Individualization of Knowledge Representation in Teacher Education in Mathematics

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The Individualization of knowledge representation requires a knowledge base in which teachers can organize contents according to their personal needs. The objective in teachers education is to combine authoring activities with the embedding of existing contents. Student teachers have different mathematical and pedagogical experiences in mathematics education. These experiences determine their focus of interest and their authoring activities in the knowledge management system. They develop for example lesson plans in geometry embedded in the pedagogical and mathematical knowledge in the system. Individualized knowledge representation is a constructivistic approach to build up knowledge according to the progress in teachers education.

From Research Grows Research

The CD-ROM *Learning about Teaching* [LAT] (Mousley & Sullivan, 1996), introduced by Sullivan and Mousley at the PME conference in Lahti is an outstanding example of a learning environment that embeds questions about a lesson's design. Analysis of the lesson is facilitated with video recordings, transcripts, and graphs. Using these tools, student teachers can approach didactical (pedagogical) concepts by examining authentic mathematics classroom material, including the lesson plan, lesson activities, children showing problem solving processes, and outcomes of the lesson. These are sources for the student teachers' reflection, discussion and writing (see also, Honebein, Duffy, & Fishman, 1993).

At the end of 1998 Stein took this CD as a starting point for the internet based *Mathematik-Didaktik im Netz* [MaDiN], a multimedia facility for teacher education in mathematics and mathematics education. The production of didactical and mathematical content and the basic objectives of the MaDiN project were modelled on the LAT CD. A further basic objective of MaDiN was accessibility on the web, and another was that the development should attend to constructivist principles by allowing users of the resource to develop their own networks of knowledge.

Cooperation between MaDiN and the *Mathematics Education On the Web* [MEOW] in Edith Cowan University, Perth, began in 1999 (see Herrington, Herrington, Oliver 1999) .

Further, since 2001, four working groups from different German cities led by Weth (Erlangen), Weigand (Würzburg), Tietze (Braunschweig), and Stein (Münster) have joined the MaDiN project, focussing on different mathematical and didactical aspects, in primary, lower and upper secondary teacher education.

This demonstrates how one innovative resource, growing out of mathematics research, can lead to further developments. This paper addresses the nature of these developments and describes the structure of the knowledge base of the mathematical and didactical contents in MaDiN.

Knowledge Representation

Knowledge representation is one objective of MaDiN and of its development through the working groups. Knowledge representation is an aspect of knowledge management (Na Ubon & Kimble, 2002) that describes the way contents are structured and linked, and it is a crucial element for the organization and individualization in a private workspace. The basic idea of the MaDiN-project is *context dependent knowledge representation.* The classification of information is achieved by themes, accessible from a desktop that serves as the user interface. The method for structuring themes has been outlined by Ernst and Stein (in press) and McAleese (1998).

The basic suppositions made about the didactical and mathematical knowledge in MaDiN are that (a) the known scope of German teacher education can be represented in a structured way, and (b) that this structure can be organized as a directed tree (see Figure 1 below). We refer to the elements of this tree as "nodes". In MaDiN, the nodes in the tree represent a *collection* of different types *of information* (HTML-pages, video, audio, animations, etc.) for a special theme. If we take, for example, the subject *"Problem Solving in Geometry",* this collection contains the following nodes:

- a *survey,* which gives a short description of the contents of the desktop;
- a *video* of student solving a Tangram problem in geometry;
- *activities* for student teachers to analyse the geometric problem solving activity of children (including analysis of difficulties that the children have);
- *internet links* to the subject *"Problem Solving in Geometry"*, for example to geometric problem solving activities for lower secondary schools;
- *theoretical* background information to the applications of *Problem Solving* in primary schools;
- additional references to *literature* on problem solving in geometry; and
- *news*, for example, relevant up-coming conferences.

A link between tree nodes in MaDiN is a link from one collection of information to another collection.

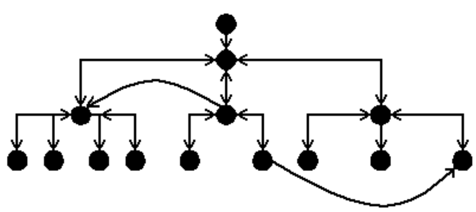

Figure 1. Directed tree.

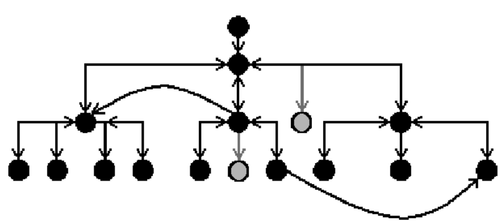

Figure 2. Individualized tree with grey nodes.

Following a *constructivistic approach* a learning process is individualized construction of knowledge and abilities. The structure of the tree should represent the process. Individualization of this tree for specific users or user groups includes uploading and editing of contents in the desktop and the embedding of new tree branches (the grey nodes shown in Figure 2) with existing desktop subjects.

We then needed an interface for this collection of different types of information. We chose a desktop as metaphor, as used by the MEOW-Project (Herrington, Herrington, & Oliver, 1999). Thus when accessing the resource, students see a desk (see Figure 3 below)

Problem Solving in Geometry

Figure 3. Desktop for “Problem Solving in Geometry".

Some drawers may be highlighted meaning that the desktop provides these elements of information on the subject *Problem Solving in Geometry*. Other information categories may be not highlighted because there is no information of that type available. Clicking on each of the labelled elements provides a different entry point to the information embedded in the website, so users can choose an individual approach and explore the subject *Problem Solving in Geometry*. Behind this interface, the material is arranged in a tree structure where we think of the nodes as further desktops, and some are linked. Thus when a user is navigating from one collection of information to another the drawers appear to be filled with hypertext, videos, links and references according to the subject the user is looking at.

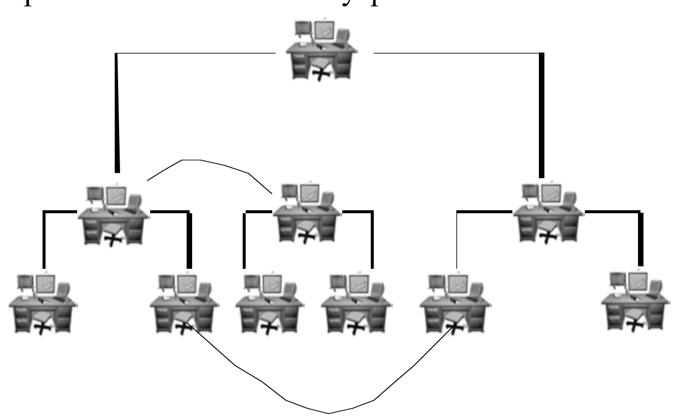

Figure 4. Information in the desktop depends on the tree node.

This *context dependency* of the desktop has the objective that the user will only get the information on the chosen subject, and only the specific media that are available on that topic

Teaching Experiences and Didactical Knowledge

When student teachers have completed their first teaching experiences they have only a limited knowledge about organizing and initiating learning processes for the children, so learning about teaching has to start from these limited preconditions. Because they teach different lessons in different classes, and have favorite teaching methods, there is a necessity to organize knowledge in a personalized way. Catering for these needs is a further principle of the research project.

Student teachers are encouraged to do online authoring in order to document their teaching experiences. This includes entering lesson plans and their reflections after the lessons into the resource base. Sharing such material can help other students in developing their lesson plans cooperatively on the web. This individualization of the knowledge representation and cooperative development of ideas makes it necessary to have the contents accessible to them as web authors on the internet. The student teaches create web pages and multimedia material for the information system, and this information also serves as a basis of discussion in seminars. The MaDiN system is designed in a way which demands (nearly) no technical knowledge for the generation of web based information, so that the didactical concept focuses on the *organization* of web based contents and the *structuring of mathematical and didactical knowledge*.

Beside the contents generated by student teachers, didactical and mathematical experts offer content for the knowledge base, so the knowledge base is continuing to develop.

In order to personalize knowledge representation, skills for authoring and embedding of contents is taught to student teachers. The following three items illustrate the process from the rec*eptive* to the *constructive* role of a teacher student (see also Simons, 1993).

Lectures (Introduction to Knowledge Representation). Lecturers use material like animations, videos, and HTML-pages in their presentations and these have been drawn from the MaDiN knowledge base. Here, students are in the *receptive* mode, but after the lecture the student teachers can access the information online and access additional information and see how the material fits into the wider organization in the information system.

Seminars (Analysis of Authentic Material). Here the mode is both *receptive* and *constructive*. In seminars, student teachers can analyse authentic classroom situations. Their analysis can be documented in their individualized knowledge representations. For example, they may work on problem solving activities with the Tangram in primary schools, and contribute solutions or other information about what happened. Beside the fact that this work of the students is presented in their own private workspace of MaDiN the student teachers have to integrate some of their contents into the existing information system of MaDiN. Thus the individualized information system of the student teacher combines personal material with material of the official MaDiN information system. For this combination of personal area and the official expert contents the student teacher has to explore the MaDiN information system for helpful connections (links) to the subject of the seminar. This includes further major *receptive work* with MaDiN.

Final Examination *(Knowledge Analysis and Structuring).* When student teachers in Germany take their final examinations they have to write a homework exam (duration 3–6 months). The student teachers' writing in the MaDiN project consists of *web-based contents* and a *theoretical text*. The web-based contents are their contributions to the MaDiN knowledge base about a didactical subject (for instance about "mathematically gifted children"). The theoretical text describes the learning principles they used in structuring mathematical and pedagogical knowledge in preparing it for use in the knowledge base. After assessment of the homework, their own web based product of good quality will be made accessible to other students via the internet as part of the MaDiN project. Even if the contents are not of very high quality it becomes part of a further knowledge development cycle in seminars and examination homework. This stage of their work is entirely constructive.

In-service teacher education (Participation in Knowledge Development). Here, student teachers are in a receptive-constructive mode, and their supervising teachers who work at school can benefit from the material developed at the university with students. The usage of the MaDiN materials in schools also provides teacher educators and student teachers with a feedback, and this has a further impact on the re-development and refining of the contents at the university.

Individualization of Knowledge Representation

According to Jacobson and Spiro (1995) and Niehaus (in press), individualization of web based knowledge representation means that:

- the users (student teachers, teachers, or academics) have private workspaces;
- each workspace contains only the chosen parts of a knowledge base that they see as important for their work;
- in the web based workspace, users can embed new contents according to their personal needs and add their own material that they produce for application in schools;
- users can grant access rights to documents in their private workspace; thus facilitating cooperative work in groups of student teachers and teachers.

While individualized web based contents (for example lesson plans or projects in geometry) are at first only visible for a single student teacher or teacher, we have found that these contents can be useful for others. If somebody grants access rights to their contents, other student teachers or teachers can embed these contents in their own private workspaces, and can add to them. This collaborative interaction (granting rights, embedding and authoring) is illustrated in the following figure. Further, granting rights to group of student teachers open up private contents for a collaborative development cycle by the group, and this information could then be opened for public scrutiny and use. Developments, here, need not be unidirectional (see Figure 5).

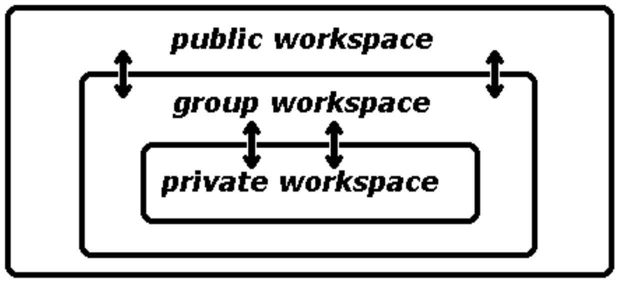

Figure 5. Cooperative work in individualized knowledge representations.

Keeping the constructive aspects of the didactic concept in mind, it is necessary that students can participate in the construction process of MaDiN knowledge without modifying the basic structure of the knowledge base. In the Figure 6 we can see black tree nodes and white tree nodes, symbolizing one single desktop. The black nodes symbolize the publicly accessible knowledge base. The white nodes symbolize a private modification.

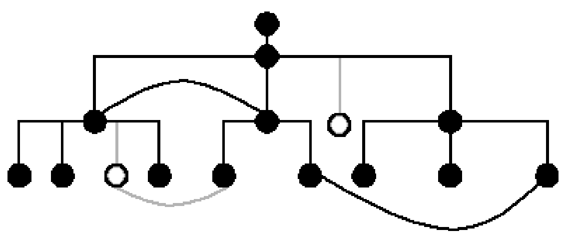

Figure 6. Public and individualized nodes in the tree.

The private white nodes in tree shown in Figure 6, could represent, for example, an evaluation of a geometric problem solving strategies of a particular student teacher in a specific primary school, using a problem from the section of the knowledge base that attends to Problem Solving in the primary-school geometry lessons. The student teacher (and supervising teacher and lecturer if given access) could see all of the black and white nodes. However, another student or a guest navigating through the mathematical and didactical knowledge base of MaDiN would not have access to the white nodes or be able to use the grey links because these would not be visible.

Conclusions

In the resource described above, individualized knowledge representations focus on the personal needs of a teacher for the organization of learning processes in mathematics. Building up this private network of resources and understandings is an objective in out teacher education program so that student teachers are able to share ideas and to develop and modify material for mathematics education collaboratively. In addition to the material produced by student teachers, the private workspaces also contain embedded contents from lectures and seminars.

MaDiN is now a didactical concept which supports teacher education from university to in-service training to teaching. This development follows a constructivistic approach in that it involved personal networking of ideas, but representations of these ideas are generally available for the use of others. The underlying idea of constructivism, together with the "object oriented" concept of multimedia development, presents a didactical approach which mixes the role of the author with the role of the reader. The student teachers involved have become not only receptors of information but also creators of an extensive and useful resource. In MaDiN system, *expert user, author* and a *didactical novice* share and embed contents in a knowledge base. Granting rights to the private workspace facilitates collaborative work and joint development of mathematical material in schools.

Evaluation, reorganization, creation, and embedding of contents represents a learning process in the private workspace as well as in the broader public arena. It is our contention that the skill to adapt the individualized knowledge representation is a key element for an integrated knowledge development from teachers education in universities to in-service training to the teaching profession.

In summary, this paper has reported on the development of an interactive knowledge base that grew out of research initially carried out in Australia. Elements included in the *Mathematik-Didaktik im Netz* [MaDiN] were developed in conjunction with other Australian researchers and multimedia products. The paper illustrates the value of international co-operation in mathematics education research and development.

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