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KNOWLEDGE MANAGEMENT IN EDUCATIONAL ENGINEERING DESIGN PROJECTS

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1. Aims and Objectives

This paper describes an approach to a more systematic and goal directed way of handling knowledge in educational Engineering Design projects. Knowledge is the main resource to be generated, acquired, and exchanged in project teaching and learning. In Engineering Design knowledge management is, like generally in modern conceptions of management and organisation, of increasing importance.
Project management of real life projects in all its complexity can not be anticipated in teaching at a university. However, the fundamental techniques (e.g. time and capacity planning) as well as necessary social skills can be trained as part of a curriculum. Likewise, knowledge management in problem-based learning can and will not be a blueprint of knowledge management in enterprises, but should introduce students to the basics.
The following questions and problems will be addressed in this paper:

- How do you and your students access the right knowledge at the right time?
- How can individual resources of knowledge be delivered and held accessible to a project team?
- How can information be exchanged effectively and easily?
- How can the organisation of knowledge be integrated into the organisation of a problem-based course or project?

This contribution is based on experiences in problem-based teaching in Engineering Design projects at the Technical University of Berlin as well as on experiences in implementing knowledge management into industrial practice.

2. Which Knowledge has to be Organised in Engineering Design Projects?

Knowledge can be regarded as a superordinate concept of everything we think our students should learn in our courses. It can be subdivided into two classes of knowledge:

- explicit knowledge, which can be document and delivered as “stand-alone” information or data;
- tacit (or implicit) knowledge, which can be regarded as the sum of individual knowledge and skills related to a person as individual faculty or even expertise.

The handling of knowledge and its efficacy very much depends on the diffusion and sharing of knowledge and thus of co-operation and communication. “Knowledge is created by means of interactions among individuals or between individuals and their environments, rather than by an individual operating alone.” (Nonaka et. al. 2001], p. 22). Thus, teaching is not only a question of

"spreading explicit knowledge" ([Brödner et. al.][1], p. 13). "For adaptation [of explicit knowledge] the ability to apply acquired knowledge under given constraints is needed. This specific ability of situational appropriate dealing with knowledge needs *faculty* or *implicit knowledge*. Explicit knowledge delivered by diffusion is adapted to a new context by the use of implicit knowledge and thus made utilisable. This process is labelled as internalisation of explicit knowledge. Because of the fact that new knowledge can be derived only as implicit knowledge, in particular from situations-based experience, it cannot be distributed in this state. It first has to be transferred into the stage of codified explicit knowledge by the process of de-contextualisation." (loc. cit., p.13) In addition, this process needs a "shared context in which knowledge is shared, created and utilized" ([Nonaka et. al. 2001], p. 22)

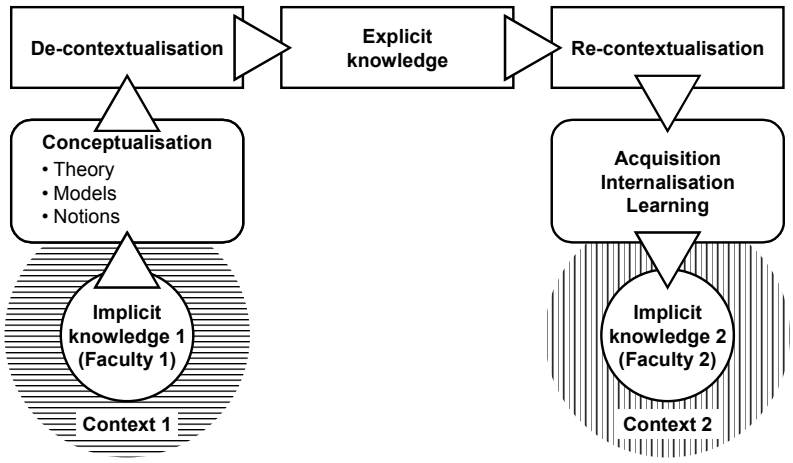

Figure 1. Phases of the diffusion of knowledge and the process of learning ([Brödner et. al.], p. 13)

In our approach, teaching and learning shall enhance the continuous conversion and diffusion of knowledge as the basis of a feedback-driven process of experiential learning [Kolb 1984].
For further refinement of the concept of explicit and implicit/ tacit knowledge Snowden [Snowden 1998] set up his HANSE-model of knowledge consisting of **H**euristics, **A**rtefacts, **N**atural Talents, **S**kills, and **E**xperience. In Engineering Design projects explicit knowledge like the following has to be handled:

- Heuristics, like catalogues of methods, written instructions, "rules of thumbs", etc..
- Artefacts, like technical drawings, sketches, requirements lists, calculations, catalogues, literature, standards, prototypes, etc.;

This information and data has to be organised in a way that provides easy access and effective exchange.
Tacit knowledge occurring in Engineering Design projects might be:

- Natural Talents, like e.g. the ability for spatial imagination, the ability to analyse, etc.;
- Skills, like e.g. sketching abilities, etc.;
- Experiences, like e.g. individual background knowledge of what a team member has experienced in earlier projects.

The handling of artefacts - and to some extent also of heuristics - can be improved by the use of information technology. Tacit knowledge is much more an issue of communication and training within problem-based projects. It might be supported by CSCW[2] (Computer Supported Cooperative Work) but it mainly remains subject to face-to-face team work.

[1] All translations of quotations from German literature carried out by the authors.
[2] in some literature also named CSGW (Computer Supported Group Work)

3. How to Manage Knowledge in Engineering Design Projects

Knowledge management as it is understood here is an aspect of all types of student team work. It should be supported for three reasons:

- to improve the handling of knowledge within the given learning unit;
- to support storage and retrieval of knowledge gained from a project to forthcoming semesters;
- to ease the understanding of knowledge management for future practice.

For the transfer of professional methods and tools of knowledge management into the area of university, we prefer a pragmatic step-by step approach (as described in [Thoben et. al. 2001]). Thus a new method or tool shall be intuitively applicable to the user and can be implemented fast and easily. It is implemented by active participation of the users and has an noticeable direct value at low costs and effort.

Some general conditions should be recognised:

- The process of knowledge management has to be integrated into the project workflow and should not be perceived as an additional task.
- Knowledge generated within the project by the students shall be processed as well as knowledge "delivered" from outside, e.g. by the teacher.
- Knowledge management also means to deal with the fact that the available knowledge never will be enough to completely cope with the task. Therefore it is of high importance to make effective use of that knowledge, that is available.
- Tacit knowledge often arises when nobody expects it. In many cases the process of clarifying a problem within a team discussion leads to associations opening access to unconscious and latent knowledge. For that reason communicative face-to-face situations (even without pre-defined purpose) shall be provided regularly and can not be replaced by CSCW!
- Knowledge management is a mutual process, so coaching and facilitating the learning group has to make sure that individual knowledge will be made available to the whole team. Therefore sharing knowledge must be rewarded by the teacher.

Effective knowledge management as proposed here consists of two main components:

- a team and project related knowledge platform consisting of a common database and of a communication platform supporting data storage and exchange, communication and fundamental project management activities (like e.g. time-scheduling)
- a knowledge management training as an explicit (transdisciplinary) topic and objective of teaching and learning, integrated into the training of other fundamental transdisciplinary competencies. The achievements of this training have to be implemented into the course of work.

4. A Knowledge Management Platform

Research into student project work has shown that finding time slots for team meetings is a limiting factor to team work ([Longmuß 1998]). Therefore, a platform with a common data base, allowing to share knowledge and documents without the need for a face-to-face meeting, is helpful to support team work.

A knowledge management platform for Engineering Design projects should

- allow to file all project related documents;
- allow the users to determine and rearrange the structure of the database;
- allow to identify and handle different versions of documents by different users;
- provide a simple tool for workflow management and time scheduling;
- provide communication features like mailing lists and automatic notifications;
- be accessible for all team members from any place at any time;
- last but not least be easy to operate.

The knowledge platform should be provided by the university, probably and ideally as a standard service of the department for different projects, workgroups, lectures, etc.. As a first pragmatic step into this field free of charge commercial platforms available on the internet meet the demands

mentioned above to a good degree and can be recommended as an interim solution. To trigger and encourage the use of the platform it might be used by the teacher to deposit most of his/her input of explicit knowledge for the students. In our experience students are very eager to use this tool. It is easy to handle, it is new and "cool" (and brings them ahead of most of their professors...), they expect working methods like these to be part of their training and so it rises their motivation for team work considerably. They often use this type of platform already without instruction by their teachers. So the task of a teacher sometimes is rather to assure that all students have access to the platform and can handle it.

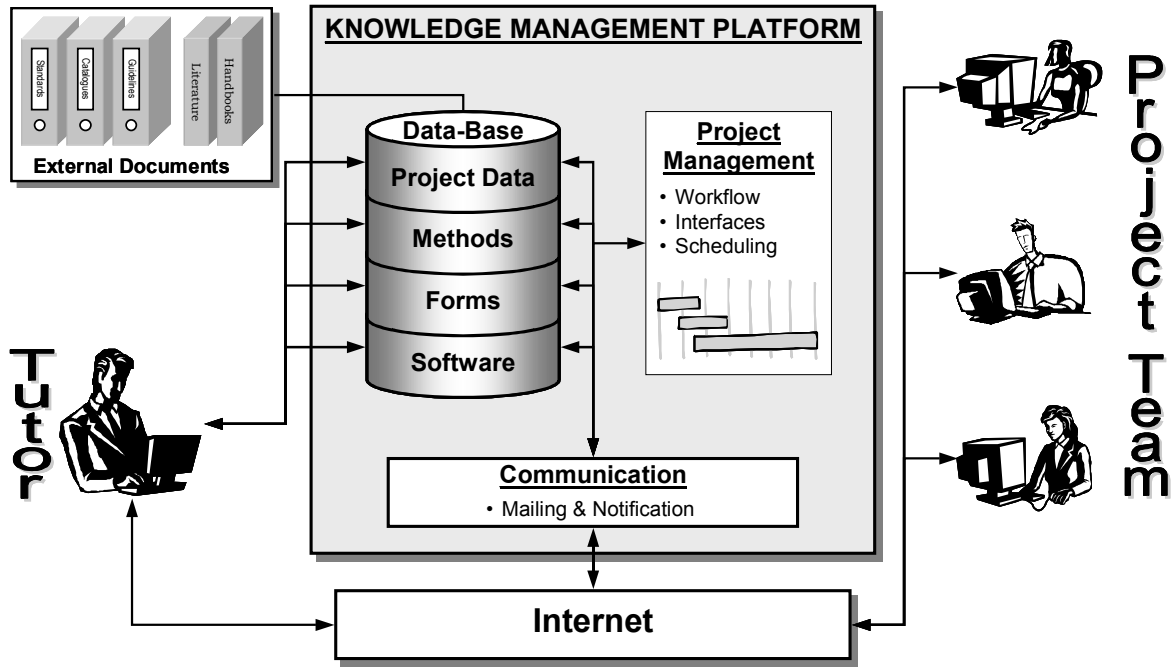

Figure 2. A knowledge management platform for engineering design projects in education

5. A Knowledge Management Training

Generating and processing knowledge can be regarded as a never ending process of learning. A very convincing model of experiential learning has been set up by Kolb [Kolb 1984]). Kolb postulates experiential learning as a cycle consisting of the four phases *concrete experience, reflective observation, abstract conceptualisation,* and *active experimentation*.

It is important to make sure that this cycle is closed within the students' process of learning not only for subject-specific but particularly for transdisciplinary teaching objectives. Therefore a conscious and deliberate process of teaching and learning that can be influenced and communicated has to be implemented ([Bender, Bernd 2001], [Longmuß 1998]). To reach the completion of "Kolb's cycle" during a project, in our approach two project training workshops (each lasting a whole day, described in detail in [Bender, Beate & Longmuß 1997 and 1999]) are hold to train for

- project management,
- presentation,
- communication, and
- moderation.

We propose to enhance this approach by integrating (not simply adding!) knowledge management aspects into this training. The explicit training of these competences shall constitute stability and homogeneity of the shared project context as a fundamental prerequisite of successful sharing, creating and utilising of project knowledge. To cover all four phases of "Kolb's cycle", an introduction of knowledge management into project work should allow

- experimentation with different aspects of knowledge management in the course of the teamwork,

- making experiences with these aspects,
- collective reflection of these experiences together with the teachers, and
- a more general and theoretical overview on what the objectives and means of knowledge management are and which tools might serve for which purposes.

The handling of explicit knowledge has strong relationships to project management (workflow, time scheduling and the effective flow of communication within the project) according to the necessity to make the appropriate information available "just in time". So the introduction and implementation of a knowledge platform should be integrated with the project management subjects of the project training. However, it should be mentioned that this has not only an IT-aspect. Before looking at hard- and software, the purposes and learning objectives of a platform with it's chances and limitations have to be clarified.

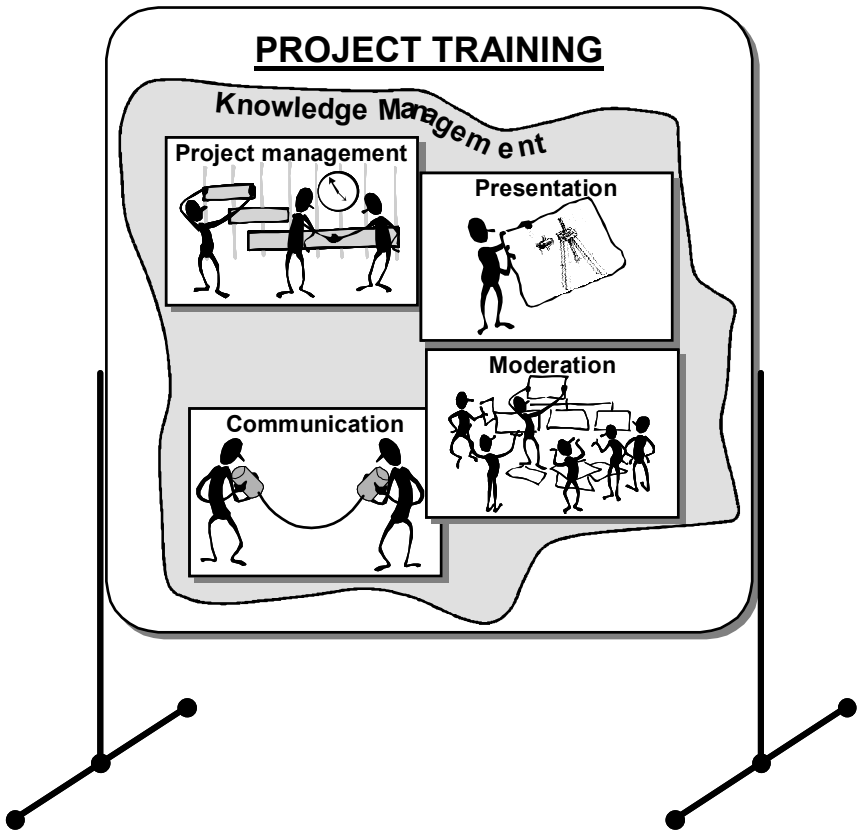

Figure 3. Knowledge Management as a framework for project training

Tacit knowledge is –as mentioned above – a question of human interaction and thus has strong relationships to the communication and co-operation part of the project training. Oxman in her approach [Oxman 2001] focuses on making explicit the *structure of knowledge* they are developing within their work to the students. She provides a conceptual framework for discussing knowledge processing issues consisting of *representation*, *construction* and *implementation* of knowledge structures which is useful for adaptation to a knowledge management training. Therefore after several weeks of team work, questions to be addressed are: "What (types and what structure of) knowledge do we produce, what knowledge do we need, how can we handle this?". The answers should be part of a "Plan of Action" to improve team work. Other aspects of knowledge management in this plan could be the description of interfaces or other agreements on handling information.

An important part of an effective project training is the reflection of its outcomes during and at the end of the project. So at least when a project is finished, the students should summarise their "lessons learned", e.g. as part of the project report or a final presentation. They should include both the subjects they worked on and the process of their work ([Longmuß 1998]). This is a strong tool to make tacit knowledge explicit!

If knowledge management is not only the declared goal of a single course but of an entire curriculum, the way knowledge had been handled in one semester can also be an issue in the following ones. Students than can recognise what efforts were helpful to keep the gained knowledge at reach and useful, what they would have liked to remember on top of this and which valuable knowledge they lost despite all measures.

6. Conclusion

According to our experience, students are willing and interested to get into knowledge management. It has to be considered that they do this only if they can see immediate benefit for their actual work or have a realistic hope that it eases future learning. If this is made sure, the introduction of knowledge management can improve the handling of knowledge within a given course as well as its use in future projects. The pragmatic introduction of knowledge management very much fits into the inductive overall approach of problem-based learning. On top of this, it helps the students getting familiar with a new aspect of modern organisations that is of rising importance.
To us, there are two important steps yet to be taken in this field. One is the integration of knowledge management into curricula of a higher organisational level, e.g. for entire programmes, at least into a string of consecutive courses. The other is the training of teachers to handle knowledge management and its tools themselves: Do what you preach!!

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