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Collaborative Design of Ontologies: Theory, Opportunities and Convenient Applications

Abstract

Increased demands on users have led to information and media competence gaining a very high priority in today's information society. Thus, they are giving rise to challenges in the process of teaching these competencies in universities. In this paper, a concept for a blended learning approach will be proposed. The framework of this approach allows key qualifications to be taught through the implementation of contextual teaching. This involves focusing on the process of the collaborative design and development of knowledge structures. In this process students must envision implicit associations within a subject area and discuss various points of view, concepts, and understandings in cooperation with their fellow students and visualize them in the form of topic maps. The approach is based upon new insights from the areas of cognitive learning psychology, education and didactics. The process of collaborative ontology development occurs in a learning environment that was developed and implemented over a number of years and which is explicitly geared towards the teaching of key qualifications.

1. Knowledge and Learning through Collaboration and Participation

1.1 Current challenges facing university teaching

Today's information society is characterized by the permanent development of information and communication technologies and new media. Information and media competence are therefore some of the most important key

qualifications. Teamwork and networking have gained an important role in professional life. Collaborative working patterns are becoming the norm and the generation of knowledge and open exchange of knowledge have become the success factors of productive systems.

Current developments, which can be summarized under the heading "Web 2.0" (O'Reilly, 2006; Musser et al., 2006), make the trend clearer: the focus is increasing on collaboration, the creation of collectively generated contents, and the collaborative development of knowledge structures and orders. In constructing corresponding learning environments, the development of Web 2.0 has opened up a range of technical, functional and community-building possibilities. New forms of social interaction and technical functionalities thus lead to new aspects in the shaping of knowledge. Innovative methods of teaching and learning arise from this and they too significantly influence the knowledge exchange. University teaching has been rapidly faced with the challenge of transforming itself against this background.

1.2. The relevance of teaching information and media competence

A number of studies and statements deal with the high priority that information competence has gained in our society today (Hütte, 2007; Hapke, 2007; OECD, 2005). It becomes clear here that a command of information competence is becoming more and more important in almost all spheres of our daily lives and that this trend will continue to increase in the future.

According to Hütte (2007), the reasons why the skills that fall under information competence have become such a priority so fast can be explained by the following factors:

- Technological advances: rapid developments in hardware, the introduction of new mobile devices, and new types of software and software ranges, as well as the prevalence of the Internet as a dominant medium, require new competencies in dealing with media and technologies. The learning cycles are decreasing and users must become familiar with innovations and learn how to use them in increasingly shorter times.
- Increase in the range of data and information overload: the steadily increasing volume of data means that classical processes for handling

information, such as searching, selecting, evaluating and interpreting information in different contexts etc., are becoming more important.

- Changes in the provision of information: automatic services and information services available over the Internet are taking over the provision of information from professional information providers. This requires a higher competency on the part of the user because they must acquire the information themselves and not simply explain to an information provider what sort of information they require.

Furthermore, in a study on the topic of key competencies (2005), OECD refers to the globalization and modernization of our society as the reasons behind a networked world which have led to the development of new challenges for individuals in terms of dealing with information.

Universities should be seen as important places where the competencies for dealing with the challenges described above can and should be taught.

1.3. Comprehensive blended learning concept

A blended learning concept (Hierl et al., 2007; Böller et al., 2007b) allows us to react to these new challenges and to create a frame of reference for integrating the active and comprehensive teaching of methods, social, professional, media and information competencies into the curriculum. The concept has been developed over a number of years and has been incorporated into the curriculum for information science at the University of Applied Sciences HTW Chur. The approach is characterized by the fact that first-semester students actively require the relevant competencies within the framework of the underlying module and therefore have to acquire them (Brändli 2007). The concept of blended learning serves as a basis, making this process possible. Consciously working with and integrating different types of media and ways of communicating clearly show the increased value for learners as well as instructors clear. The frame of reference is made up of the following learning scenarios and opportunities of which the students can see themselves availing (Böller et al., 2007a; Böller et al., 2007b):

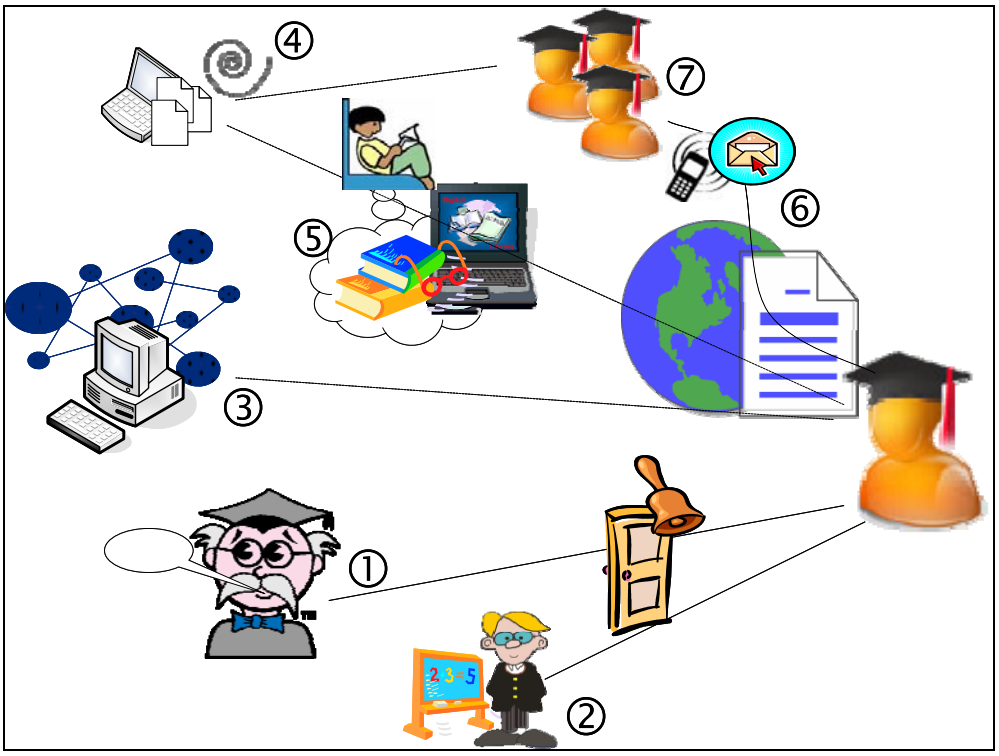

Figure 1: Learning environment and learning scenarios

Interconnected learning units support the learning progress of students throughout the semester. The weekly face-to-face lectures ① serve as a classical method of knowledge dissemination, whereby content learned can be explored in depth in group and individual projects ⑦, through reading assignments ⑤, exercises and collaborative online assignments ⑥, seminar papers ④, and the use of an e-learning platform with lecture materials ③. Individual questions are answered in weekly tutorials ② which take place parallel to the lectures and encourage an active exchange between the students.

The main emphasis of this approach is on encouraging students to work collaboratively by using wiki software. Within a collaborative working environment, students are taught in six steps how to extend their knowledge together, critically reflect on topics, and thus develop key competencies by writing a seminar paper.

The six steps are:

- **Focusing**
  Students actively acquire information on a suggested subject area. They identify research questions and topics they feel should be

discussed by debating their relevance and supporting this with arguments.

- **Writing**
  Students write and work on a paper within the collaborative working environment of wiki software.
- **Presenting**
  Papers are made accessible to all members of the group. Students develop both determination and self-confidence in making their own presentations available to their fellow students at each stage.
- **Reflecting**
  Students read a selection of the presentations written by their peers analytically and critically. They have to question and reflect on topics by going into deeper research.
- **Criticizing**
  Students comment on and constructively discuss individual papers with the help of the comment function in wiki software and collect additional points in this way.
- **Collaborative optimization**
  Using the comments as a basis, students can decide how they want to improve their own paper, and they learn how to deal with both positive and negative criticism by actively reflecting on their work and developing their own strategies for solving problems (Himpsl, 2007).

We have termed this pedagogical didactic approach within the learning environment the knowledge-enhancing helix (Böller et al., 2007a). The spiral and the gradual expansion show the process that leads to the expansion and improvement of knowledge step by step. It can be illustrated as follows:

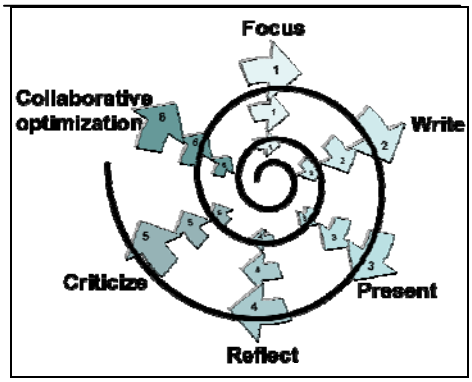

Figure 2: Knowledge enhancing helix

Every step in this process integrates the skills and content learned in the previous phase and therefore leads to a continuously improved knowledge exchange. Knowledge is actively acquired and disclosed, and an open knowledge base is constructed. This concept has worked well so far in practice and students appreciate it.

In the following, we will discuss how the principle of the knowledge-enhancing helix can be transferred from the writing of a seminar paper to other teaching and learning aspects. First of all, we will look at the implementation of a knowledge order in a blended learning environment within the context of its development (Chapter 2). We will then go on to look at transferring the spiral model to the collaborative topic map development as a special case of a knowledge order (Chapter 3).

2. Criteria for Creating a Knowledge Order within a Blended Learning Course

2.1. Knowledge order as an alternative representation of learning content

The contents of new lectures and seminars are often difficult for students to structure and understand without in-depth prior knowledge in a particular subject area. This leads to a situation where new students in particular acquire individual aspects of topics in an isolated way where connections between the topics cannot be identified without an understanding of the knowledge area. They are only able to incorporate what they have learned into an overall context and add these aspects to their competency repertoires when they can recognize the overarching associations.

Classically, learning material is structured in a hierarchical manner (lecture → reading → subject areas → classes etc.). This method of organizing learning content in textbooks is increasingly being applied to digital learning materials and e-learning courses (Dicheva & Dichev, 2005) without exploiting the non-linear or non-hierarchical character of electronic data archives and the corresponding hypertext mechanisms.

By using a knowledge order of the content of a course as a basis that must not necessarily be constructed in a linear or hierarchical form, the problem discussed above can be overcome. The knowledge order makes an

overview of the entire topic possible and makes it easier to distinguish it from other subject areas and also to focus on individual aspects. Furthermore, the new areas that have yet to be learned can be embedded in what has already been learnt, which provides students with points of references and associations (Brand & Markowitsch, 2004) that they can use to orient themselves and gain entry into the new subject area.

The structure of such a knowledge order represents the structure of the neurological network of a human brain according to findings from neurophysiology and brain research. This makes it much easier to absorb information within the framework of a learning process (Müller & Schwärzel, 2005).

2.2. Theoretical assumptions for individual and group learning processes

Within this neuropsychological understanding (Müller & Schwärzel, 2005; Thissen, 1997) of the human brain as a neurological network, learning is understood as an active process of knowledge construction according to the constructivist findings of brain research: new knowledge is always organized in connection with pre-existing knowledge and it is embedded in the pre-existing neuronal structure, while knowledge that cannot be incorporated is discarded. The most important prerequisite for this process is the active participation of learners in the knowledge acquisition process. This is supported in a number of ways including independent or collective evaluations of learning content through an individual, active examination of the subject area. Learners should be able to deal with the offered material using their own approaches because according to Thissen (1997) learning is the construction of mental, cognitive maps that are continuously improved and made more detailed over the course of individual learning processes.

This point of view also corresponds to the contextual teaching and learning (CTL) approach suggested by Clemente (2007). The CTL approach is based on the three learning theories of connection theory, constructivism and active learning, whereby new contents are embedded in a concrete context with which the students are already familiar, new knowledge is actively constructed by the students, and learning becomes an active process conducted by students guided by instruction.

Many of the requirements for active knowledge construction can also be found in Reigeluth's elaboration theory (2000), which looks at how learning material is structured and discusses how this can be transferred to multimedia learning environments. An important method of content provision is the zoom metaphor which allows for a representation of learning content going from the general to the specific and thereby contributes to the construction of cognitive knowledge maps. This means that new contents can be understood on the basis of existing knowledge and be integrated into the bigger picture. This method also proves the importance of prior knowledge at every stage in the learning process. The term "elaboration" means "to expand differentially" (Göttel, 2001) and includes the classification and sequencing of the selected learning contents. In this context, "chunking" is also spoken of. "Chunking" is the structuring and subdivision of knowledge contents into what are know as knowledge building blocks which can contain three types of content: concepts, procedures (processes), and principles (theories) that build on each other successively and the complexity of which can vary extensively (Peachter, 1996). This classification of content according to the elaboration theory is not just useful for the didactic structuring of lessons, but it is also helpful as a theoretical basis for the creation of topic maps, which are a semantic web concept that allows ontologies to be represented visually and also operates using information chunks. However, topic maps go one step further in that they qualify and explain the relationships between individual knowledge building blocks.

In order to organize the process of creating a knowledge order collectively in a group, the discourse-based meta-communication model developed by Yetim (2005) provides us with systematic guidance using structured group communication. The model is rooted in the "Theory of Communicative Action" (Habermas, 1984) and the further development of this in the form of the “Discourse Theory” (Habermas, 1993; Habermas, 1996).

The meta-communication model offers support for the articulation, determination and identification of knowledge or ideas in a group and for the discourse looking for the meaning, positioning and importance of individual topics. According to Yetim, every meta-communication consists of a verbal examination aiming to clarify the facts. This communication can be systematically and appropriately structured and organized by using a

staircase model which contains all of the important successive steps involved in collective sense-making. Should differences of opinion come into play, an additional communication level – the discourse level - can help which tries to balance the different viewpoints through an argumentative examination of the topic (Yetim, 2005). To summarize, the discourse-based meta-communication model supports the development of a collective understanding of certain facts or a particular subject area in which all participants develop a unified basic understanding and perform team work in a collaborative learning environment.

2.3. Objectives behind the creation of a knowledge order

The use of knowledge orders in blended learning and e-learning environments has already been discussed in a variety of different forms (Dicheva & Dichev, 2006; Herget, 2004; Hierl, 2005). The semantic web concept of topic maps (Pepper, 2000) in particular has huge potential (Feasey, 2002; Gerstorfer, 2001): topic maps allow the reuse of learning objects that already exist in a semantic form and are used as a tool for structuring and organizing knowledge.

The approaches discussed in the literature have the following in common: they all use a knowledge order in the form of a topic map (or a number of topic maps) as a basis for a lecture or blended learning course and thus allow learners access to learning material that is not just hierarchical but also thematic and multi-relational. In each case, the knowledge order is created to suit the course materials by the supervising lecturer and then it is made available to students (Bauer et al., 2007).

This type of approach has already been applied to the information sciences study program in the University of Applied Sciences HTW Chur and it is currently being evaluated (see Figure 3).

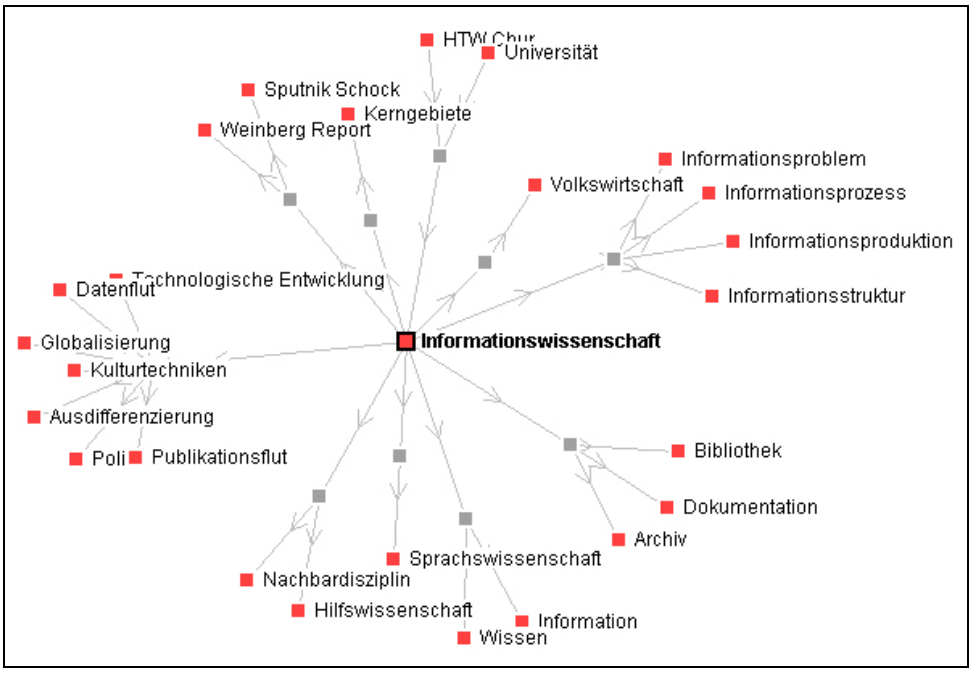

Figure 3: Example of part of a topic map on an e-learning website for the lecture course on the basics of information science at HTW Chur

The process of logically designing a topic map can involve a great degree of complexity (Dicheva & Dichev, 2005) and requires an in-depth thematic examination of the concepts and contents depicted.

Moreover, this analysis is also used to identify and explicate specialized knowledge and knowledge structures (Smolnik, 2005). Designing and constructing a topic map can therefore be understood as both the explication of existing knowledge and a learning process whereby the author visualizes associations and works out a cross-linked formation of concepts. Other things that should be taken into account are quality criteria of ontologies that lead to discussion, how worthwhile terms and definitions are in reality, how they are accepted in a community, and in what context they can be linked to and interact with other terms.

The creation of a knowledge order does not simply lead to a gain with regard to the knowledge base that is produced as a result and which is made available to students to use as a means of access to the learning material. More importantly, it becomes clear that the process involved in designing a knowledge order also has the potential of being consciously incorporated into the learning process. If students conceive a knowledge order, for example, the process teaches them according to the principle that "the path is the goal".

At the same time, existing resources can be used as learning material for the course once they have been appropriately adapted. A similar constructivist approach has already been successfully implemented in Norwegian schools where the creation of a knowledge base in the form of a database for learning progress was performed by students and therefore functioned as a learning tool (Lavik et al., 2004).

The organization of knowledge by students represents a learning moment and serves the following two objectives:

- **Creation process as a learning objective**
  The above points are taken into account here because they show how authors of a topic map create and acquire new knowledge on the basis of their existing knowledge through the process of designing a knowledge order. During this process, students learn how to:
  - explicate implicit knowledge,
  - identify individual knowledge building blocks in the material provided,
  - recognize the associations between different subject areas, knowledge building blocks, and aspects of knowledge,
  - define concepts within an application or thematic context, and to accordingly configure the quality criteria of an ontology,
  - embed the acquired and newly learned knowledge in an overall context,
  - exchange and discuss in a team with the aim of achieving collective sense-making.

- **Result of the creation process**
  These objectives include the result of the process, i.e. the representation of the knowledge order in the form of a navigational and expandable topic map, which is made available to learners. Here, the knowledge order is used
  - as a non-hierarchical method of accessing course materials that illustrates the associations between the individual aspects of a subject area,
  - to create an overview and differentiation of the topics taught,
  - as a cross-linked representation of contents that embeds new aspects that have yet to be learned in pre-existing knowledge,

and thereby provides links for the internalization of new material,

- as reference material that defines terms in the contexts in which they are used and that forms the basis of all learning matter in an ontology.

The idea of incorporating this process of designing a knowledge order or of representing a knowledge order into the teaching process appears extremely promising. The complexity of the design process, however, poses a problem in that it asks too much of some students if they are left to their own devices. Against this background, the following will suggest an approach in which students support each other by collaborating throughout this process and thus profit from their cooperations according to the principle of the knowledge-enhancing helix.

3. The Collaborative Creation of a Topic Map

3.1 Applying the principle of the knowledge enhancing helix

The points made in the first chapter make clear how far the collaborative acquisition of learning and the participation of students in the two-way learning process within the framework of a university course actually serve the development of key competencies. The much tried-and-tested approach of collaboratively drafting seminar papers in the locally installed wiki software has led to good learning successes, and along with increasing motivation amongst students, it has also contributed to the construction of collective knowledge.

If a topic map is not drawn up by one person alone, but rather in collaboration with other students, then this exchange offers an opportunity for students to profit from each other's knowledge and to create a framework for targeted, subject-specific exchanges on a particular topic or lecture. Discussions on things such as associations in a subject field that have been understood differently or different understandings of concepts lead to an expansion of knowledge because different perspectives, viewpoints, and experiences are exchanged. At the same time, it becomes possible to reflect on one's own learning processes and misunderstandings can be detected.

In the following, a concept will be outlined that allows the collaborative development of a topic map to be used as a concrete learning tool for students.

3.2 Possible implementation in university teaching

The collaborative creation of topic maps can be added as another important didactic and methodical concept to the course framework outlined in Chapter 1.3 for the lecture on the basics of information science, and it can also be integrated without any problems into the blended learning environment illustrated in Figure 1. The topic maps should ideally be created collaboratively by a small team made up of a maximum of five students.

The weekly tutorial provides a good framework for introducing the concept of topic maps and for explaining how they work. This involves explaining the basic terms required, showing how a topic map is created, presenting the tool that is used for collaborative creation, and letting students practice using all contents learned by means of a small example topic map. Finally, the course can be divided into individual teams and they can then be assigned the various subject areas that the course instructor has previously decided upon should be represented in the form of a topic map.

It is fundamentally decisive in this phase that the most important basic steps necessary for designing a topic map are explained to the students in order to ensure that all groups follow the same procedure during the collaborative creation process later.

The relevant steps for designing topic maps that must be borne in mind can be summarized as follows (Hierl, 2005; Müller & Tockenbürger, 2001; Rath, 2003):

- differentiation of the selected subject area
- breaking down of contents into information chunks with the aid of the knowledge structuring approach as expounded by the elaboration theory
- structuring and classification of information chunks
- development of topics from the resources above and beyond the level of the object
- identification of associations between the topics

- determination of other elements
- discussion of the results, validation, consolidation
- software-based application of the topic map draft
- (possible) linking of all topic maps using the merging principle

All of the important methods and the tools that are necessary in the team phases must also be explained. This includes:

- compilation of the issues involved on an individual basis in order to gain an understanding of the subject area,
- brainstorming sessions in order to collect all individual opinions in the team for a subsequent discussion which mainly makes use of flipcharts and mind maps as support material,
- use of the meta-communication model for achieving collective consensus,
- use of the card sorting procedure to help structure information chunks (Gaffney, 2000) or to create mind maps,
- alternatively, the last step could be conducted collaboratively in the topic map software (this depends on the type of system in use and the support available for individual phases, including the previous steps).

Extending these learning methods to higher semesters or rather to masters' courses is strongly recommended because collective viewpoints and reflections are just as helpful here in associating knowledge that has already been learned with new contents.

4. Summary

The current paper presents a new collaborative learning and teaching method that can be incorporated into a blended learning environment. It utilizes the collaborative acquisition of knowledge by students using an existing approach that has been proven itself valuable in developing key competencies in the past. Furthermore, the concept embodies a learning process in which students learn to reflect on their learning activities and work collaboratively in small groups to design a knowledge order on a subject area addressed by lectures.

The knowledge order designed is presented visually in the form of a topic map, which has the potential to help the learner associate new contents

better with pre-existing knowledge. Moreover, the resulting topic map can be used as a tool that provides additional access to content.

The process of designing topic maps therefore serves as a learning tool from which students profit as a result of the active acquisition and expansion of their knowledge. They also learn how to systematically undertake and document their learning preparations and the repetition of lecture contents.

The approach serves as the basis for an active and comprehensive teaching of information and media competencies and other key qualifications which are becoming extremely relevant in today's society due to a number of different technological developments, the ever-increasing volumes of data, and the increasing challenges that these developments bring with them for the user and processor of information.

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