wire} = \frac{\lambda}{2\pi\varepsilon_0}$ (p. 868)	a. Electric field of a long, charged wire $\varphi_e = \oint \vec{E}.d\vec{A} = \frac{Q_{in}}{\varepsilon_0}$ is a concept with mathematical format. b. Gauss's Law $E_{Wire} = \frac{\lambda}{2\pi\varepsilon_0}$ is a law.	Gauss's law → EM → Electric field of a long, charged wire
3. Visual model (VM)	**FIGURE 28.8** Gaussian surface surrounding a charge.  (p. 854)	a. Gaussian surface is a concept. b. Electric field of a charge is a concept.	Gaussian surface → VM → Electric field of a charge
4. Statement of fact (SF)	There are three important observations regarding Coulomb's law: [...] 3. Electric forces, like other forces, can be superimposed. (p. 802)	a. Coulomb's law is a law. b. Superposition is a principle.	Superposition principle → SF → Coulomb's law
5. Reasoning (R)	According to Lenz's law there is an Induced Current in the ccw direction. Something has to act on the charge carriers to make them move, so we infer that there must be an *electric field* tangent to the loop at all points. This electric field is caused by the changing magnetic field and is called **induced electric field.** (p. 1059)	a. Induced current is a concept. b. Induced electric field is a concept.	Induced electric field → R → Induced current
6. Reference to previous knowledge (RPK)	We've derived this expression for energy density based on the properties of a solenoid, but it turns out to be the correct expression for the energy density anywhere there's a magnetic field. Compare this to the energy density of an electric field that we found in Chapter 30. (p. 1068)	a. Energy density of magnetic field is a concept. b. Energy density of electric field is a concept.	Energy density of magnetic field → RPK → Energy density of electric field

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Appendix II

The questionnaires were designed as follows:

1. In questionnaires, a) textbook's name (FLP, FP, PSE), b) topics (Biot-Savart law or Ampère's law) and c) chapters in original textbooks (chapters 28, 29 in FP or chapter 33 in PSE or chapters 13, 14 in FLP) were presented in the header.
2. The questionnaires were based on a five-level Likert scale: (1) Strongly disagree (2) Disagree (3) Neither agree nor disagree (4) Agree (5) Strongly agree. The Likert scale is used for each questionnaire.
3. Each questionnaire includes several questions about the links between basic elements. Since only Biot-Savart law and Ampère's law is analyzed, related parts from the textbooks were copied in the questionnaires. In addition, the covered pages from the textbooks were copied on a whole. Thereby the lecturers could read the excerpts from the textbooks concerning the categorized links and if they felt that the copied part did not give sufficient information, they had the direct access to original pages of textbooks in order to judge the categorization.
4. As mentioned before, each question presented a link, which connects the basic elements. After each question, there was Likert scale and it was asked that lecturers mark only one level (1…5 of Likert scale) concerning their agreement about the categorization. After the Likert scale, the categories of links were listed, so that in case of that the lecturer disagreed, he/she had the possibility to choose link category, which in their opinion better described the character of the link. In the end of each question, there were space for comments of reviewer.

Agreement Results

Mean values greater than 3 (mean value > 3) means that the categorization of the link is valid. Each mean value is presented with its standard deviation that point out how much lecturers opinions vary from their mean value. In other words, high standard deviations indicate that the opinions are spread out over a very different range, while low standard deviations represent good agreement in opinions. In Figure II-I the agreement results of lecturers' opinions in case of FLP is shown.

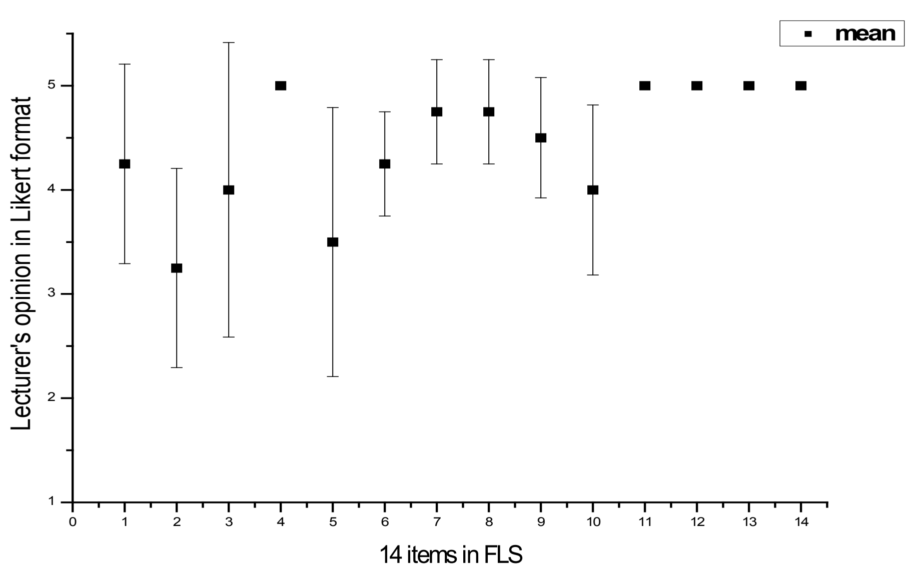

Figure II-I. Mean values and standard deviations of lecturer's opinion in case of FLP.

All of the questionnaire items (i.e. questions) concerning FLP are located above number 3 in vertical axis of Figure II-I and thereby the items hold good validity. The standard deviation of items 1, 11, 12, 13, and 14 are zero which reflect that all lecturers strongly agreed about these items. Furthermore, the numbers of items with high and low standard deviation are roughly equal.

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