AC 2009-316: "THE LEARNING NETWORK": A CONSTRUCTIVIST TEACHING MODEL USING WEB DIDACTICS, USER MONITORING, AND NEW MEDIA TECHNOLOGIES IN THE EDUCATION OF CIVIL ENGINEERING STUDENTS

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"The learning network" - A constructivist Teaching Model using Web-Didactics, User-Monitoring and new Media Technologies in the Education of Civil Engineering Students

Introduction

The teaching model described in this paper covers the civil engineering subject area of "theory of stability" (TOS) and "elastic second order theory" (ESOT). Both areas are based on the theory of differential equations. They can be used apart from each other but together they build a global coherence. The traditional teaching model at the Technische Universität Darmstadt follows the usual triad of lecture, followed by an instructed exercise and homework. The new model presented in this paper will give an alternative teaching model the same temporal and contextual conditions.

The objective of the new conceptual model is a deeper understanding of the content by the learner. First of all students have to identify the individual phenomenon of each area. After this they have to acquire basic knowledge of each area including the theory, the mathematical and mechanical descriptions, different analysis methods and the applications in practice. Based on this knowledge a higher knowledge can arise. By combining and analyzing the single areas the coherence of both can be build. Once the students are aware of this coherence engineering problems in the field of compression loaded systems can be identified and solved.

The new concept is based on a three step model. First of all the knowledge unit will be initiated. The whole sphere of knowledge will be presented. Also a connection between the new sphere of knowledge and the prior knowledge will be built. Furthermore a personal and emotional engagement between the learner and the knowledge can arise.

Following the first step the students will be divided into two groups with independent knowledge content. One group handles the subject TOS and the other group the subject ESOT. It is possible to divide these two subjects because both are based on the same mechanical theory but can be achieved in an independent manner.

In this step learning will be done immediately on the content. The students will work in a web based setting. The content will be presented in a multilinked semantic network. According to the Radical Constructivist Theory of von Foerster and Glaserfeld [1], [2] based on Piagets constructivist model a personal differentiation takes place by the individual learning method. In this way the students can choose their own speed of learning. Furthermore an explorative learning takes place. Thereto every student can choose his own path of learning in the semantic

network and build in this way his individual mental model. A personalized speed of learning as well as a learning history can be realized in a web based setting.

To assess the activity and the behavior of the students it is necessary to record the individual clickstream (history of visited websites) within the network. To evaluate the individual clickstream all learning objects as well as the relations within the semantic network have to be classified and analyzed. Therefore the didactical ontology by Meder [3] can be helpful.

This paper begins with the statement of the problem. The results of a final written test will show the achieved educational objectives of a traditional lecture. Afterwards the development of the innovative learning network will be described. Reasons of choosing the subjects of ESOT and TOS will be given as well as the general ontology of the network elements.

Beside the development of the infrastructure several didactical assumptions have to be analyzed. Therefore the general educational objective will be shown and the implementation in the concept will presented.

Then the execution of the concept will be explained. The different steps will be shown and explained. At last selected results will be shown followed by a conclusion and further steps of the project.

At the beginning a receptive acquirement of the knowledge exists. In progress the constructivist learning arises. An active acquirement replaces the receptive acquirement. Existing elements will be linked in a new way. New elements will be created. Interactive behavior starts. The final step is defined by pure explorative learning. The groups will get together in a collaborative setting. Within groups a teaching-learning-setting stabilizes the own mental model and produces connections to unknown knowledge elements. The personalized semantic networks from the second step form a visual aid.

Statement of the problem

Common engineering knowledge can be divided into several parts. As figure 1 shows, above the elementary factual knowledge a structural model and process knowledge exist. These three parts can be organized into a hierarchical order. The structural model and process knowledge as a meta-knowledge exist above the elementary factual knowledge. The construction of a structural model and process knowledge is based on the factual knowledge. This structure of elementary knowledge and meta-knowledge can be found in several areas of the engineering education.

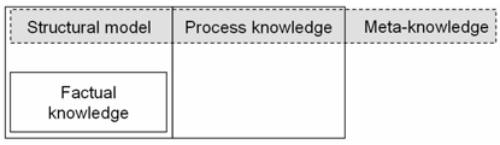


Figure 1: Structure of different types of knowledge

The development as well as the cognition of this structure is one of the superior educational objectives for learners [4]. The elementary factual knowledge can be achieved very often by the learner. However the meta-knowledge will be achieved rarely by the learner himself. The teaching-learning-model described in this paper will give an opportunity to achieve both educational goals.

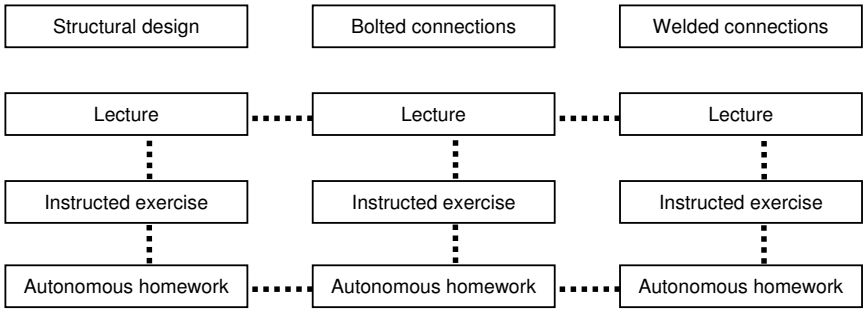


Figure 2: Traditional teaching model in civil engineering
Steel construction at Technische Universität Darmstadt

The teaching model is used in the education of civil engineering students to equip them with factual knowledge as well as the network structure of this knowledge. Beside the factual knowledge the students should get methodical and social collaborative competences. The new Master Scholastics based on the Declaration of Sorbonne [5] and the European Bologna-Process [6]. The goal of the European Bologna-Process is to harmonize the European study conditions and the universities degrees. The Master Scholastics demands a high level of autonomous learning by the students. This demand is considered within this new concept. It is placed in a basic lecture of civil engineering in the field of steel construction and replaces the traditional teaching setting. The traditional setting follows a sequential order. Several contentual chapters will follow each other. Each chapter follows a usual triad. Firstly there is the teacher centered lecture in a mono directional way. The lecture is followed by an instructed exercise where the students enlarge their knowledge supervised by mentors. Finally an autonomous homework will finish the chapter. This triad is shown in the vertical directions in Figure 2. The students can develop and repeat their knowledge. Figure 2 also shows in its horizontal direction three different chapters. These are connected at the lecture as well as the homework. In the lecture

connections to other chapters can be shown by the teacher. Also during the homework often other chapters are needed to solve the exercise.

Often the homework raises the knowledge factual knowledge and structural as well as methodical knowledge. e horizon. By transferring the knowledge into new areas a cognitive stabilization of the knowledge should arise. After finishing a chapter the next contentual chapter will follow under the same methodical and procedural conditions. All chapters are connected at the levels “lecture” and “homework”. The instructed exercises are not connected to reduce the cognitive load.

The new concept replaces the chapter of ESOT and TOS of the traditional lecture. Thereby the temporal conditions as well as the lectures content will be retained to fulfill the universities institutional requirements. A final written test at the end of the traditional lecture showed a great discrepancy between the educational objective of factual knowledge and structural as well as methodical knowledge.

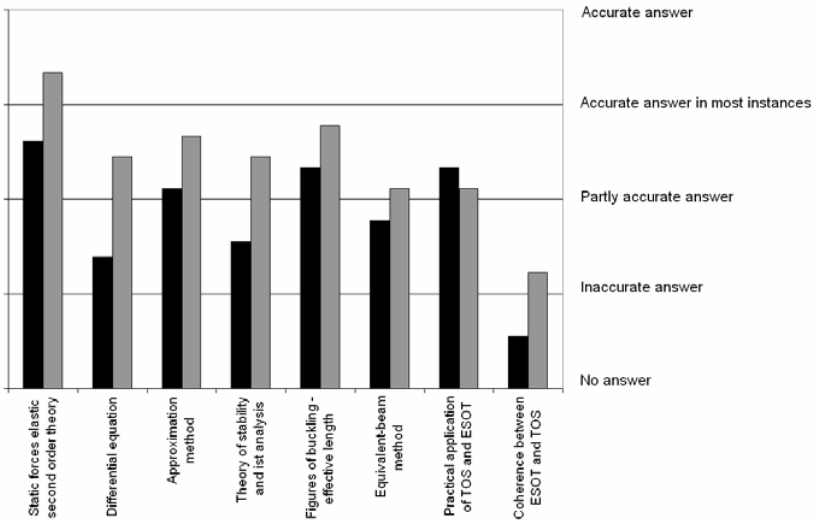


Figure 3: Results of a student survey

Figure 3 shows the results of the test of third-years students in the black columns. The first seven columns are items of single knowledge elements representing the factual knowledge. The student’s descriptions of these items were classified. The results can be located between “partly accurate answers” and “accurate answer in most instances”. The last column is related to the question of global coherence between ESOT and TOS. There the spectrum was between “inaccurate answers” and “no answer”. This test results show the discrepancy between factual and structural knowledge. Whereas the students were able to get factual knowledge, structural knowledge did not arise. The grey columns show the results of fifth-years students. In spite of

further studies of ESOT and TOS the test results raised up in contrast to the third-years students. But also a clearly discrepancy between factual and structural knowledge is visible.

Development of the network and its basic of structure

For the selection of the content within the new teaching model several applicable criteria were used. These criteria follow the ideas of the so called "radical constructivism" [1], [2].

First the aim is to get a subject with a high level of difficulty. This criterion assures that each learner can reach its own cognitive limit. Also a clear segmentation between different types of learners and different strength of learners can be achieved. The structure of the content can be most granular. It is desired to get a subject with a high level of academic and scientific foundation. If a subject is most widely analyzed within the scientific community and has clearly defined structure of the content as well as semantic relations then a most unambiguous network will arise.

Beside these contextual and methodical criteria also the discrepancy between the educational objective that were demanded and the educational objective that were reached was the reason of choosing ESOT and TOS. Furthermore these subjects show clearly the discrepancy between factual and structural model respectively process knowledge.

Beside the content also the technical and the procedural framework have to be planed. To build the network of content into an online based framework the software Mediawiki 1.9.3 [7] was used. This database software is also used for the well known world wide online resources WIKIPEDIA, WIKIVERSITY, WIKTIONARY, WIKIBOOKS etc.

The state of the art of ESOT and TOS are still fixed in several printed media. To use it in an online and multimedia version the current framework has to be transformed. The content must be split into several single elements. They have to be generated as well as the network with joints between the single elements. Furthermore several examples based on the related content were generated. These examples were also fit into the network. Theory and examples result in a multilinked network generated in the Wiki.

The content of the subjects is connected very deeply. Both fields are based on equal mathematic and technical theories. Figure 4 shows a visualization of the Wiki's structure.

In figure 4 different types of elements can be seen. There are elements which tie many other elements. Several bidirectional links occur. These so called "centric-elements" have many references to other elements. Furthermore several elements relate to the "centric-elements". Also

there are “reference elements”. These types of elements can be compared with glossary or index items. They annotate a phenomenon or explain and describe a definition. “Reference elements” do not refer to other elements. They are like a dead-end street.

Other elements are bridge gaps between different thematic areas. They consist of common or generic descriptions. They build the entrance to one area and finish another. These “bridging elements” can be generated in a mono-directional as well as a bi-directional manner. Bi-directional “bridging elements” combine thematic cognate areas. Hence they have an equivalent as well as associative character. Mono-directional “bridging elements” describe relations in a hierarchical manner.

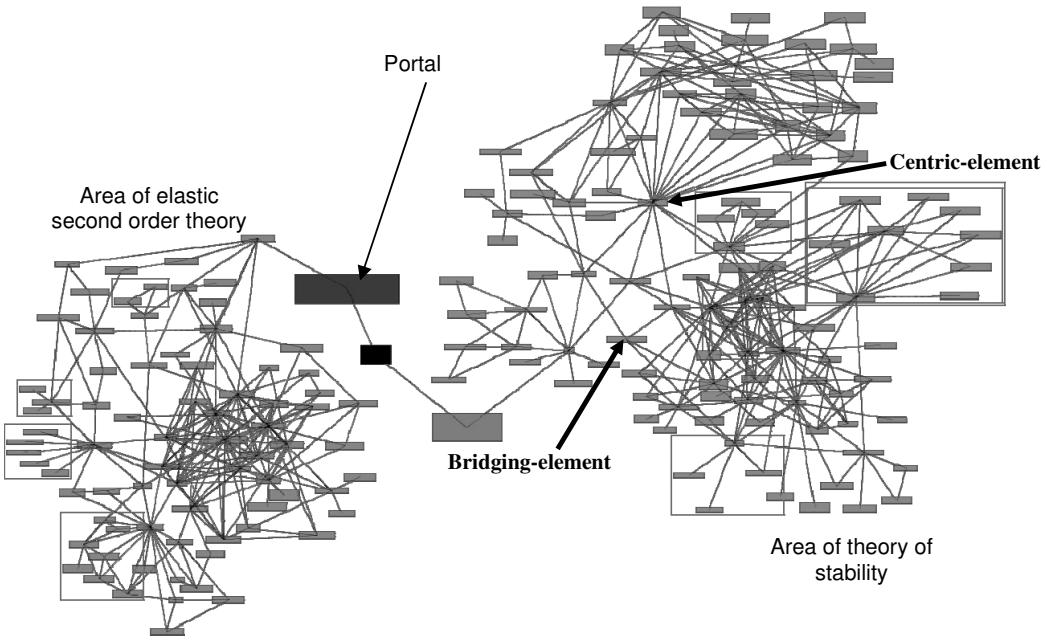


Figure 4: Visualization of the contents structure map / Wikimap

The wiki as a databased framework in the internet is available with all common www-browsers. To get information of the students behavior a client sided user monitoring is used. The advantages of this are given in [8], [9]. This plug-in records the pattern of use together with a timestamp and sends it to a defined Webserver.

Definition of the educational objective

Among the development of the content structure the didactical design of the project as well as the performance of the educational scenario is relevant. Therefore the educational objectives have to be defined and designed.

The major educational objective is the improvement of cognizance in the subjects of ESOT and TOS as well as the comprehension of coherence between both subjects. Therefore the hierarchical order is strictly defined. The improvement of cognizance in each single subject is the foundation to build upon the superior cognitive comprehension of coherence. Getting the comprehension of coherence gives the possibility to renew and redesign the foundation. Both parts of the educational objective affect each other and lead up to a meta cognitive level of comprehension and redesign of the comprehension. This level describes the constructivist learning. The knowledge will be developed by the student by using her own research and experience process. By comparing the own knowledge with outer knowledge the viability of the knowledge and its structure can be checked and redesigned [1], [2].

The methodical educational objective will be the development and consolidation of an autonomous learning strategy and the self-directed creation of mental models. To learn to structure and link several objects or artifacts as well as the cooperation and collaboration between different persons is another goal. Especially team work helps to check the viability of the individual mental models.
The secondary educational objective is the development and growth of competence in acting with new media technologies. These major educational objectives are implemented in the actual universities program requirements based on the Bologna Process [10], [11].

Skills in new media technologies as a secondary educational objective were not initialized in the main project. For this a pre project with an introduction of the Wiki-software was arranged to reduce the cognitive load.

Major project and selective results

The major project can be divided into three steps. First of all the knowledge was initiated. The whole sphere of knowledge was presented to the students. Therefore a teacher centered lecture gave the students an initiation of content about the subjects ESOT and TOS. This lecture was characterized by its highly practical component. To tie to existing experiences the students could relate their existing cognitive structures with the new sphere of knowledge. In the lecture the new sphere of knowledge was regarded from different points of view that initiated an interrogative and reflexive behavior. Beside the initiation of the content in a second lecture the project's schedule and further administrative advises were given to the students. The well-known Wiki software as well as the personalized user monitoring were shown again.

Beside the content the projects timetable as well as information about the motivation and the research objectives were given to the students. The possible certification modus and the prospected course achievements were presented.

At the end of the lecture the students were divided into two groups. One group had to learn within the knowledge area of ESOT and the other group had to learn in the area of TOS.

The second step of the project started with a receptive knowledge acquisition. Therefore an overview of the sphere of knowledge had to arise. Without an orientation and guidance the students had to start working online. During two weeks they were able move in the Wiki and their movements were tracked by the monitoring software. The analysis of the tracked data showed that only short hits to most of the websites existed. Due to a so called site-surfing the students got an overview of the Wiki's content. After some days this "overview-working" decreased. In this moment a specified assignment was given to the students. Several contentual catchphrases from the areas of ESOT and TOS were given to the students. These phrases were built up in the Wiki as its centric-elements.

These catchphrases were chosen in the area TOS.

- Buckling resistance of steel frames
- Buckling resistance of rigid systems
- Solution of the differential equation
- Euler's cases I to IV
- Natural frequency and figure of buckling

These catchphrases were chosen in the area ESOT:

- Analytic calculation of stress by using ESOT
- Stress distribution of ESOT
- Approximation methods
- Spring stiffness
- Convergence and divergence
- Imperfections

By using these phrases the students were able to compile the Wiki's centric-elements. After the students got an overview by surfing in the Wiki, they were able to build their own rudimentary mental model. The centric elements supported an orientation within the sphere of knowledge and developed an evolutionary cognitive structure. Also there were several points to start an explorative learning.

Next to these supports the students got also a personal support within a methodical framework. There were daily office hours offered for the students. Questions, problems as well as scaffolds were discussed between the students and the mentors/teachers. As already mentioned, instead of the traditional lecture there was a voluntary and not moderated lecture in a universities computer-lab. There it was possible to demand a support within the process of learning. This support provided the opportunity for the students to compare their own cognitive structure with the mentor's/teacher's cognitive structure. The second step of the project happened in an isolated and autonomous didactical framework. The students had no methodical contact to other learners. Indeed there was an informal communication between them but this communication was unverifiable by any outer persons.

Subsequent to this receptive step an active phase started. The students got the task to develop an example within their own sphere of knowledge. This example should follow a common process of work. A structure should be abstracted into a static system. Thereto a way of looking at a problem had to be developed. By using several distinguished questions the path of solution had to be prepared. Furthermore the related sample solution had to be developed. The successive development of the questions should also be used in the sample solution. Both exercises, the example as well as the appropriate solutions, were documented in the Wiki. This had to be done in as many single sites as possible. The newly developed and personalized Wiki pages should also connect to the existing content. The students had to include links to all related pages in their knowledge sphere.

The active generation of examples, the publishing in the Wiki as well as the networking between their new developed content and the still existing sphere of knowledge, changed the students activities from a stringent mono-directional into a bi-directional workflow. An interaction between learner and computer started. At this point the presence of other learners could be noticed. Each student was able to follow the online workflow of other learners. Their personal cognitive structure was updated by integrating other students work. During this step also office hours and a moderated lecture in the computer-lab were offered. Contrary to the receptive step, in this step the students used the mentoring much more. Beside theoretical problems most of the students demanded assistance concerning their sample solutions. The mentoring clearly showed that most of the students had problems to connect their samples solutions with the existing sphere of knowledge.

The access to the Wiki in the first step was done mostly by the “centric elements” as well as the catchphrases. Therefore the cognitive structure was built on the basis of these elements. If there were no connections between these elements and their representation in the cognitive structure and the own example a networked structure between both could not arise. The mentor’s advice to built new links between the Wiki and the sample solution developed a viable system, within which the students were able to restructure their mental models. One of the most effective ways to update the cognitive sphere was the use of pathways. These pathways were given by the Wiki’s examples.

The third step was realized by a “Human-Computer-Human-Interaction”.

Furthermore the development of a meta-structure had to be realized. The so far separated spheres of knowledge were brought together to built an entire cognitive structure of ESOT and TOS. This meta-cognitive structure as a higher mental model will allow understanding the coherence as well as the concurrence of the two areas of knowledge. At this point the learner is able to analyze and evaluate problems and situations with engineering methods.

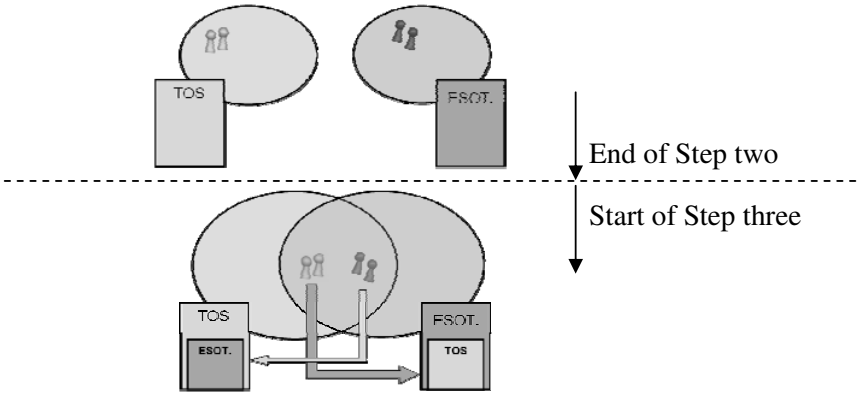


Figure 5: Human-Computer-Human interaction

Like in the first step the students start to explore the unknown content areas. Thereby they were able to use their existing abilities in explorative and receptive learning. The students used the same methodical structure as before. It was a lot easier for them to fill their methodical structure with new content. They built a mental copy of the structure and applied it in the same way as before. Figure 5 shows that parallel to this the example they developed should be amplified to the new areas content. Therefore the example had to be renewed respectively updated to a new question. Furthermore the students had to form teams by four to six members. Half of them were advanced learners in ESOT and the other half were advanced learners in TOS. Within these teams the beginners had to correct the advanced learner's example-solution. This should be done by using the discussion module of the particular Wiki's page. Therefore the students had to change their role. After the development of the cognitive structure they had to use this knowledge to analyze and evaluate the written knowledge of other learners. In "Bloom's Taxonomy – learning in action" [4] the educational objective describes in its hierarchy the analysis and the evaluation as its upper levels. Due to this the students had to raise this level and change from the learner into the role of a teacher respectively an expert. The amplifying of the students examples also asked the students to reflect their still existing example as well as the solution. This reflexive and evaluative analysis of the work helped to tighten the cognitive structure and the mental model. After amplifying the example the students got a structure to analyze the combination of the two subjects, ESOT and TOS.

This step showed two appreciable facts. The tracked data of the student's behavior in the Wiki showed that a new methodology in the learning and working process happened. The students did not enter any longer the online content by using the catchphrases respectively the "centric elements". Instead they used the samples solutions generated by other students to enter the content. Also a transition to flexible the process of learning happened. The learning in an online

setting changed into a learning and working process by using different types of media. Some students worked paper centered with printed hardcopies of the online content. During the office hours the students presented hardcopies. These print-outs did not help very much. Using the online Wiki network was much better due to the various links. Therefore the students took their laptop to coordinate and explain their problems. Qualitative oral interviews with the students at the end of the office hour support this thesis.

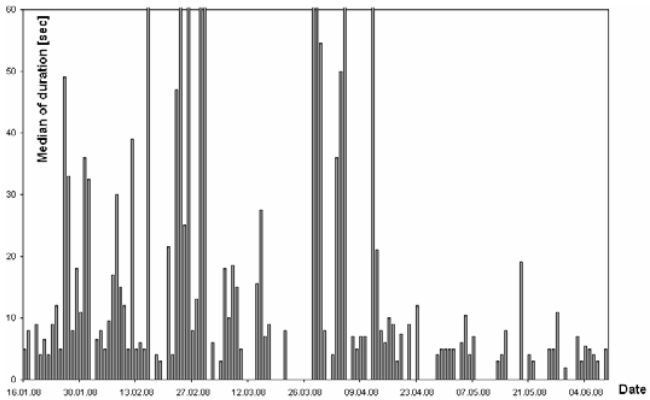


Figure 6: Median of duration on a single Wiki's site

In combination with the online data a connected learning process started. By the way the Wiki was used to give the content a structure. The content was generated into a semantic order. The printed hardcopies could not be structured like this. The combination of both resulted in a cognitive structure out of semantics and content. This effect can be shown in the duration of a student's visit on a single Wiki page. Figure 6 shows the median of duration on a single page per day of all students. Until the end of the project the median of duration declined. The process of learning did not happened in the Wiki any longer. Only an online surfing to get the semantic structure existed.

Data: acquisition, analysis and application

The online behavior of the learners was tracked by the client sided monitoring software integrated into the browser as a plug-in [8]. Each student had to register his or her own access software. Therefore they had to log in with a verified username. This username was personalized to certificate the online processes later. To protect the privacy of each participant this registration was optional. The tracked data were:

- Timestamp
- Username
- Wiki-URL
- Browser-Tab ID

With these data the personalized duration connected with the pathway through the Wiki was generated.

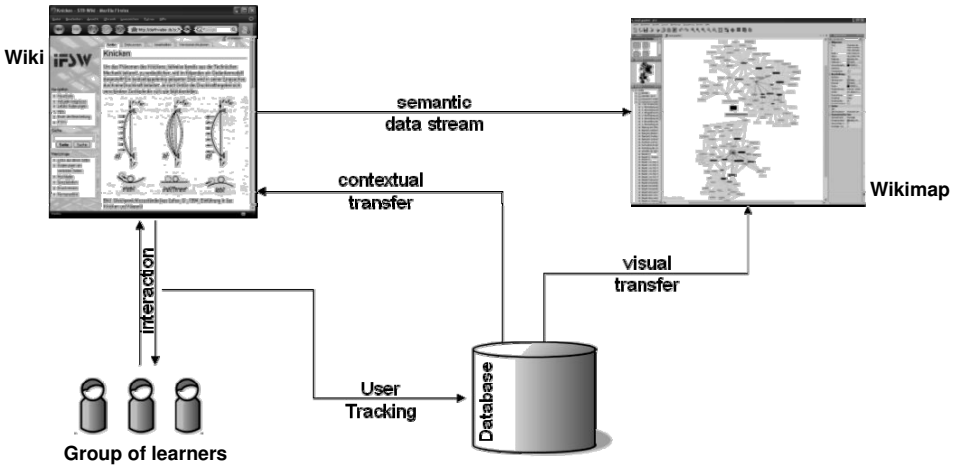
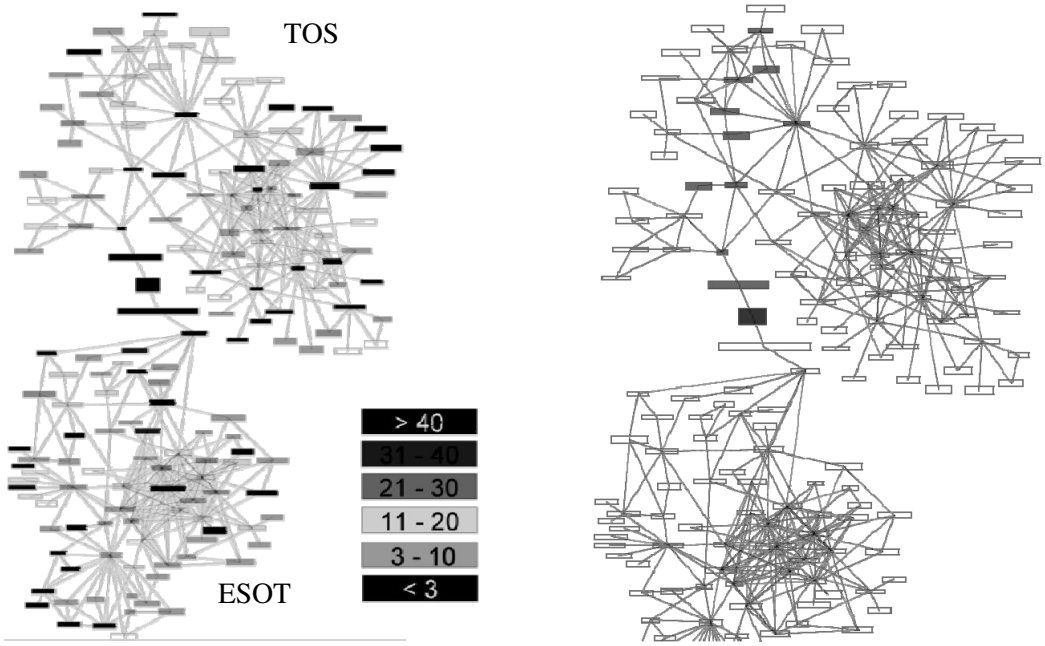


Figure 7: Feedback system of the projects scenario

To analyze and evaluate the user's data mind-mapping software was used. Figure 7 shows the structure of the project and its feedback loops. The structure of the Wiki and its meta-data were imported to the mind-mapping tool. The nodes as well as the joints were transformed. Hence a so called Wikimap was formed. In the next step the Wikimap was connected with the user's data. These data were imported into the Wikimap and visualized. The clicking pathway through the Wiki was visualized. Furthermore the duration, the frequency as well as the allocation at the pages was shown. This could be done for a single learner, for a group of learners as well as for the whole group. This combination of the Wiki's structure and the user's behavior enabled the feedback loop between learner and its own behavior. Figure 8 shows on the left side the accesses to the specified pages within a defined timeframe. One the right side a clickstream of a defined student is shown. This clickstream describes the path during one learning session. The learning session is defined as the access to several pages with a maximum of duration. If the duration exceeds 120 minutes for example, a new session was started.



Visited websites within a defined timeframe

Clickstream of one student within a learning session in TOS

Figure 8: Several visualizations of results

Conclusion and Projects next steps

The first run of the project in 2008 showed a lot of interesting and research-relevant aspects. The developed applications which are the Wiki, the browser plug-in as well as the Wikimap and the combination of the Wikimap and the user database were tested. Also the content of ESOT and TOS were tested on their reliability. Next to these technical and administrative aspects the methodical and procedural implementation was an important point.

The students had problems to start learning without a defined structure. There had to be an initial cognitive sphere, for example a list of "centric elements" that built a basic structure. Within this basis the students developed their individual mental model. During the project the process of learning and acting changed lasting. The use of the Wiki changed form a medium of content to a medium of orientation. During the development of a cognitive structure to a mental model the viability of the structure was fluently checked by comparing it with the Wiki's structure.

All together a lot of small hindrances existed. These hindrances will be solved in this year's project version 2. This updated version contains a lot of methodical and technical improvements. The feedback loop between the learner and the Wikimap will be used to scaffold the learner in its process. Therefore the Wikimap will be given to the students to orientate them during their activity. Due to the fact that the use of the user monitoring was voluntary a lot of students did not

use this option. Also the use of the plug in decreased steadily. In the new version the use is obligatory. The students will have only the option to use the software anonymous or personalized.

One of the biggest problems was to visualize the student's mental model as well as to measure the achievement of the educational objectives. The empirical data by analyzing the questionnaires as well as the analysis of the annual examinations could not be used to visualize the models. Up to now no evidence was provided to proof that deeper understanding is achieved by this method. In version 2 personal interviews will be used to visualize the mental models. Furthermore the interactive and collaborative step will be modified. Subsequent to the receptive work within both areas a moderated session with the four to six member teams will be done. There the students will discuss the effects of ESOT and TOS on a model of a steel structure. Additionally they will create a structure within the Wiki with their results and combine it with the sphere of knowledge. The result will be used to analyze as well as visualize the common mental model of the teams.

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