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Separation of educational and technical content in educational hypermedia

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A submission presented in partial fulfilment of the requirements of the University of Glamorgan/Prifysgol Morgannwg for the degree of Doctor of Philosophy

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Abstract

The creation and development of educational hypermedia by teachers and educational staff is often limited by their lack of computing skills, time and support from the educational institutions. Especially the lack of computing skills is a hinderance to most of today's educational experts. The problem is to find out how those educational experts could be supported by computer based tools which are tailored especially to their needs without having any technical limitations.

In this study the separation of technical and educational content in educational hypermedia is examined as a solution to this problem. The main hypothesis of this study is that the separation of technical and educational content is possible if it is based on a fine-grained structure of different teaching and learning strategies and their conversion into an authoring tool. Such an authoring tool would make the creation of educational hypermedia very easy for teachers and therefore enable them to overcome the existing obstacles.

The development of a new model, the creation of a new XML language and the implementation of a new authoring tool form the basis for a detailed investigation. The investigation was done by undertaking several research tasks like the evaluation of the XML language and the authoring tool by a group of educational experts of different knowledge domains, the practical usage of the authoring tool for the creation of real-life based educational material and the analysis of the gained research results.

The analysis of the qualitative data showed that the separation of educational and technical content in educational hypermedia is possible and that it can be applied by educational experts with low computing skills as well as by technical experts with no educational background. Furthermore, the analysis allowed some additional insights into the creation of educational material by teachers and how it can be improved.

The main conclusion of this study is that authoring tools in educational hypermedia should use the separation of educational and technical content based on different teaching and learning strategies which allows educational experts with low computing skills to create educational content for delivery via the World Wide Web.

Contents

List of Figures

List of Tables

List of Abbreviations

ADL - Advanced Distributed Learning

AHS - Adaptive Hypermedia System

AJAX - Asynchronous Java Script and XML

CAL - Computer Aided Learning

CBT - Computer Based Training

CBL - Computer Based Learning

CETIS - Centre for Educational Technology and Interoperability Standards

DCMI - Dublin Core Metadate Initiative

DHTML - Dynamic Hypertext Markup Language

DVD - Digital Versatile Disc

EFTECS - Extensible Framework of Technical and Educational Content Separation

EH - Educational Hypermedia

EHP - Educational Hypermedia Primitive

EHS - Educational Hypermedia System

EM - Educational Module

GLC - Global Learning Consortium

HAT - Hypermedia Authoring Tool

HEAT - Hypermedia Educational Authoring Tool

HTML - Hypertext Markup Language

IEEE - Institute of Electrical and Electronics Engineers

IMS - Instructional Management System

JISC - Joint Information Systems Committee

LCMS - Learning Content Management System

LMS - Learning Management System

LOM - Learning Object Metadata

LTSC - Learning Technology Standards Committee

NPC - Non Personal Character

PhD - Doctor of Philosophy

QA - Question and Answer

QML - Questions Markup Language

RSS - Really Simple Syndication

SCORM - Shareable Courseware Object Reference Model

SMIL - Synchronised Multimedia Integrated Language

SQL - Structured Query Language

TLS - Teaching and Learning Strategy

UPI - User Profile Interchange

URL - Uniform Resource Locator

WBT - Web Based Training

WWW - World Wide Web

XEML - eXtensible Educational Markup Language

XHTML - eXtensible Hypertext Markup Language

XML - eXtensible Markup Language

XSL - eXtensible Stylesheet Language

Declaration

This work has not previously been accepted in substance for any degree and is not being concurrently submitted in canditure for any degree.

Signed .... (G. Hilmer, Candidate)

Date ....

This thesis is the result of my own investigations, except where otherwise stated. All sources are fully acknowledged in the text with explicit references.

A bibliography is appended.

Signed .... (G. Hilmer, Candidate)

Date ....

Signed .... (Prof. Dr. Tudhope, Director of Studies)

Signed .... (Dr. Cunliffe, Supervisor)

Signed .... (Prof. Dr. Kopp, Supervisor)

I hereby give consent for my thesis, if accepted, to be available for photocopying and for interlibrary loan, and for the title and summary to be made available to outside organisations.

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1 Introduction

1.1 Aim of project

The current situation in World Wide Web (WWW) based education is that educational material is created and authored by a small group of experts [1]. In addition to their educational background, these experts have the technical computing abilities to implement the educational content for delivery via the WWW [2][1]. The educational content itself is not only built on lecture notes but uses all the functionality of hypermedia.

At the beginning of the 21st century this situation is not satisfactory. The political, cultural, commercial and general community are focusing more and more on the Internet. It cannot be denied that the WWW will form and influence the future of mankind in almost every area of our daily life. Therefore, it seems illogical that only a small group of experts is producing good educational material only because they have a technical knowledge advantage over teachers without a technical background. This seems even more disturbing if it is taken into consideration that a teacher or an educational expert usually has several years of practical teaching experience, but cannot apply the knowledge gained from this experience on teaching via the WWW.

The question that results is: Is it feasible to separate the technical tasks in web based educational authoring from the educational tasks in such a way that a teacher or educational expert is capable of producing educational material mainly based on his educational expertise? The answer to this question is regarded as an aim of this research work and is given in chapter 8.

1.2 Justification

The authoring of "good" educational material is a difficult task. Even more difficult is the authoring of educational material for the WWW. This is a massive hindrance to the further development of educational hypermedia. The question is why the authoring is so difficult.

First of all, average teachers have no technical knowledge of authoring web based educational data [1]. They have to concentrate on their teaching mission and usually do not have the time, nor the interest, to learn how to use new technical development packages. Their expertise lies in the field of education. They usually have practical experience in educating and teaching students. Many of them are surely interested in using the medium Internet for their teaching, but are also focused on the teaching, not on the technical solutions for porting the teaching material into educational material for the WWW. Additionally, it has to be stated that even if the educational experts were aware of the potential of technical content or functionalities, they still would have to be able to use these technical options. On the other hand, it is probable that the teachers are able to use word processing and multimedia systems.

Therefore, it is necessary to create a system that makes the creation of WWW based educational hypermedia simple and easy for the teachers. Consequently, one has to ask which issues have to be addressed to provide a solution to this necessity.

First of all, the authoring process is usually difficult for teachers or educational experts. This is a direct result of the tightly woven structure of web content at the moment. The idea of how to solve this problem is to separate the educational (teaching) content, from the technical content (transfer protocols, transfer, implementation of code, complex interactions, etc.).

Secondly, this separation would also mean that the educational experts are not burdened with technical details. For example, several technical functionalities could be capsuled into a module and this module could be used by a teacher. However, the scope of this PhD focuses on the separation of the technical content from the educational content on a very fine-grained level with the help of educational hypermedia primitives that were especially developed for this task.

1.3 The two main domains of educational hypermedia

The two domains of educational hypermedia, educational components and technical components, need a kind of "interface", so that they can communicate with each other. Such an interface is necessary because in the run-time of an application the educational content has to be delivered to the student via the technical content. The technical content can also be seen as a kind of "wrapper" around the educational content. The advantage of the separation of educational and technical content is that the educational content is not woven together with the technical content and potentially stays highly accessible and reusable.

Once the need for a communication interface is identified, the next step is to design that interface. It seems a good decision to build this interface upon teaching and learning strategies (TLSs). This decision is based on the fact that teaching and learning strategies are a part of both content domains. The educational content is naturally based on TLSs, the technical content is only indirectly based on the TLSs, but if it is taken into consideration that the display to the student has a different structure in each TLS this can be seen more clearly. Therefore, it was decided to use TLSs as a base for the communication interface in this project.

The term TLS will henceforth be used as a synonym of all the different approaches and strategies that are applied in classical teaching and learning as well as in WWW based teaching and learning.

1.4 Problem areas

There are, of course, numerous issues that have to be addressed in the project. One problem is to know how the educational content can be separated from the technical content. Separating the two domains should produce a modularised framework and it should be possible to implement this framework into an authoring tool for teachers which enables them to create educational material for the WWW (cf. section 3.1).

Furthermore, once authored, the educational content should be highly reusable and, if it is wanted, interchangeable between different authors. To achieve this kind of reusability it is proposed to tag the educational data with meta-information.

To tag the data with this kind of information it is necessary to create an appropriate meta-tag system. Since the tagging of the educational material by the teachers results in additional work for them it should be as easy as possible. To guarantee the quality of the tagging a quality assurance process should be implemented. Once the information is properly tagged, there must be some tools to provide the author with the search, find and interchange functionality. The authoring process itself should be easy and based on TLSs. Then, the educational content must be delivered to the student. This delivery process should be done by the system to facilitate the author's work.

Another aspect that has to be addressed is how teachers and students can communicate with each other or how adaptation of the educational material to the student's preferences can be realised.

Altogether, several issues have been named so far that have to be considered in the framework for this project, even if they are not implemented into the prototype application.

1.5 Approach

To address the problem areas of this PhD project, the ongoing research in this field has to be analysed. This literature review will be introduced in chapter 2. Based on this review, a specialised framework for the separation of educational and technical content will be developed and introduced in chapter 3. This framework will focus on the single parts of teaching and learning strategies in order to address the issues of the educational experts stated above.

The created framework will then be used as a basis for the implementation of an authoring tool for educational hypermedia. The design of this authoring tool will be outlined in chapter 4.

A prototype of this authoring tool will then be used for the evaluation of the framework. This evaluation and the evaluation strategy will be introduced in chapter 5 and then be undertaken in two steps.

Firstly, an interview evaluation will be done in which several technical and educational experts describe their experience with the framework and the authoring tool. The interview evaluation will be outlined in chapter 6.

Secondly, a practical evaluation will be undertaken in which we explain insights into the framework gained from practical work with the authoring tool. The practical evaluation will be presented in chapter 7.

The results gained from the interview and the practical evaluation will be discussed critically in chapter 8.

Finally, the conclusions of this project will be given in chapter 9.

1.6 Research objective

As described above the main research objective of this project is the separation of educational and technical content in educational hypermedia. This separation is expected to be especially beneficial to educational experts, e.g. teachers, supporting them in their task of creating educational material without having to have a high technical expertise.

To achieve the separation of educational and technical content three main research objectives were identified:

- The first research objective is to create a suitable framework for the separation of educational and technical content in educational hypermedia based on teaching and learning strategies.
- The second research objective is to evaluate the created framework and to determine its usability for teachers and educational experts.
- The third research objective is to evaluate the created authoring tool and to analyse its usability for educational experts.

Finally, the results will be analysed and discussed in chapters 8 and 9 to prove the success of this study and its original contribution to knowledge.

2 Literature Review

The research in the field of e-learning has been constantly growing over the last years. To position this research project within the existing and ongoing work in the field, this literature review will address the specific aspects of e-learning that have an influence on this PhD.

Several aspects will have to be addressed, for example the different kinds of e-learning approaches, the underlying pedagogical principles and the various projects going on at the moment.

Finally, the research objectives for this project will be formulated within this literature review.

2.1 Definition and history of e-learning

2.1.1 Definition

Before starting to work in a specific research field, it is necessary to define what the field actually comprises. In such a diverse field as e-learning there obviously exist different views on the topic and therefore different definitions. However, the definition we want to use for this project is the following one:

> E-learning is learning facilitated and supported through the use of information and communications technology. E-learning can cover a spectrum of activities from computer supported learning to blended learning (the combination of traditional and e-learning practices), to learning that is entirely online. Whatever the technology, however, learning and teaching are the vital elements [3].

Since this project focuses on educational hypermedia it is important to define the term hypermedia:

> Hypermedia is a logical extension of hypertext, in which graphics, audio, video, plain text and hyperlinks intertwine to create a generally non-linear medium of information [4].

Furthermore, the term educational hypermedia will be used in this work as follows:

> Educational hypermedia is all kind of hypermedia that is used for educational purposes and therefore the combination of e-learning and hypermedia in which the grade of integration of those two domains can vary.

The World Wide Web would be an example of hypermedia, whereas a non-interactive television presentation is an example of standard multimedia.

2.1.2 History

The development of e-learning based on the definition given in 2.1.1 started in 1588 with one of the first applications, Agostino Ramelli's "Book Wheel" [5].

This "Book Wheel" allowed the user to access several books at the same time without having to close and store them. The books were attached and secured to a wheel that could be rotated by the reader. This could be seen as a first example of allowing a user to navigate between different contents of learning material.

In 1945, Vanebar Bush introduced a theoretical device called the Memex for Memory Extender. The Memex was described by Bush as a device that allowed the user to create links between different media types (books, films), to navigate between them and therefore to extend his or her[1] memory [6].

In 1989, Tim Berners-Lee extended the idea even further and created the World Wide Web (WWW), which is a wide-area hypermedia information retrieval initiative that aims at giving universal access to a large universe of documents [7]. This idea finally resulted in the now existing World Wide Web which forms the technical basis for e-learning in most of the ongoing projects in this area.

E-learning projects have always been existing throughout the years, but have gained a lot of importance especially from the 1990s until today [8][9]. In 1994

[1] From this point forward all gender specific expressions should be considered to be gender neutral.

Bob Jensen and Petra Sandlin identified the leading hypermedia and hypertext systems in higher education and described them in detail [10]. This study is a good indicator that especially in the area of educational hypermedia several major projects were going on at that time. Furthermore, several research groups were formed and are still working in the field of e-learning [11][12][13][14].

Additionally, the research on the pedagogical side of e-learning is constantly going on. The goal of all these projects is to improve the situation of both learners and teachers in e-learning [15][16][17][18][19][20][21].

2.2 Forms of e-learning

2.2.1 Computer Based Training

Computer Based Training (CBT) is a term that specifies learning software which can be used by the learner with a high temporal and spatial flexibility, i.e. the student can learn wherever and whenever he wants. The learners or students are not in contact with other learners, teachers or tutors. CBT programs can contain multimedia content, for example animations or videos, and are usually distributed via CD-ROM or DVD.

Furthermore, CBT usually focuses on an auto-didactic way of learning, i.e. the student is in control of what and how to learn. Communication between learners, tutors and teachers takes place asynchronously, if at all.

Wagner and Flannery state that CBT practitioners should pay attention to organisational, cultural and individual characteristics with regard to the aspects of self-determination and self-management as central components in order to understand the adult user's acceptance of computer based training [22].

2.2.2 Web Based Training

Bransford et al. point out that Web Based Training (WBT) is a further development of CBT and is based on the World Wide Web and its functionality [23]. Therefore, the different learning contents are not stored locally on a data storage device, but provided dynamically via the Internet from a web server. Additionally, the usage of the World Wide Web allows the usage of communication tools like e-mail, news, chats and discussion forums. Furthermore, all collaborative approaches are WBTs because of their usage of those communication tools.

Scheines et al. compare a traditional lecture format with an online format in order to determine whether online courseware can replace large lectures without decreasing learning outcomes [24].

The analysis of learning outcomes indicates that the online courses are as effective or significantly more effective than large lecture courses, which supports the claim that online courses can replace large lecture courses. In addition, a regression analysis shows that recitation attendance most strongly predicted final exam performance (2% more per attendance). This means that regular face-to-face meetings in person are critical to the learning process even in online settings.

Furthermore, Mioduser et al. point out that the situation regarding web based learning environments could be summarised as one step ahead for technology, two steps back for pedagogy [25]. For example, most sites elicited cognitive processes such as information retrieval (52%) or memorising (42%), whereas only 32% required analysis and inference; higher cognitive processes such as problem solving (5%) were rarely required. Interaction types were more or less restricted to browsing (76%) and multiple choice (31%); complex (3%) or online (6%) activities were rare. Collaborative learning was only manifest in 3% of the sites. The most common form of communication was e-mail (65%); more advanced tools for collaboration were hardly used at all.

Cheaney and Ingebritsen point out the aspects of problem based learning [26] and Sung et al. analyse the design and application of web based self- and peer-assessment systems [27]. Both of them claim that the students' learning success was growing when they used e-learning in a WBT environment.

2.2.3 Hypermedia Authoring Tools (HATs)

Hypermedia Authoring Tools (HATs) are development tools for the creation of hypermedia learning content. Elliott defines their purpose as the creation and modification of hypermedia learning content, for example the support of teachers during the creation process of educational material [1]. There are fairly easy to use authoring systems, so that the authors of the educational content do not need a lot of technical expertise. However, these easy to use systems aim at the creation of single-focused material, for example the creation of material that will not be reused later on.

More sophisticated authoring systems aim at the reuse of material, but are not very easy to use for the author [28].

A rough classification of HATs is:

- Authoring systems for media types, for example HTML sites, graphics, animations, etc.
- HATs for the creation of educational material
- HATs for the presentation of educational material

Some HATs aim at integrating all the described functions, allowing the easy creation of educational material including different media types and the professional delivery of the material. The media types text, images, video and audio files are usually supported.

Dedicated HATs are systems that are specialised in specific learning environments, but are only creating material for those environments.

The navigation through the educational material is sometimes controllable by programming or scripting languages.

Generally, the easier to use a HAT is, the more limited is the flexibility of the created learning material. HATs that are very flexible are often difficult to use and much more complex [1].

2.2.4 Simulations

Simulations aim at recreating or simulating real models and their relevant attributes. Learners or students are then allowed to do free or guided experiments within the simulation. The students can observe the results and can learn by transferring the knowledge gained by the simulation to the original situation. For example, Thissen describes and analysis the simulation for the training of members of management [29].

Whitehouse explores the question whether web-enabled simulations provide new ways of learning and describes the development process and marketing strategy of web-enabled simulations [30]. The Learning Lab has developed 18 web-enabled simulations, real-time learning experiences and interactive programs that challenge students to think strategically across multiple business functions [30].

De Jong et al. and Dumblekar show that the application of simulations supports the creation of beneficial e-learning scenarios [31][32].

As a further example of simulations and extended simulations, real laboratories can be named that exist already and can be accessed and used online [33].

2.2.5 Video conferencing / Teleteaching

The technology of video conferencing allows the creation of virtual classrooms, where the spatial border between teacher and student can be crossed and communication is possible. This variant of e-learning is sometimes also addressed as teleteaching. Its main characteristic is the transfer of audio and video which allows a communication between the teacher and the students very similar to a traditional classroom situation.

However, the relatively high requirements to the technical equipment limits the usage of teleteaching. The growing bandwidth of Internet connections will probably allow new technologies, e.g. video and online teaching via the WWW [34].

Chua et al. present for example a tool called Conversant Media for the use of synchronous and asynchronous discussion of videos and report preliminary results of an evaluative comparison of using this tool versus using an off-the-shelf threaded discussion tool [35]. The tool allows participants to engage in discussions of video footage by attaching comments to video frames. A timeline shows the frames to which comments were attached. The tool presented is interesting because it is quite novel. Also, it shows that there are many instances where off-the-shelf tools are too restrictive and do not meet the pedagogical requirements. As there is an increasing educational use of computer-mediated communication, it would be interesting to see more tools which explicitly satisfy a particular educational need [35].

Adams et al. present an interesting project about the usage of a telepointer for e-learning [36]. A telepointer essentially is a mouse that gives the presenter the opportunity to focus on a particular spot on a remote computer. While investigating the optimal technical details of telepointers, the researchers designed their work to fill a gap in experimental knowledge about performance and satisfaction derived from using this tool. The most impressive finding is the great advantage that the telepointer groups had in retaining their knowledge from both the online and local experiment after a five week period in the first experiment, despite the fact that they had spent less time on task. The telepointer group was also faster at grasping the answers to the questions the expert was asking and did not require clarifying questions to understand his point.

Additionally, it has to be remarked that the distribution of documents, e.g. presentations, is another important issue in the area of teleteaching or video conferencing. For example Adobe connect [34] provided the technical platform for a teleteaching situation in the academic year 2008 at the University of Applied Sciences in Regensburg.

2.2.6 Learning Management Systems

A system that supports and manages online or offline educational material is called a Learning Management System (LMS) [37][38]. The support of the LMS can include the complete workflow of the administration of learning and teaching processes including the administration of resources or only parts of it.

An LMS can fulfil the following tasks:

- Planning: covers the planning and construction of (online) learning material, the creation of individualised learning plans and the creation of learning profiles for learning groups
- Registration: covers the online registration to all the offered learning courses, often with interfaces to an e-commerce system where the material can be purchased
- Allocation of course material: covers the administration and storage of learning materials in different formats for the different learning approaches, for example WBT and standard classroom situation
- Measurement and administration of the students' learning successes

Some LMSs also include teacher and room management to administer the resources and resolve possible conflicts, e.g. time-tabling of teachers and rooms is supported.

Additionally, the existing data can be analysed and used for the creation of reports, for example room occupancies, time tables or learning improvement of individuals.

Martins and Kellermann's findings indicate that the students are strongly influenced by perceived performance consequences and by social influences from their instructors and their peers in assessing the usefulness of a new LMS [39]. Students were more likely to perceive the system to be easy to use if they believed that there was adequate technical support available when they needed help with the system, and if they had greater prior experience in using computers and the Web.

2.2.7 Learning Content Management Systems

The tasks of a Learning Content Management System (LCMS) [37][40] are the creation, the reuse, the search and the delivery of learning materials. The content is often administered as learning objects in a centralised content repository. The learning objects can be referenced from different educational courses. Therefore, if a learning object is changed, it only needs to be changed in the central repository and the changes are known immediately in all the learning courses. The LCMS usually has a user management (in contrast to the HATs) that allows to distinguish between different users and user groups and to assign them different roles and rights to realise different kinds of access to the learning content.

Furthermore, this multi-user functionality allows to administer concurrent user access to the same learning object and to avoid unwanted changes of the learning object. Additionally, LCMSs usually implement a versioning control of the changes to a learning object.

One of the most important tasks of an LCMS is to allow the reuse of learning objects. The goal is to avoid unwanted redundancies and contradictory information about the learning objects.

2.2.8 Game based learning

A digital learning game is a game that tries to transfer knowledge by applying hard- and software to the player. The aspects of traditional learning games, e-learning and entertainment focused games are mixed to achieve the desired effects.

Digital game based learning mainly differs from traditional learning games and not game based e-learning in the following respects: the digitial learning games are designed like modern computer games and use a completely different methodology of the knowledge transfer [41], but they still focus primarily on that knowledge transfer and not on entertainment. Furthermore, the story line and the para-social relation between the player/learner and the NPCs (Non Personal Characters) [42] are used to achieve the wanted learning activity in the fictional gaming world.

Based on the many attributes that distinguish individual learning from group based learning, game based learning can be divided into [43]:

- digital learning games that are focused on the individual learner
- digital learning games that are focused on learning groups

Gee does not offer any solutions, recipes or recommendations for e-learning professionals, neither does he pretend to do so [44]. His work is rather designed to provoke thoughts and reflections of use for those planning, designing or delivering e-learning simply by creating important references to how game designers manage to get players into learning mode not only voluntarily but continuously [44].

Pensky [45] supports a very positive attitude towards the potential of game based learning. He substantiates his assessments with pedagogical, business and pragmatic arguments in a plausible way.

2.2.9 Blended learning

Reinmann et al. define blended learning as the mixture of standard teaching and learning approaches with the approaches of e-learning [46].

Denise's work presents a possibility of adapting theoretical principles and lessons learned from self-directed learning to a blended learning system for adults [47]. The seven pillars she refers to are as follows: a project-oriented pedagogy, a mechanism for introduction and pre-training, new roles for trainers, an open training resources environment and a triple level of follow-up approaches.

It can be summarised that the experiences and results of the study show that there is an importance of offering a flexible curriculum that matches the learner's needs and a necessity to provide pre-training to learners entering blended programs.

2.2.10 Web based collaboration

Web based collaboration focuses on the collaboration on a specific learning task of a student group via the Internet. Ng'ambi and Hardmann built and evaluated a knowledge-sharing scaffolding environment based on learners' questions as an example for web based collaboration [48].

2.2.11 Microworlds

A microworld is a tiny world inside which a student can explore alternatives, test hypotheses, and discover facts that are true about that world. It differs from a simulation in that the student is encouraged to think about it as a "real" world, and not simply as a simulation of another world (for example, the one in which we physically move about).

For example, White introduces several microworlds [49]. For every microworld four phases were identified:

- Motivation phase
- Model evaluation phase
- Formalisation phase
- Transfer phase

One of the most notable results is that on a set of classic force and motion problems, sixth graders taught by following the suggested curriculum significantly outperformed high school students taught by using a traditional, text book based curriculum [49]. With regards to e-learning, it should be noted that it cannot be determined how much of this effect is due to the curriculum approach itself (i. e. focus on qualitative understanding, collaborative learning) and how much of the effect is afforded by the use of computers (i. e. use of interactive microworlds).

2.2.12 Visualisations

Barwise and Etchemendy show that visualisations of processes within modularised content can be used for e-learning [50], for example the WebDance project [51]. Within the visualisation of the process the single steps of the process will be presented to the learner with the help of audio and video. This presentation can lead to learning and to new knowledge of the student [52].

Donath discusses three research projects whose main interest lies on visualising online social interactions [53]. However, the focus does not lie on the context of learning, but on the online interactions by learners. The visualisations focus on providing the viewer with a qualitative sense of what is going on in a virtual discussion setting, synchronous or asynchronous.

2.2.13 Learning communities and social learning

Learning communities are formed of groups of learners that have the same learning goals or interests. They can build a commonly shared knowledge base via the learning community online and offline. Every member of the community can share his knowledge with the community.

Therefore, the knowledge base of the community is constantly extended and adjusted [54][55][56].

Furthermore, computer supported collaborative learning is an important form of e-learning, particularly in open and distance learning. McAlister et al. introduce an especially interesting type of collaborative activity, educational synchronous online dialogue between peers, which structures messages by time and topic thread, as is typically done in discussion forums [57]. To help learners to argue, it also requires students to choose sentence openers from a pre-defined list for each message.

The tool AcademicTalk shows that interface design, with a sound underlying educational design, can result in clear educational benefits. From an interface perspective, the tool is a small enhancement of standard chat tools, yet the impact on the dialogue is significant. As there is an increasing educational use of computer mediated communication, it would be interesting to see more tools that explicitly support online dialogue [57].

Dalsgaard argues that although universities across the world have implemented LMSs by now, it is necessary to move beyond LMSs in order to effectively use the Internet as a teaching tool, especially within the framework of a social constructivist pedagogy [58].

Firstly, the concept of social software is defined with regard to the educational setting. It comprises networked applications which encourage people to learn together. Examples of such tools are blogs, Really Simple Syndication (RSS) software, social bookmarking tools, and WIKIs.

Secondly, de Laat shows that it is not necessary to use an expensive LMS for online collaboration; "small pieces loosely joined" [59] could provide an adequate learning solution as well. In fact, social software might provide a starting point for the personalisation and individualisation of learning.

De Laat makes a distinction between learning in social interactions and collective learning. Furthermore, he subdivides collective learning into learning in networks, learning in teams, and learning in communities [59].

2.3 Advantages and disadvantages of e-learning

Only a couple of years ago e-learning was regarded as *the* education form of the 21st century. In the meantime it has become clear that e-learning cannot replace the traditional forms of education completely [60]. E-learning can only be an important support in the whole learning process. Learning can be optimised by the combination of different approaches of knowledge transfer. This is very important for students that prefer using the computer and the Internet instead of reading books. They can profit from the usage of e-learning in particular [61].

The usage of different media types is only responsible for a minor part of the success of the learning process. Therefore, it cannot be claimed that e-learning assures more efficient learning [62].

Only if a high number of factors come together, e-learning can be successful.

2.3.1 Advantages

The biggest advantages of e-learning are the possibilities and flexibility it offers [60][62]. The student can learn when and where he wants and at his own learning pace. This makes e-learning education excellent for students that are working full-time or have family responsibilities.

The students and their learning are independent of spatial and temporal borders [60]. The transfer of knowledge can take place regardless of the physical presence of the student. This is realised by the usage of computers, the WWW and LMSs.

Another advantage is that e-learning courses can be interactive, the learning outcome of the student can be monitored individually and the learning content can be adapted to the students specific learning preferences [60][62].

Additionally, the economical aspects must be counted among the advantages of e-learning. The costs of learning can be reduced, for example if a student wants to repeat a learning session, he can simply restart the e-learning material without any additional costs [61]. Furthermore, existing e-learning material can be reused for different students or institutions. Generally, it can be claimed that the initial costs are higher with e-learning, but the more users are using the once produced material, the more costs are avoided.

Other advantages of e-learning are the possibility that students can communicate or collaborate with fellow classmates regardless of spatial distance and that educational material can be adapted to the learners' preferences. Additionally, difficult topics can be visualised or presented with simulations [61].

However, e-learning does not only have advantages but some disadvantages as well which will now be introduced.

2.3.2 Disadvantages

The first disadvantage of e-learning is that students and learners must first learn to work with the new forms of learning, knowledge transfer and media types. Additionally, the presentation of the educational content is often dominated by technical aspects instead of educational aspects [60]. This is based on the fact that e-learning is influenced by technology and technical experts that create the content.

Another disadvantage of e-learning is the missing face-to-face communication between the students and the teacher and these issues can make personal tutoring very difficult. However, the application of teleteaching or virtual classrooms could address this issue. Sometimes students state that they experience a feeling of isolation in the process of distance learning [60]. However, the application of forums and computer based communication forms can help to overcome this obstacle. Furthermore, if collaborative e-learning is used, the students need to be very disciplined during their work to avoid delay times during the communication between the students [61].

Another issue that has to be acknowledged is that the implementation of e-learning can be very expensive during the initial phase.

However, taking everything into consideration, the advantages outweigh the disadvantages of e-learning and therefore justify the research undertaken for this PhD project.

2.4 Pedagogical elements and approaches

Pedagogical elements are an attempt to define structures or units of educational material. For example, this could be a lesson, an assignment, a multiple choice question, a quiz, a discussion group or a case study. These units should be format independent.

Once the author of the e-learning content starts the creation of educational material, the pedagogical approaches he wants to use need to be evaluated. Simple pedagogical approaches are easier to create, but are not as flexible and reusable as more complex approaches. On the other side, the complex approaches, e.g. complex and highly adaptable learning systems, are more difficult to implement and take more time until they can be used.

Therefore, the author has to decide on the ideal pedagogical approach that will allow a compromise between the two sides.

It is possible to use various pedagogical approaches for e-learning which include the following aspects.

2.4.1 Instructional design

The arrangement of media and learning content for the most effective knowledge transfer is called instructional design [63]. This arrangement is generally based on a determination of the current knowledge of the learner, the specification of the goal of the learning process and the creation of the necessary steps to make the learning process possible. Ideally, the process is based on tested teaching and learning strategies. Furthermore, the learning process can be student-only based, teacher driven or group based.

As a field, instructional design is historically and traditionally rooted in the fields of cognitive and behavioural psychology.

In 1955 Benjamin Bloom published a taxonomy [64] broadly accepted in the field that specifies three domains of learning:

- Cognitive skills (what we know or think)

- Motor skills (what we do physically)
- Affective skills (what we feel or what attitudes we have)

These taxonomies still influence the design of instruction [15][63][65][66].

However, the model probably most commonly used for creating instructional material is the ADDIE Model introduced by Molenda [67]. The acronym symbolises the 5 phases of the model:

- **A**nalyze - analysis of the learner characteristics, the knowledge that has to be transferred and so on
- **D**esign - design of the educational material and the selection of the pedagogical approach
- **D**evelop - the actual development of the educational material
- **I**mplement - delivery of the created educational material
- **E**valuate - assessment of the learning success

Strickland argues that most of the current instructional design models are variations of the ADDIE model [68].

Instructional theories also play an important role in the design of instructional material, for example the Instructional Transaction Theory as introduced by Merrill [69]. The instructional strategies can be described as methods of manipulating the elements of knowledge objects. They allow the specification of executable knowledge.

Furthermore, the pedagogical perspectives introduced in 2.4.3 also have a major influence on the outcome of the educational material.

2.4.2 Constructivism

The formalisation of the theory of constructivism is generally attributed to Jean Piaget, who articulated mechanisms by which knowledge is internalized by learners. He suggested that through processes of accommodation and assimilation, individuals construct new knowledge from their experiences [70]. Constructivism is a theory of learning based on the idea that knowledge is constructed by the learner by mental activity. Learners are considered to be active organisms seeking meaning. Constructions of meaning may initially bear little relationship to reality (as in the naive theories of children), but will become increasingly more complex, differentiated and realistic as time goes on.

Jonassen defines constructivism as follows:

> Constructivism claims that reality is constructed by the learner based upon mental activity. Humans are perceivers and interpreters who construct their own reality through engaging in those mental activities. Thinking is grounded in perception of physical and social experiences which can only be comprehended by the mind. [71][17].

Bednar et al. go on further:

> The learner is building an internal representation of knowledge, a personal interpretation of experience. Learning is an active process in which meaning is developed on the basis of experience. Conceptual growth comes from the sharing of multiple perspectives and simultaneous changing of our internal representations in response to those perspectives as well as through cumulative experience [72].

Tenenbaum et al. show that there is a wide gap between how teaching processes should foster and encourage learning processes according to constructivist pedagogy and how far the theory is actually practised [73]. Furthermore, they conclude that this gap might be the result of a lack of knowledge of these principles by instructional designers and educators, and call for the stakeholders to try to bridge the gap between theory and practice. This makes it clear that very little of what is normally preached is really practised. The finding does not come as a big surprise to anyone who is actively involved in teaching, and is constantly trying to make the best of available time and resources.

2.4.3 Pedagogical perspectives

While examining the pedagogical attributes of e-learning, the pedagogical perspectives, i.e. the different viewpoints from which pedagogy can be regarded, must be taken into consideration. The outcome of any learning process is influenced not only by the learning material, but also by other factors or perspectives that have an impact on the learner.

The following pedagogical perspectives are important, but for this project left out of scope, due to the fact that this project is focusing on the separation of technical and educational content. Additionally, the application of the different pedagogical perspectives lies within the responsibility of the author of the educational material.

Cognitive perspective

Bloom and Krathwohl state that cognitive perspective focuses on the cognitive processes involved in learning as well as the way the brain works [74].

Emotional perspective

Baath argues that the emotional perspective focuses on the emotional aspects of learning, like the motivation of the student [75].

Behavioural perspective

The behavioural perspective focuses on the skills and behavioural outcomes of the learning process, for example role-playing and learning on-the-job scenarios as described by Areskog [76].

Contextual perspective

Black and McClintock point out that the contextual perspective focuses on the environmental and social aspects of the student that can influence the learning.

This can cover the communication and interaction with other people, the tutoring of the student as well as other factors, such as pressure [77].

2.5 Educational research

2.5.1 Education and educational research

Berliner points out that since 2002, within United States policy circles and elsewhere, there has been a growing call for enhanced evidence that educational innovations are working. Doing science and implementing scientific findings are so difficult in education because humans in schools are embedded in complex and changing networks of social interaction [78]. Berliner's conclusions are extremely relevant for the e-learning community. If we as e-learning developers accept the fact that there are unique complexities to be taken into account when learners use our tools, then a single-minded approach to researching the impact of e-learning on the learner is faulty.

The fact that a lot of research has been undertaken in the different areas of e-learning shows the general interest in the research area [79][80][81] [82][83][84].

Macpherson et al. state that most of the literature on corporate e-learning concentrates on the benefits, such as cost advantages and flexibility in delivery of learning [85]. However, it is argued that the issue of flexibility is only addressed in an organisational or financial dimension but not in a pedagogic dimension addressing the variety in individual learning styles. Several drawbacks of current implementation policies which are characterised by an enthusiasm for technology are addressed: bias in the balance of quality versus cost, lack of a supportive and interactive context of learning, and low learner and trainer acceptance.

Furthermore, Young introduces a survey involving more than 2300 professors in the US on the impact of the Internet and the Web on education [86].

The study ends by noting that at institutions of higher education, there is still much uncertainty about the efficient and effective use of information and communication technologies for education. It is recommended that further education for professors should focus less on the use of the technologies in general, but rather on the teaching strategies for their particular subjects.

Harley suggests that the future e-learning landscape will depend on how institutions respond to a number of variables [87]:

- Costs and sustainability
- Technology
- Students
- Public expectations and needs
- The realities versus perceptions of new competitive markets

Furthermore, it is assumed that there will always be a market for residential higher education and that new markets will emerge.

Ward and Newlands undertook an experiment on web based lectures replacing traditional lectures which took place in 1997 at Aberdeen University [88]. Nine lectures of a course on Economics of Public Policy were conducted as web lectures. 53 students had access to the lecture notes on the web.

Of the six potential advantages that students were asked to rate, the most important perceived advantages were richer learning resources and greater freedom of when to study and of the pace of study. Of the eight potential disadvantages that students were asked to rate, the most important perceived disadvantages were loss of contact with staff and other students, and lack of access to computers.

This experiment shows that students may not always use the web as imagined by course developers, even though too much generalisation of these results should of course not be attempted. Additionally, it was argued that students approached the web lectures conservatively and with a reluctance to explore and experiment [88].

2.6 Teaching and learning strategies

Over the last few years, there has been increasing growth of hypermedia information bases available over services such as the WWW [1]. Senac et al. argue that the contribution in terms of openness, accessibility, extensibility and portability of the WWW make it a good choice for the design of global hypermedia applications [89]. However, global hypermedia applications are difficult to build and it is important to create tools that allow them to be constructed efficiently. Korcuska points out that altough generic authoring tools have allowed people without extensive technical training to create software, they have not provided much help with creating educationally effective software [90]. Furthermore, Walker and Hess state that if someone can teach, it is not necessarily the case that this person can become a competent developer or, perhaps even more importantly, will want to become a competent developer [2].

Therefore, we suggest the separation of the knowledge based content, e.g. teaching strategy and expertise of the teacher, from the technical one, e.g. programming languages and distribution medium. The result should be an improvement in the authoring field of educational hypermedia over the WWW (cf. section 3.1). A part of this improvement should be provided by the semi-automated production of educational hypermedia as described by Bultermann and Hardmann [91].

Four different TLSs have been selected as an initial basis for this PhD project: Question and Answer (cf. section 2.6.4), Lecturing (cf. section 2.6.5), Case Study (cf. section 2.6.6) and Problem-Solving (cf. section 2.6.7).

2.6.1 Problems

As Elliott states, most teaching staff can use word processing packages and, perhaps, a drawing package, but would stall at the challenge of progressing to more complex software packages [28]. He argues that there is a lack of adequate Hypermedia Authoring Tools especially designed for teachers. This raises the question of how to create such a tool to simplify the task of authoring for the teachers. To answer this question, we will try to separate the knowledge based content provided by the teacher from the technical content. Ideally, the technical content or the part of the development expert could be minimised and the teacher would have an easy to use tool for the creation of educational hypermedia.

To achieve this result, several problems have to be solved. At the initial stage of the project, we are dealing with three major aspects:

- What specific requirements for a hypermedia authoring tool do teachers have?
- What kinds of teaching strategies exist and how are these strategies computable in educational hypermedia?
- What technology should be used to achieve the separation of functional and knowledge based content?

2.6.2 Approaches

What specific requirements for a hypermedia authoring tool do teachers have?

To answer this question, several approaches had to be considered. The following steps were planned: Literature review, questionnaires and personal interviews. Further work on the project required additional investigation, and other techniques like prototype testing and evaluation were used.

What kinds of teaching strategies exist and how are these strategies computable in educational hypermedia?

Research in the field of teaching and learning strategies is extensive and many teaching and learning strategies have already been analysed and described [2][18] [19][20]. Some of these strategies are of a computable nature, e.g. Guided Tours, Question & Answer, others, like the learning of motor skills, e.g. how to hold a pen with one finger, are not. A taxonomy of these teaching and learning strategies was built and their suitability in educational hypermedia was evaluated during this project. For this taxonomy we used hypermedia primitives, like conditional navigation, sequencing nodes, dynamic node construction, and so on. If a teaching or learning strategy can be expressed by these primitives, then we regard the strategy as computable in our framework.

What technology should be used to achieve the separation of functional and knowledge based content?

The taxonomy described above provided the basis for a prototype of a hypermedia educational authoring tool. Walker and Hess et al. emphasise that a critical issue for such an application is platform independence and the combination of authoring aids and graphics capabilities [2]. Therefore, the selection of the underlying techniques is an essential part in the development of the prototype. There are two possible approaches. Either an existing hypermedia authoring tool will be used for further development or a new, specialised authoring tool needs to be developed. The second approach was selected for this project and a decision concerning the development languages and tools also needed to be made. Java is the de facto standard for a platform independent programming language and was chosen for the prototype development [92]. Furthermore, the educational material produced must be deliverable over the WWW. The intention for this project was to use one of the existing WWW standards, XML (Extensible Markup Language) [93], for the indexing and linking of the knowledge based content in our framework. SMIL (Synchronised Multimedia Integrated Language) seemed to be an option for representing and defining our hypermedia primitives in hypermedia authoring, because SMIL is a language for describing interactive synchronised multimedia distributed over the WWW [94].

Additionally, it has to be mentioned that during the work on this project several new technologies have emerged. Those new technologies, for example the .net-Framework [95] of Microsoft could also have been selected for this project.

However, due to the platform independence of the Java framework, this work focuses on this technology.

2.6.3 Non-computable teaching and learning strategies

During the identification process of teaching and learning strategies it was recognised that not all of them are computable or appropriate for this project at the moment, e.g. the acquisition of motor skills [96][97][98].

2.6.4 Question and Answer

The Question and Answer teaching and learning strategy (QA-TLS) is mostly used for testing purposes [19], but can also be used to determine a student's existing knowledge, e.g. profiling his knowledge in adaptive hypermedia systems. Rushby identified several sub-types of the question and answer strategy [19]:

- One question, several answers, single choice
- One question, several answers, multiple choice
- One statement, true or false
- Matching a list

The QA-TLS is highly structured and therefore simple to implement into our framework for these selected question and answer types. There are several other question and answer types, e.g. discussion questions, but this project does not aim at defining every possible QA-TLS neither is it based on a didatic model of education. However, the goal is to create a generic framework for the creation of TLSs in the future.

The next task is to analyse which meta-information is needed and has to be used for this generic framework. This step will be explained in chapter 3

2.6.5 Lecturing

The lecture teaching and learning strategy (Lecture-TLS) is the classical type of delivering information from the teacher to the student as described by Cotton [96].

It is usually used when one teacher has to teach many students. Communication between the teacher and the student is usually one-directional from the teacher to the student. Research in this field has identified several theoretical strategies for lecturing [96]:

- inductive
- deductive
- networked

However, it seems more likely in a real classroom environment that single elements of the theoretical approaches are mixed up dynamically.

2.6.6 Case Study

The Case Study teaching and learning strategy (Case-Study-TLS) tries to give the student a view on one specific object from different angles. For example, a business process can be viewed from the accountant's or the salesman's perspective. Additionally, Cotton points out that already existing content and expertise can be used [96]. The interesting issues of the Case-Study-TLS for this project are how it can be expressed with meta-tags and how several subtypes of a Case-Study-TLS can be realised with those meta-tags (cf. section 3.3.3).

2.6.7 Problem-Solving

Ram et al. have underaken research in the meta-tagging process of problem solving skills [99], but this teaching and learning strategy will not be regarded during this PhD, because it is not considered to be beneficial at this stage of the project. However, it should be reviewed during future work (cf. section 9.2).

2.7 E-learning and meta-data projects

During this project the following research interests and projects have been found which have an influence on e-learning design at the moment.

Universities are and have been focused on the research of e-learning [100][101]. Not only is the research concentrating on the different aspects of distance learning as described in 2.2, but also on the preparation and the allocation of educational resources for students [102][103][104] and teachers [105].

Furthermore, the interest of governments and governmental research institutions in e-learning has been continually growing over the last years. Especially countries with a low population density, for example Australia [106][13] or Canada [107], are supportive of and interested in e-learning .

However, other countries support e-learning as well, for example Germany [108] or the member countries of the European Union [109].

Additionally, corporate driven projects and research institutes are continually working on the further development of e-learning [110][111][112][113].

All this research in the field of e-learning resulted in the creation of several plattforms for e-learning and material sharing of educational content [114][115] and the establishment of conferences and the foundation of scientific journals [116][117].

Based on all these research fields there have been several attempts to build a meta-tagging standard, i.e. a commonly accepted set of meta-tags to tag educational material in an educational context. Those meta-tagging projects are especially interesting for this work as they are a possible way of separating educational and technical content by tagging the educational material with meta-data.

The following projects have been identified and are being regarded as having the most important influence on this project.

IEEE LTSC

The Institute of Electrical and Electronics Engineers (IEEE) Learning Technology Standards Committee (LTSC) operates under the auspices of the IEEE Standards Association and the IEEE Computer Society Standards Activity Board.

The IEEE LTSC is chartered to develop accredited technical standards, recommend practices and guides for learning technology. This includes software components, tools, technologies, and design methods that facilitate development, deployment, maintenance, and interoperation of computer based education and training components and systems [118].

The IEEE LTSC developed a meta-data tagging standard named LOM (Learning Object Metadata) [119] which focuses on the following areas of metadata for educational material:

- General
- Life Cycle
- Meta-Metadata
- Technical
- Educational
- Rights
- Relation
- Annotation
- Classification

As this PhD project focuses on the educational part of meta-tagging, the educational side of the LOM is of special interest. The suggested meta-tags and their designated values in the educational part of the standard are:

- Interactivity Type - Values: active, expositive, mixed
- Learning Resource Type - Values: exercise, simulation, questionnaire, diagram, figure, graph, index, slide, table, narrative text, exam, experiment, problem statement, self assessment, lecture
- Interactivity level - Values: very low, low, medium, high, very high

- Semantic density - Values: very low, low, medium, high, very high
- Intended End User Role - Values: teacher, author, learner, manager
- Context - Values: school, higher education, training, other
- Difficulty - Values: very easy, easy, medium, difficult, very difficult
- Language - Values: different languages possible

The suggested tags are not focusing on the single components of teaching and learning strategies, but on a higher level of educational material. Therefore, the framework introduced in this PhD project should focus on the fine-grained level of educational information.

However, several other projects have adapted the LOM standard, for example CanCore Learning Object Metadata [11]. CanCore provides best practice recommendations for the implementation of the LOM standard to maximise the opportunity for interoperability between projects.

IMS GLC

The Instructional Management System (IMS) Global Learning Consortium (GLC) creates standards for the development and adoption of technologies that make high-quality, accessible, and affordable learning experiences possible. IMS GLC is working on digital learning services, combining new forms of digital content, assessment, applications, and administrative services.

IMS GLC members provide leadership in shaping and growing the learning industry through community development of interoperability and adoption practice standards and recognition of the return on investment from learning and educational technology [12][120].

Regarding the educational meta-data used by the IMS GLC it has to be stated that they are using LOM as their standard for tagging educational material.

Dublin Core

The Dublin Core Metadata Initiative (DCMI) is an open organisation, incorporated in Singapore as a public, non-profit company, involved in the development of interoperable online metadata standards that support a broad range of purposes and business models. DCMI's activities include work on architecture and modelling, discussions and collaborative work in DCMI Communities and DCMI Task Groups, annual conferences and workshops, standards liaison, and educational efforts to promote widespread acceptance of metadata standards and practices [121].

The Dublin Core Education Group [14] focuses on educational hypermedia and has also opted to use LOM as their standard for meta-tagging educational material.

JISC CETIS

The Joint Information Systems Committee (JISC) Centre for Educational Technology and Interoperability Standards (CETIS) is an Innovation Support Centre for UK Higher and Post-16 Education sectors funded by the Joint Information Systems Committee [122], and managed by the University of Bolton. The centre provides strategic advice to the JISC, supports its development programmes, represents the sector on international standardisation bodies and works with the educational community to facilitate the use of standards-based e-learning [123].

The JISC CETIS is using a LOM based meta-data standard named UK LOM [123] that basically covers the same meta-tags as LOM.

ADLNET and SCORM

The Advanced Distributed Learning (ADL) Initiative develops and implements learning technologies across the U.S. Department of Defense and federal government. They collaborate with government, industry, and academia to promote international specifications and standards for designing and delivering learning content [124].

ADL has developed the Sharable Content Object Reference Model (SCORM), which integrates a set of related technical standards, specifications, and guidelines designed to create accessible, interoperable, durable, and reusable content and systems. SCORM content can be delivered to learners via any SCORM-compliant LMS using the same version of SCORM [125].

The SCORM standard references back to LOM as a possible meta-data standard for tagging, but is aiming at an even higher level of educational material as identified by Friesen [126]. Therefore, the exchange of complete educational modules is feasible with this standard, but it is not an optimal standard for addressing the research questions of this PhD project.

Overall, it can be claimed that these projects use tags especially designed for educational purposes, but aim at the educational module level rather than at detailed teaching and learning based levels. The challenge for this project will be to address the problem on a very fine-grained level of the very basic components of teaching and learning. One of our goals is to design a framework that will provide better reusability of previously tagged elements as well as semi-automated or fully-automated authoring during the future work.

2.8 Knowledge and learning objects

The development of high quality learning resources is a costly affair [127]. Boyle and Cook show that a hugely promising aspect of educational technology is that it offers the potential to slash the costs of learning resources development by selecting bits of material that can be used in various contexts. These reusable materials are called learning objects. Furthermore, those learning objects, their perspectives and their development are analysed and researched in the ongoing work in the field [127].

The search for a universal definition of learning objects has not been fruitful. It would rather be more advisable to find a model that throws light on learning objects from various perspectives.

One point of view is that the goal should be to develop the smallest possible learning objects, whereby information contained in the learning objects is entirely separate from the educational context. This approach maximises the chances of reusability.

McGreal at el., however, hold that content and educational context cannot be considered separately. In this view, a learning object is regarded as a learning resource that sets a minimal educational objective. These outlooks are not considered to be contradictory, but rather as different levels of abstraction, both of which merit inclusion in a model for learning objects [128].

Currier et al. claim that the process of creating the actual metadata has largely been ignored, and is often trivialised as being "straightforward" for the content authors, where it cannot be generated automatically by the computer [129]. They developed a taxonomy to classify learning objects. Their result was not as good as expected. For example, only about 50% of the "ideal" classifications were agreed upon by more than half of the users. There was a very significant variation in classification, which leads to many inconsistencies which in turn drastically decrease the value of the metadata.

Furthermore, a collaborative model for creating metadata may be most appropriate: The content authors provide metadata such as their name and title of resource; a metadata specialist then checks these metadata for accuracy and adds the classification metadata. This approach improved results in two of the case studies presented in the article. Additionally, a problem with metadata that could be overlooked lies in the detailed work that has to be put into the design of the metadata.

The instructional use of learning objects is an important research field in e-learning as stated by Wiley et al. [130]. Two major issues regarding learning objects are discussed from an instructional design point of view by Wiley [131]. With regards to combination or sequencing, to use an instructional designer's term, the standards discussion has largely ignored instructional design issues, even though promises of automatically composed lessons are frequently made. With regards to granularity, the big question is the appropriate size or scope of a learning object. This is an issue which does not have a clear answer [131].

The main point is that instructional design theory must be incorporated in learning objects implementations that aspire to facilitate learning.

However, Friesen addresses problems associated with learning objects [126]. For Friesen, *learning objects* is a vague, overly broad term which holds little meaning and has little resonance for teacher practitioners who are pressured to promote and incorporate such *objects* into their classrooms.

Friesen is sceptical of the way in which e-learning standardisation is portrayed as supporting "multiple forms and practices of learning" and questions how such standardisation can capture the wide spectrum of pedagogical approaches. Referring to a specific example, the author is critical of the SCORM [125] programme which, Friesen claims, oversimplifies the teaching and learning processes it attempts to systematise.

Friesen does not suggest more profitable terms that could replace *learning objects*. He concludes by challenging developers and designers of e-learning technologies and infrastructures to recognise and choose relevant (and probably differing) pedagogical positions, but he offers no specific advice about how such objectives can actually be achieved. Therefore, it was desided for this project to concentrate on the separatione of educational and technical content.

2.9 Project management and e-learning

The management of e-learning projects and e-learning in business is becoming more and more important [132]. At the beginning of every e-learning project the management of this project should analyse the complexity of the project and the technical infrastructure.

Tiemeyer states in an article that the management of e-learning projects requires the consideration of the following aspects [132]:

- Organisational aspects
- Pedagogical aspects
- Human resources and economical aspects
- IT aspects

Furthermore, it is important, he argues, to install four phases for a successful project management:

- Planning phase
- Design phase
- Production and implementation phase
- Application and assessment phase

To guarantee the long-term success of e-learning in business Leithner et al. suggest using a balanced scorecard as a strategic tool for evaluating e-learning for companies. Leithner et al. state that the implementation of a balanced scorecard is difficult and is often underestimated, but the invested work is well spent on strategically implementing e-learning in businesses [133].

Buerg et al. state in their work [134] that the influencing factors for e-learning in companies are:

- Individual factors: social aspects, cognitive aspects and motivational aspects
- Contextual factors: organisational and technical aspects, learning environment

Another very important aspect for companies concerning e-learning is the cost factor. The usage of open source software is getting more and more accepted. However, open source software is mostly used in academia and regarded as a cheap, if not free alternative to commercial products. Kiedrowski states that the implementation of open source software in companies can only be successful if the technical and pedagogical resources are available [135].

Laurillard aims at developing a benefit-oriented cost model that enables innovators to plan and understand the relationship between the expected learning benefits and the likely teaching costs [136].

In her article several limitations in the existing approaches to costing are identified. From the criticism of existing approaches a list of seven requirements for a different approach is generated. The model should:

1. define benefit parameters that can distinguish between old and new methods
2. define the cost parameters that can be associated with comparative benefits
3. focus on the major cost driver of staff time
4. represent value to the learners in terms of use of their time
5. support the local exploration of the cost-benefit relationship
6. represent technology-specific benefits
7. represent benefits in terms of improvements in learning.

The development of this model proposes an interesting idea to refresh the established "return-on-investment" discussion in e-learning.

Altogether, the work in the field of e-learning in business is constantly going on, but is left out of scope for this PhD project, since the focus of this work lies on the fine-grained analysis and application of teaching and learning strategies.

2.10 Reuse of material

Much effort has been put into the technical reuse of electronically based teaching materials and in particular into the creation or reuse of learning objects. These are self-contained units that are properly tagged with keywords, or other meta-data, and often stored in an XML file format. Creating a course requires putting together a sequence of learning objects. There are both proprietary and open, non-commercial and commercial and peer-reviewed repositories of learning objects such as the Merlot repository [115].

A common standard format for e-learning content is SCORM (Shareable Courseware Object Reference Model) [125] whilst other specifications allow for the transportation of learning objects or the categorisation of meta-data [137].

These standards themselves are still in their maturity process and are continually augmented.

Littlejohn addresses seven critical questions about the reuse and sharing of educational resources [138]:

- How can digital resources be used to support learning?
- How can resources be reused in different teaching models?
- Why is standardisation necessary?
- Is there an optimal size for reusable resources?
- Should resources include contextual information?
- How will educational institutions change?
- Is it possible to share resources on a global scale?

Additionally, Rehak describes learning objects as the digital building blocks in LCMSs and argues that when threaded together, they produce as if of their own accord dynamic and completely computer-controlled lessons and courses. In this case many aspects need to be regarded: the relationship between the context of the course and the method of approach; the paradox between separate learning blocks and constructivist learning theory; the need for meta-data and the willingness to apply it [139].

Furthermore, Koper points out that the link between reusable learning resources and pedagogically meaningful learning units [140] is established and his research shows that learning activities can be described generically and embedded in templates. In turn, Laurillard argues that these templates then themselves become learning objects [141].

On the other hand, there are boundaries to the reuse of educational material. McNaught et al. states that one problem identified is how to organise this wealth of material for educational purposes [142]. This would require an enormous amount of work and technical resources. This case illustrates that having access to information is far easier than knowing how to embed it in an educational context. Secondly, the barriers identified in the paper were inadequate funding, technical platform problems, and insufficient production of the modules.

Finally, the topicality of the created content has an influence on its reusability. Some educational material ages faster than material from another subject area, for example a recipe for a specific dinner is valid longer than an instruction set for a technology that will be outdated in a year.

2.11 Adaptive Hypermedia System

The research interest in an Adaptive Hypermedia System (AHS) [143][144] and WWW based AHS has grown over the last years [145]. The working scope of an AHS lies in the adaptation of links, content or both based on a user's profile and his interaction with the system [146].

Furthermore, it is recommended by Shute et al. that the creation of adaptive e-learning methods should be preferred to the creation of "one-size-fits-all" learning solutions [147]. Therefore, a concept of an "adaptive engine" is developed that can be used to build e-learning environments in which e-learning does no longer have to be confined to making learning material accessible but can focus on improving learning by adapting instruction and content to suit individual learners.

Research on adaptive e-learning and AHSs is not only going on in a general area, but for example also in adaptive scaffolding. Azevedo et al. suggest analysing the impact of different scaffolding instructional interventions on the students' abilities to regulate their learning of complex science topics with hypermedia [148]. The main focus is on investigating the effectiveness of various scaffolding techniques in order to enhance the learners' abilities to shift to more sophisticated mental models and to regulate their learning. Scaffolding is defined as providing assistance to students on an as-needed basis, fading the assistance as the competence increases. Although the use of scaffolds in hypermedia environments is quite common, there is a paucity of empirical research on the subject, particularly with respect to exploring the impact of various types of scaffolding techniques on supporting learning of complex topics.

However, the apects mentioned above provide a major challenge to existing technologies, since it is currently impossible for any hypermedia system to emulate the role of the tutor. Hence, more investigation in the context of hypermedia environments other than the one used in this research will shed more light on the significance of AHSs for the process of facilitating the learners' abilities to regulate their learning.

2.11.1 Link adaptation

The adaptation of links inside a hypermedia document is one of the major topics of adaptive hypermedia. The navigation of the user through the hyperspace is hereby the main focus. Brusilovsky identifies several techniques for link adaptation, for example [143]:

- link hiding
- link suggestion
- sorted list

It is important for this project to understand the different types of possible link adaptation techniques. Because of the importance of adaptive hypermedia for educational hypermedia systems it is also necessary to review the content adaptation techniques in AHSs.

2.11.2 Content adaptation

Content adaptation in general is the modification of the content depending on the user's profile or his navigation through the content as stated by Brusilovsky [143]. Different techniques of content adaptation are for example:

- content hiding
- display of different content
- display of additional content

Research is also going on in this area, therefore additional methods will be or have already been developed. However, it is rather a difficult task to effectively change the content based on the user's navigation through the hyperspace. Therefore, it will be considered to be out of scope for this PhD project. Furthermore, the field of education has always been a research area of AHSs [143]. Every AHS that not only displays prepared content to a student but also changes certain styles of display or paths through the content is regarded as an Educational Hypermedia System (EHS). Additionally, an increasing number of hypermedia projects use the WWW as their delivery medium [149][150][151][152] to transport the educational material to the students.

2.11.3 User and knowledge management

The last major parts of an AHS are user information and knowledge management. To adapt the content or the links within an AHS it is necessary to have information about the user. This information can be gained in two different ways:

- Collaborative approach: The system needs some data input from the user to build up the user profile of the student.
- Automatic approach: The system tries to create a profile of the user just by analysis of the user's navigation and interaction with the system. This approach is much more difficult than the collaborative approach and will therefore be considered to be out of scope for this project.

The information about the user is then stored and managed inside the AHS. There are many different user management strategies, for example:

- Stereotype, i.e. students are divided into groups rather than being classified as individuals as described by Boyle [153].
- Boolean, de Bra and Calvi suggest that several variables are used to classify a student. Each variable represents a specific piece of knowledge the user has or has not [150].
- Percentage values, i.e. variables represent the user's knowledge about a certain domain. Each variable has furthermore a graded value that holds the graded knowledge of the student about that domain as pointed out by da Silva et al. [154].
- Time based values, i.e. the knowledge of the student about a certain domain diminishes over time as discussed by de Bra [155].

Once the AHS has built the user profile it can adapt the presentation of the content and the navigation through the content to the student's profile.

2.12 Technology

This section of the literature review will consider the technology used in World Wide Web (WWW) based educational hypermedia. Educational meta-data projects will be identified as well as the technology that is taken into consideration for this project.

2.12.1 Web 2.0 Technology

Richards identifies in his work [156] the following new technologies which are used for education:

- Weblogs: Good catalogue of the possibilities for education offered by weblogs, with examples taken from all levels of education.
- WIKIs: Easy Collaboration for All: Using Wikipedia as an example, the principle and possibilities of WIKIs are explained, followed by examples and a discussion of various WIKI tools.
- RSS: RSS (Really Simple Syndication) rightly takes central stage in the book. Again, first the book gives an explanation of how it works (without the technical details), followed by examples from use in education and practical tips for application and maintenance of RSS feeds.
- The Social Web: Learning Together: Social bookmarking services are taking off, and the possibilities seem endless. Communities are created due to the social aspect of sharing information (sources) within a group.
- Podcasting and Screencasting: Multimedia Publishing for the Masses. Besides the well-known broadcasting, an era of narrowcasting has dawned, which allows anyone who owns a computer plus Internet connection to provide an audio/video transmission for a very specific audience.

Demb et al. show in their results of a survey which explored student reactions to a campus-wide laptop initiative that expectations are not always fulfilled. The most important conclusion is that the major factor affecting student perception of the value of their laptops to their academic success is their perception of the quality of faculty utilisation of the laptops for teaching. This is consistent with findings at other campuses [157].

2.12.2 XML

The Extensible Markup Language (XML) is defined as follows:

> "The extensible Markup Language (XML) is the universal format for structured documents and data on the Web" [93]

It is a new accepted standard which allows the definition of markup languages in a structured form. Several books have already been written about it [158][159][160] [161] and it is used in educational projects on the WWW (cf. section 2.7). However, XML focuses on the meta-information about specific information and not on its presentation to the user. This task is done by the Extensible Stylesheet Language (XSL). XML will be used in this PhD project to create a special teaching and learning strategies oriented markup language. Educational data will then be marked up with meta-information within this language.

2.12.3 XSL

Extensible Stylesheet Language (XSL) is a language for expressing stylesheets. It consists of two parts:

- A language for the transformation of XML documents
- An XML vocabulary that specifies formating semantics

An XSL stylesheet specifies the presentation of a class of XML documents by describing how an instance of the class is transformed into an XML document that uses the formating vocabulary [162]. Boumphrey claims that the usage of stylesheets in a WWW-context is also accepted and used in the field [163]. Specially defined XSL stylesheets will be used to display the educational data to the student.

2.12.4 SMIL

The Synchronized Multimedia Integration Language (SMIL) is another standard suggested by the World Wide Web Consortium [164]. It focuses on the simple authoring of multimedia presentations, comparable for example with television. It is also a markup language designed to deliver multimedia over the WWW. It is not supported by the standard browsers yet, but special plug-ins or players can display it, e.g. Real Player G2. For this project it is possible to use SMIL as one out of many output formats. It could be supported, but it is not a necessity.

2.12.5 HTML and Dynamic HTML

The Hypertext Markup Language (HTML) and its later extension, the Dynamic Hypertext Markup Language (DHTML) are both accepted standards for delivering content via the Internet. The content is marked up with HTML [165] or DHTML as described by [166] and a WWW browser displays the content to the user on the client side. There is yet another standard suggested by the World Wide Web consortium: the Extensible Hypertext Markup Language (XHTML) [167].

However, it was decided that HTML will be used during the project.

2.12.6 Java and Java Script

Java and Java Script are programming and scripting languages especially developed for the WWW. They are accepted within the WWW development community and will be used during the development of a prototype for this project. This decision is based on the fact that there is no other programming language for the WWW that possesses the capabilities of Java. Furthermore, there is good support by literature for Java [168][169][170] and Java Script [171][172].

Other technologies that should be named in this context are the .net framework [95] and the AJAX (Asynchronous Java Script and XML) approach, which are used to create interactive WWW based Internet applications [173].

However, it was decided that the Java approach based on the experience gathered during the development of the prototype of an hypermedia educational authoring tool, even if other technologies could also have been used.

2.13 Research objectives

Although a growing research interest in e-learning and e-teaching is recognisable (cf. section 2.7) it does not seem as if a big focus was put on the teachers themselves. However, in the education of students as well as in the information transfer from the teacher to the student, the teacher plays an important role.

At this point it is of great interest to know how the support for teachers in e-learning and e-teaching can be improved and how their work can be supported efficiently. As stated in the previous chapter (cf. chapter 1) a new type of such support will be evaluated in this study. The three major research objectives that should be answered as a result of this work will be introduced now.

The literature review above leads to the hypothesis that if the separation of technical and educational content is possible, it could lead to the creation of a new framework based on a fine-grained structure of different teaching and learning strategies. This framework and its conversion into an authoring tool could make the creation of educational hypermedia very easy for teachers and therefore enable them to overcome the existing obstacles.

To evaluate this hypothesis the following research objectives are defined and will have to be addressed.

2.13.1 Creation of a suitable framework for content separation

The first research objective is to create a suitable framework for the separation of educational and technical content in educational hypermedia. The framework must address teaching and learning strategies as well as the question of how they can be structured in a way that they are usable in a computing paradigm. Furthermore, the framework should focus on a fine-grained representation of teaching and learning strategies.

2.13.2 Evaluation of the framework

The second research objective is to evaluate the created framework and to determine its usability for teachers and educational experts. Furthermore, it must be analysed if the created framework is convertible into an authoring tool for teachers to create educational hypermedia. Therefore, an authoring tool based on the created framework must be designed and implemented.

2.13.3 Evaluation of the authoring tool

The third research objective is to evaluate the created authoring tool and to analyse its usability for educational experts. To undertake this evaluation it seems necessary to apply it to the creation of some real educational material.

Finally, if all the research objectives are achieved, the results must be analysed and discussed to prove the success of this study and its original contribution to knowledge.

3 EFTECS

In order to realise the separation of educational and technical content in educational hypermedia it is important to follow a systematic approach. The approach selected for this PhD project is to create a framework that describes the desired content separation and provides the basis for a practical feasibility study of a prototype authoring tool. From this point forward the created framework will be referred to as the **:**

EFTECS - Extensible Framework of Technical and Educational Content Separation.

In chapter 4 the implementation of an educational authoring tool based on the EFTECS will demonstrate the feasibility of the EFTECS.

3.1 Theoretical approach

As outlined in the introduction and the literature review it is important to separate the educational components from the technical components in educational hypermedia in order to simplify the authoring process of educational hypermedia material. It has also been mentioned that these two components are generally tightly woven together. Therefore, the separation of the two components is one of the most important issues of this PhD project.

The EFTECS is designed to provide an easy to use model to separate the two components from each other. The general concept of the separation has already been shown in the existing work [14][121] in the field. In the literature review the drawbacks of the competing approaches have already been addressed (cf. section 2.7). However, it is necessary to point out the most important aspects once again:

- The EFTECS should be based on educational teaching and learning strategies.
  The major focus of this work is based on the simplification of the authoring

process of educational material for educational experts. The most promising approach to achieve this simplification is to use a model that educational experts are used to.
Special focus will be laid on the very detailed analysis of the components of the teaching and learning strategies as identified in section 2.7.

- The EFTECS should provide the complete separation of educational and technical content.
  A partial separation of the components would simplify the technical implementation of the model. The higher the degree of separation will be, the more difficult the technical implementation of the EFTECS will become. This relation is based on the fact that educational material which is tightly woven together, e.g. a web page, can easily be authored by a technical expert without an authoring tool. If an educational expert with some technical expertise wanted to design the same web page, he would need an authoring tool, for example “Front Page”. However, if the authoring process is simplified so much that the educational expert does not need any technical knowledge at all, which is the desired state since he can concentrate on his educational task, then he will need a well-designed authoring system that focuses on his educational skills.

- The EFTECS should be easily extensible to allow further development and reuse of material.
  It is very important for the acceptance and further development of the EFTECS that the authored material is as easy to reuse for different purposes as possible. This issue has to be addressed in the EFTECS and will allow the educational expert to search, find and reuse educational material that has already been authored .

- The EFTECS should be applicable in practical authoring.
  It is not desirable to just create a theoretical model which is not usable in a practical situation. Therefore, it is not only the EFTECS that has to be designed, but a feasibility study in form of a prototype also has to be designed, developed and tested. This prototype will be introduced in chapter 4.

- The EFTECS should allow the import of already existing educational material.
  Another important aspect that has to be considered in the design of the framework are import functionalities for already existing educational material.

Furthermore, it has been decided to apply a top-down approach to analyse educational hypermedia content and to build the EFTECS based on this analysis. This top-down approach will look at the educational hypermedia content in the following order:

1. At an Educational Module (EM) Layer, e.g. complete courses and modules.

2. At a Teaching and Learning Strategy (TLS) Layer, e.g. single lectures or teaching components which form a complete EM.

3. At an Educational Hypermedia Primitive (EHP) Layer, e.g. the elements such as a question or an answer of a question and answer teaching and learning strategy, forming a single TLS.

The three different layers, the communication between the layers and their working together, as shown in figure 1, will form the basis of the EFTECS analysis.

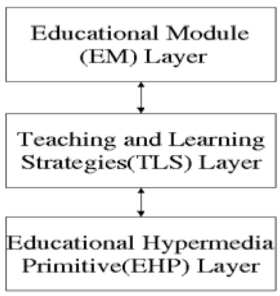


Figure 1: The three layers of the EFTECS

Based on this analysis, the EFTECS is able to grow in size and complexity.

All the results of the theoretical analysis of the content space will have an influence on the development of a new XML language called XEML - eXtensible Educational Markup Language. The XEML will be introduced in detail in section 3.9.

The approach selected for this research project is that the different TLSs can be split up into their basic educational components. In a QA-TLS for example there are single components like Question, Answer, or Correct Answer. A combination of some multimedia content with one of these components is referred to as an Educational Hypermedia Primitive (EHP).

Obviously, the different TLSs need different EHPs, for example a lecture cannot be represented by using the EHPs of the QA-TLS. Therefore, it will be necessary to determine which TLSs need which EHPs. However, it is an aim of the project to reuse as many EHPs as possible to bring down the organisational overhead, for example a "Help-EHP" can be used in most TLSs and can therefore be reused.

Once it is realised that a specific TLS can be broken down into its single educational components, another fact has to be considered. If a TLS is broken down into its components and then filled with multimedia content, those EHPs have to be viewed as a very specific instance of this TLS. Furthermore, several instances of TLSs need to be linked together to create a complete Educational Module (EM) which can be presented to the student. This results in a three layer model: a layer that covers the EHPs, another that covers the different instances of TLSs and one that focuses on complete EMs (see figure 1).

3.2 EFTECS at EM-Layer

The first layer of the EFTECS, the Educational Module Layer, is aiming at complete educational modules, e.g. complete courses. Several other projects are also working at this level, for example the IMS [12] or the ARIADNE [174] project. From the student's point of view the EM-Layer of the EFTECS is his main interface. The student does not need to know anything about the EFTECS or its implementation. It is just the educational module that is delivered to the student, whereas the underlying framework is not noticeable for the student.

The first step at this layer of the EFTECS is to separate the educational information about the complete educational module from the technical information. The educational module is considered to be a big, tightly woven together piece of educational and technical material. To simplify the authoring of the material, the EFTECS is aiming at the educational information about the complete educational module. After reviewing existing projects (cf. section 2.7) the following items of educational information about complete educational modules were identified and added to the XEML (cf. section 3.9):

- Author
- Authoring date
- Domain area
- Difficulty
- Target audience
- Language

This list does not cover all possible educational information about an educational module, however, the EFTECS as well as the XEML are generic frameworks which can be extended quite easily.

At this point, the educational information about a complete educational module can easily be described and authored. However, the bigger part of the educational material is still woven tightly together and must be analysed more deeply, because the regarded educational material is still not on a fine-grained level. During the following analytic steps, it could be observed that the educational modules are formed by several instances of teaching and learning strategies. Those TLSs are linked together and form the EM. The next step is to analyse the rest of the educational information from a TLS point of view.

3.3 EFTECS at TLS-Layer

In the EFTECS an educational module is regarded as the superstructure of the TLSs. Several instances of TLSs form an educational module.

Whereas the purpose of the EM-Layer is to describe the educational module in general, the TLS-layer works one level below. Its main purpose is to use the information about the identified Teaching and Learning Strategies and to provide the author of the educational material with the possibility of “binding” together the single components of the TLSs. The TLS-layer works on and manages the relations between these single components. This process of linking together those single TLS components in a specific way creates new instances of a TLS. For example, a question, several answers, at least one correct answer and the type of the TLS (Single Choice, Multiple Choice, Yes or No) build one instance of a QA-TLS. Basically, the TLS-layer is working with and using single components of the TLSs and is linking them together. This linking is a semantic linking not a technical one in this context. This approach will result in a high number of different TLS instances. However, the number of different sub-types of TLSs, e.g. inductive or deductive lecture (cf. section 3.3.2) is limited.

At this point it is important to analyse which TLSs should be used in the EFTECS. To make this decision it will be necessary to evaluate how different TLSs can be created in a computing paradigm and how their specific meta-information has to be used in the EFTECS. Several TLSs were identified in the literature review and the ones that were selected for the EFTECS will now be introduced.

3.3.1 Question and Answer

The first TLS that was selected for an implementation into the EFTECS was the QA-TLS. It was selected due to the fact that it is already used in several educational hypermedia projects [175]. Additionally, the single parts of this TLS were easy to identify, based on the authors experience. Table 1 illustrates the identified components of the QA-TLS which can be linked together to form the following sub-types of a QA-TLS:

- Single Choice
  One correct answer to a question must be selected out of several possible answers.
- Multiple Choice
  One or more correct answers to a question are possible.
- True or False
  A specific answer to a question is either true or false.
- Yes or No
  A special type of question and answer which is used in questionnaires and in test situations.

Question and Answer meta-information
<QUESTION>
<CORRECTANSWER>
<ANSWER>
<EXAMPLE>
<HELP>

Table 1: Question and Answer meta-information

It has to be mentioned at this point that the framework does not claim to cover every QA-TLS possible. For example, the QML (Questions Markup Language) [175] is focusing on different kinds of QAs and their application in questionnaires and there are many other QA scenarios possible. However, the selected and defined types of QA will be sufficient to demonstrate the general feasibility of the framework for this project.

3.3.2 Lecture

It is important to realise that a lecture in a computing context is not the same as a lecture in a classroom environment. In the literature review three basic types of lectures were identified: inductive lectures, deductive lectures and networked lectures [96]. The Lecture-TLS was selected for implementation into the prototype, because it seems feasible to convert it into a computing paradigm. The kind of meta-information needed for a lecture is shown in table 2.

Lecture meta-information
<THEORY>
<PROOF>
<EXAMPLE>
<HELP>

Table 2: Lecture meta-information

Every piece of meta-information in table 2 represents an EHP. Different instances of the Lecture-TLS could be constructed out of these basic EHPs.

In this project a lecture is defined as the combination of information in a specific way, for example a theory of a concept is presented to the student in a browser. The student is then guided to a page where he is presented with some proof of this theory. Finally, the student is guided to a page with an example related to the topic. Throughout the presentation the student could be provided with some additional help from the system.

For the EFTECS the three following subtypes of lectures were implemented:

- Inductive
  A specific theory is followed by the proof of the theory followed by an example.
- Deductive
  A theory is developed out of an example and finally proof is given.
- Network Style
  Several Lecture-TLSs are connected and combined so that a deeper insight of a general concept can be transferred to the student.

3.3.3 Case Study

Another TLS in the context of the EFTECS is the Case-Study-TLS. The Case-Study-TLS looks at a specific object (task, process, state) from different angles.

For example, the creation of a multimedia advertisement for the WWW could be presented to the student as a case study. Each step of the production, from the initial filming, digitalisation of the material, cutting of the material and finally the output in a WWW compatible format can be described in a general way. After that the student can view the different steps from different angles or perspectives, e.g. those of a cameraman, a programmer, an animation specialist and so on. This enables the student to get a more complete view of the specific tasks as well as the global process. The following components of a Case-Study-TLS are considered to be necessary for the creation of an instance of the Case-Study-TLS. The suggested meta-information can be seen in table 3.

Case study meta-information
<DESCRIPTION>
<VIEW>
<VIEWER>
<EXAMPLE>
<HELP>

Table 3: Case study meta-information

Different sub-types of a case study that can be created with the EFTECS henceforth are:

- Linear
  The student navigates through the case study in a linear way. The different views on the different tasks cannot be investigated by the student. The main focus is on the general process.

- Circular
  The student can navigate through the different views and angles of a specific part of the case study, for example a business case can be viewed from the viewpoint of a developer, an accountant and a client. The student's main focus is on one specific task or role of the case study.

- Free
  The student can navigate freely through the case study either in a linear way,

in a circular way or in a combination of both. The major focus lies on the student's interests.

It is assumed that an instance of a Case-Study-TLS could be built based on these tags. However, further analysis is necessary and will be done during the next stage of the project (cf. chapter 4).

3.3.4 Drill and Practice

Drill-and-Practice-TLSs are already extensively used in a computing context and could easily be included in the EFTECS. In a scenario using this TLS, students are first given a "drill" or practice running of a task, e.g. the demonstration and construction of a do-while-loop in programming, and are then instructed to do the task on their own over and over again. A possible set of meta-information that could form the basis of this TLS is shown in table 4.

Drill and practice meta-information
<DRILL>
<INSTRUCTION>
<EXAMPLE>
<HELP>

Table 4: Drill and practice meta-information

The implementation of this TLS into the actual prototype was not possible due to time and resources restrictions. However, the future work (cf. section 9.2) on the EFTECS and its prototype authoring tool does not only aim at the implementation of the Drill-and-Practice-TLS but also at the implementation of several additional TLSs.

3.4 EFTECS at EHP-Layer

As introduced in section 3.1, the EHP-layer of the EFTECS works with the single components of a TLS. In this context, an EHP is defined as a single piece of hypermedia content (text, sound, animation, etc.) combined with some specific piece of educational information. Therefore, EHPs are the most basic components of the EFTECS. They are designed to build, in combination with the educational information of the TLS- and the EM-layer, material for educational hypermedia.

Additionally, the working scope of the EHP-layer lies on the lowest level of the model and it does not only manage every single EHP, but also the tagging of each EHP, the storage of the data or the retrieval of the data.

Another task that is fulfilled by the EHP-layer is to structure the educational content (text, videos, pictures, multimedia in general) by adding information about the educational meta-data. This additional meta-data divides the single multimedia elements into different categories, for example “subject area”, “difficulty” or “required previous knowledge”. The EHP-layer will also provide the educational expert with a structured view of already existing EHPs. This summation of EHPs will be addressed as Content Space and introduced in more detail in section 3.7.

To achieve a complete separation of the educational from the technical content of all the EHPs of the different TLSs it was necessary to analyse every single component of the TLSs. This analysis resulted in the fact that the additional educational information can be grouped together in the following EHP-information tags:

3.4.1 Physical information

The information about the actual place, media-type and the preferred application of the EHP is important for the authoring tool. Without this kind of information the authoring tool would not be able to build the educational module which has to be delivered to the student. The single meta-tags have the described purposes:

- URL
  The URL information about the EHP allows the EFTECS to access different

hypermedia elements at different locations on the WWW. The location of the different EHPs at different locations throughout the WWW is therefore guaranteed.

- MEDIATYPE
  At the lowest level of the EFTECS it is important for the authoring tool to know with which kind of hypermedia it is working. This allows different ways of using text, video, audio and so on.

- PREFERRED APPLICATION
  To display or use the EHPs in the best possible way it is important to know which application should be used, for example a hypermedia educational authoring tool, a specific video player or a third party application such as Apple Quicktime for specific videos.

3.4.2 Domain information

The domain information of the EHP allows the EFTECS to create an efficient structure for the content space. It is necessary to know which topic or domain the material is from. For this version of the EFTECS only three levels of domain information were created. However, if it turns out that three structure levels are not enough, the EFTECS can easily be extended by additional domain information layers.

- TOPLEVEL
  The toplevel information of the EHP provides the basic domain information of the EHP, e.g. programming.

- SUBLEVEL
  The sublevel information of the domain allows a more detailed description of the domain of the EHP, e.g. C++ programming.

- SUBSUBLEVEL
  The lowest level of the domain information, the sub-sublevel, provides the EFTECS with the finest description of the domain of the EHP, e.g. pointers.

3.4.3 Adaptation information

It is very important for the EFTECS to have access to specific information about how the EHPs can be used in an adaptive context. To achieve the adaptation of the material to the needs of different students it is necessary to have the adaptation information of the EHPs to realise the optimal adaptation.

- AGE
  The information about the age of the student who the EHP is aiming at is important and can be attached to the EHP with this meta-tag, e.g. material that is only relevant for 10th grade and above.

- PREVIOUS KNOWLEDGE
  As already pointed out in the literature review (cf. section 2.11), the knowledge of the student about a specific topic is important for the further learning process. Therefore, it is necessary for the EFTECS to have the ability to store some information about the previous knowledge of the EHP that the student must possess.

- LEARNING PREFERENCES
  To achieve the best learning effect for the student, it is necessary to have some information about the student's learning preferences. With the learning preferences meta-tag, the EFTECS can store information about how the EHP is used best in different TLSs.

- GENDER
  To allow the gender specific adaptation of the information this tag was introduced in the EFTECS. However, the meta-tag is not used in the HEAT at the moment, but could be envisaged to be used in gender specific education scenarios.

3.4.4 Additional information

Due to the fact that the EFTECS is an extensible framework, the area of additional information has already been realised in the EFTECS. If the EFTECS needs to be extended for specific tasks without changing the whole framework, it is necessary to have a dynamically extendable group. As two examples of such a dynamic extension of the EFTECS the following meta-tags were introduced.

- LANGUAGE
  For an international usage of the EFTECS and the created authoring tool it seemed necessary to provide some information about the language of the EHP. Consequently, the students can be provided with material in their mother tongue or in a foreign language.

- KEYSET
  For an even stronger internationalisation the different key sets and character sets in a global environment need to be considered. Therefore, it is possible to store the specific key set of the EHP.

3.5 Linking information

The linking of the different parts of the EFTECS is important for the implementation of the HEAT. The linking of the instances of the different layers of the EFTECS allows the later presentation of the material to the student and the navigation of the student through the material.

- Linking of EHPs
  The linking of several EHPs in a specific way allows the EFTECS to create specific instances of a TLS.

- Linking of TLSs
  The linking of TLSs in specific ways allows the creation of a complete EM within the EFTECS and the HEAT.

- Linking of EMs
  The linking of different EMs allows the creation of networks throughout the content space of the EFTECS.

3.6 Common meta-information

Another important issue is the question whether and how meta-information could be shared between several components of the EFTECS. The implementation and evaluation overhead of the EFTECS and the authoring prototype would be significantly decreased, if some of the identified meta-information could be reused for different EHPs, TLSs or even EMs. For example, it is quite predictable that almost every TLS will need “Help” information. Consequently, there is a possibility of reuse of this kind of information. Therefore, it is desirable to identify as many pieces of shareable meta-information of the different TLSs as possible.

However, it needs further work to determine which meta-information is shareable and which is not. This task should be undertaken after the implementation and evaluation of the authoring prototype tool, in order to use the insights gained during the implementation and evaluation process. However, this additional evaluation process will have to be addressed during future work (cf. section 9.2).

3.7 Content space

In order to achieve a maximum level of reusability of already existing educational material, this material has to be structured in a specific way. This structure should allow the fast and domain specific search for existing material. Within the EFTECS this structure is called content space. The content space stores all EHPs, TLSs and EMs and the linking information between them.

Furthermore, the content space is dynamically growing in size. It is extended with every new piece of authored educational hypermedia material. The bigger the content space gets, the more options an educational expert will get to reuse material.

Some desirable advantages of the content space are:

- It is growing in size with every new piece of authored educational hypermedia.
- The search for educational material should be fast and easy.
- It supports the reuse of educational material.
- The existing linking between the single elements of the content space will allow insights into the authored material.

However, the design and implementation of such a content space is far out of scope for this PhD. The authoring tool will implement a static approach of the content space in form of an SQL database, which will allow quick and easy access to the already existing material, but will not apply any artificial intelligent operations on the material.

3.8 The complete EFTECS

Finally, all the introduced aspects of the EFTECS need to be put together. This will be done in a visualisation of the EFTECS, which is shown in table 5.

EM-Layer	<EM> <AUTHOR> ...				
TLS-Layer	<TLS> <EXAMPLE> ...				
EHP-Layer EHP related	QA <QUESTION> <ANSWER> <CORRECTANSWER>	Lecture <THEORY> <PROOF>	Case-Study <DESCRIPTION> <VIEW> <VIEWER>	Drill&Practice <DRILL> <INSTRUCTION>	Common <EXAMPLE> <HELP>
EHP-Layer Domain related	<TOPLEVEL> <SUBLEVEL> <SUBSUBLEVEL> ...				
EHP-Layer Adaptation related	<AGE> <PREVIOUS KNOWLEDGE> <LEARNING PREFERENCES> <GENDER> ...				
EHP-Layer Physical information	<URL> <MEDIATYPE> <PREFERRED APPLICATION> ...				
EHP-Layer Additional information	<LANGUAGE> <KEYSET> ...				

Table 5: Review of proposed 3-Layer-Model

It is important at this point that the '...' symbolise the extensibility of the model. The model can be horizontally and vertically extended, e.g. additional TLSs could be introduced as well as additional EHPs at the different layers. Furthermore, the model also hints at how it can be beneficial to a tutor even without having an authoring tool based on it: the educational material can be structured and organised with the model, which provides the author with a good overview of his material.

3.9 The eXtensible Educational Markup Language - XEML

The technical conversion of the EFTECS into a hypermedia context is a new markup language called XEML - eXtensible Educational Markup Language. The conversion is based on XML and has been developed to tag the educational material with the appropriate meta-information that has been identified during the development of the EFTECS. The coding represents the Document Type Definition file (heat102.dtd) that is used by the HEAT.

The complete code of the XEML can be found in appendix A.6.

3.10 Summary

This chapter introduces the EFTECS (Extensible Framework of Technical and Educational Content Separation) and outlines the theoretical approach used to create it (cf. section 3.1). More specifically, the Educational Module Layer (cf. section 3.2), the Teaching and Learning Strategy Layer (cf. section 3.3) and the Educational Hypermedia Primitive Layer (cf. section 3.4) are specified. Furthermore, the linking information between EMs, TLSs and EHPs (cf. section 3.5) are introduced as well as the common meta-information (cf. section 3.6) shared between the different layers. Additionally, the content space as a basis for reusing educational material (cf. section 3.7) is presented. Finally, the complete EFTECS (cf. section 3.8) and the technical conversion of the EFTECS, the XEML (cf. section 3.9) are introduced.

4 HEAT

As mentioned in the previous chapter, it is necessary to build a prototype authoring tool to demonstrate the practical usability of the EFTECS. This prototype application will further on be called HEAT - Hypermedia Educational Authoring Tool. It was developed to address the following issues:

- How can the EFTECS - a theoretical model - be converted into an application?
- What technical solutions and standards can be used to implement the HEAT?
- How can the content space be realised without creating too much organisational overhead that would be out of scope for this PhD?
- How can existing material be searched and reused within the content space?
- How can a working example be created?

Due to the complexity of these issues it was necessary to break down the design and implementation of the HEAT into several tasks.

The first task was to decide on a general approach that covers the technical aspects like development tools or accepted standards as well as the general design aspects of the HEAT like the implementation style of the EFTECS or the realisation of the content space.

4.1 General approach

It was decided that standard software development techniques, for example object oriented programming, should be used for the general implementation approach of the HEAT. Additionally, the implementation task can be divided into the general technical solutions and the software design aspects.

4.1.1 Technical aspects

Several software development techniques like structural programming or object oriented programming were taken into consideration as a technique for the implementation of the actual authoring tool. After the implementation of several small prototype studies it was decided to use Java as the programming language to implement the HEAT. Java is a broadly accepted, third generation programming language [92]. Its most important advantages are the support of object oriented programming, its focus on the WWW and its cross-platform portability, making it possible to create an authoring tool that can be used on several platforms including WWW based communication capabilities. However, to develop a complex tool like the HEAT a professional development environment was necessary.

Several products could have been used, but JBuilder from Borland was considered to be the best solution, based on already existing development experience with this tool.

As already decided during the development of the EFTECS, the actual conversion of the framework is done with XML forming the new educational based markup language XEML. However, at the time when the HEAT was developed, there was no existing WWW browser that could render XML and therefore XEML in a proper way. Therefore, a temporary workaround needed to be developed to overcome the existing technical boundaries at the time. This workaround will be explained in 4.7 and is based on a dynamic mixture of HTML, XSL and Java Script.

For the implementation and the management of the content space the standard Java database distributed with the JBuilder package was selected to minimise the technical and organisational overhead of the creation of the content space. Furthermore, the usage of the inbuilt database guaranteed easy access to the stored material from the HEAT.

Altogether, it can be claimed that for the implementation of the HEAT and the content space broadly accepted standards have been selected and used, which facilitates the possibility of further development and compatibility of the HEAT with WWW standards in the future.

4.1.2 Design aspects

The general technical aspects pointed out in 4.1.1 were applied to the design of the HEAT. The following design aspects were applied during the development of the HEAT:

- Object Oriented Design
  The HEAT was implemented by using Borland JBuilder3 and Java2 [168][170] and by applying an object oriented approach. Additionally, the design of the HEAT is based on classical object oriented design patterns. This approach facilitates the extensibility of the HEAT. For example, if a new TLS needs to be added, it just has to implement the pre-defined interfaces and methods of the HEAT framework and it can be used. Furthermore, an object oriented approach was considered to be more feasible for the implementation of the HEAT, which consists of 15 different java-classes at the moment.

- Top-Down Design
  For the implementation of the HEAT it was necessary to decide how to convert the EFTECS into an application regarding the layers of the EFTECS. There were two possibilities, either a top-down approach that uses the EM-layer as the working space of the HEAT or a bottom-up approach that focuses on the individual EHPs. During the implementation process it proved to be more feasible to use a top-down approach for the implementation.

- Representation of the EM-layer
  The working frame of the HEAT represents the EM-layer of the EFTECS. Every TLS and every EHP that is created within the working frame is a part of the actual EM.

- Representation of the TLS-layer
  The TLS instances are symbolised by rectangles that are added to the working frame of the HEAT and therefore to the EM. The TLSs can be created, edited and deleted by mouse or keyboard inputs.

- Representation of the EHP-layer
  The EHP-layer of the EFTECS is represented by the single elements within

the different TLSs. Several EHPs can be part of every individual TLS and EM.

- Authoring process
  The author of the educational material is primarily working on the main HEAT interface, which represents the EM-layer of the EFTECS. If the author wants to modify the different TLSs and EHPs, he has to modify the information within the TLSs or the EHPs (cf. section 4.8). This is a result of the chosen top-down design of the HEAT.

- Material processing
  The creation, processing and delivery of the authored material is designed to be handled by the HEAT. The author has to specify only the directory where the educational material has to be stored - usually a web server - and the system will undertake the necessary steps.

- Material search:
  The HEAT is also designed to support the author in the search for already existing material. The HEAT provides the author with a query interface that allows him to search for every single meta-information, for example subject or target audience.

- Material storage:
  The storage of the created educational material was designed in the EFTECS to be either WWW based or database based. To reduce the overall implementation overhead of the HEAT, it was decided to use the database approach.

4.2 EHP-Layer

The EHPs that are defined in the EFTECS were implemented into the HEAT with the following design and technical aspects.

4.2.1 Design aspects

The design aspects of the EHPs that had to be considered during the implementation of the HEAT will now be introduced. The working principle of the EHPs can be split up into three categories: the creation of an EHP, the usage and modification of an EHP and finally the removal of an EHP when it is not needed anymore.

- Creation
  During the creation of an EHP it is necessary to specify its basic parts as defined in section 3.4. The name, the content and the kind of content of the EHP have to be assigned. Additionally, the EHP-information belonging to the newly created EHP must be created and filled with information. The design and the technical aspects of the EHP-information can be found in section 4.3.

- Usage and modification
  Once EHPs are created, their data can be accessed and modified in several ways. This is necessary whenever a specific change has to be made to the EHP or the connected EHP-information. For example, if an EHP is reused in some other EM, usually the domain of the EHP-information has to be changed. All the methods used to change the information of the EHP can be found in section 4.2.2.

- Removal
  If an EHP and its attached EHP-information is not needed anymore, it simply can be removed from the position it actually takes. The information the EHP held is lost, unless it was already stored in the content space.

4.2.2 Technical aspects

The following technical aspects of EHPs were designed, analysed and taken into consideration during the implementation of the EFTECS into the HEAT. First of all, it was necessary to convert the EHP-design of the EFTECS into an object oriented class concept. Therefore, a basic EHP-class was defined as follows:

Class elements were designed to hold the actual content of the EHP:

- EHPElementName(String)
  This class element stores the name of the EHP-element, e.g. correct answer.
- Content(String)
  The content element of the EHP-class stores the actual content of the EHP, for example the correct answer of a QA-TLS.
- Attribute(String)
  This element of the EHP-class stores the actual hypermedia-type of the EHP, e.g. text, audio, video.

Interface methods were designed to allow access to the class elements of the EHP-class:

- setEHPElementName(String EHPElementName)
  This method allows to assign the element EHPElementName a new value which is given to the method as a method parameter.
- getEHPElementName()
  This method returns the name of the EHP-element.
- EHPElement(String EHPElementName, String content, String attribute)
  This method is the standard constructor of the EHP-class which allows the creation of a new EHP-class instance. It needs three method parameters: EHPElementName, content and attribute. These parameters are set as the starting values of a new EHP-instance.

- setText (String content)
  The setText method allows to set or change the content of an EHP-element.
- setAttribute(String attribute)
  This method allows to set a new value for the attribute element of the EHP.
- getContent()
  This method returns the content of the EHP to the caller of the method.
- getAttribute()
  This method returns the attribute of the EHP to the caller of the method.
- toString()
  The method toString is a generalised method of the EHP-class that provides the complete output of the instance of the EHP-class. This method is mainly used for data creation, file generation and printing.

4.3 EHP-Information

During the work on this PhD project it was discovered that several attributes of the EHP-layer of the EFTECS can be generalised and can also be used for the TLS- and EM-layers. All the information that is not directly connected with the learning content of an EHP will be summarised in one globally used layer: EHP-information-layer.

4.3.1 Design aspects

Before the creation of the EHP-information-layer it is important to identify the information of the EHP-layer which can be shared globally. After re-evaluating the model the following parts of the EHP-layer were restructured into the EHP-information-layer:

- Domain related information
- Adaptation related information
- Physically related information
- Additional information

The selection of these specific information packages is based on the assumption that the information can be used for every single EHP, every TLS and every EM. For example, it does not make a difference whether the domain information of an EHP or an EM is stored in the same logical construct. Therefore, the EHP-information-layer meta-data will not only be used for EHPs, but also for the TLSs and the EMs to implement reusability and structured storage of the TLSs and EMs as well.

The actual specification of the domain information or some of the adaptation related information can be very challenging, for example the level of difficulty of some educational material will always be different for experts, teachers or students. Therefore, some of the needed meta-information must be discussed and agreed upon before it can be used within the HEAT. However, this discussion process is not the aim of this work and should be addressed at the potential educational institution where the HEAT is used.

4.3.2 Technical aspects

The technical implementation of the EHP-information is done similarly to the implementation of the EHP. A class was defined which holds all the necessary elements and methods needed.

The needed elements and methods will now be presented in table 6. The table illustrates which elements were designed and used. For every element set-methods and get-methods were implemented to guarantee data modification.

Element	Information area
DomainInformation	Domain
Age	Adaptation
Previous knowledge	Adaptation
Learning Preferences	Adaptation
Gender	Adaptation
Grouplevel	Adaptation
URL	Physical
Mediatype	Physical
Preferred application	Physical
Language	Additional
Keyset	Additional
Author	Additional
Authoring date	Additional

Table 6: Elements and methods of the EHP-information

Finally, it is important to state that every single element within the EHP-information-layer is technically implemented as an EHP. This technique allows the later modification of even the tiniest piece of information within an EHP-information of an EHP by the author.

4.4 TLS-Layer

The second layer of the EFTECS works with the identified teaching and learning strategies. The implementation firstly has to address the creation of the specific EHPs within a TLS and secondly the creation, modification, removal and linking of the different TLSs within an EM.

4.4.1 Design aspects

- Creation
  During the creation of a new TLS within an EM it is important that the EHP-information of the EM can be inherited. This inheritance sets the EHP-information of the TLS and all its EHPs to the same values that the EHP-information of the EM has, for example if the author has edited the domain information of the EM, he can inherit this information for every TLS he creates and therefore can save some work. Additionally, all the necessary EHPs for the selected TLS need to be generated. Finally, the presentation style of the educational content must be set. A possible adaptation of the presentation style is not an issue at this point, but must be addressed during the presentation phase.

- Modification
  The modification of the TLS allows the changes of everything within the TLS. This means that all the EHPs of the TLS, the presentation style can be edited. The only exception is the selected TLS-form, which cannot be changed at this point.

- Removal
  The removal of a created TLS from the EM is possible at any given time. However, the linking to and from the TLS is lost as well as the content of the EHPs within the TLS.

- Linking
  The linking of the TLSs is extremely important for the EM and the later navigation of the student through the material. The linking is realised by

an indexing system which includes all the existing TLSs in the EM and is presented to the author with colour-coded lines in the HEAT.

4.4.2 Technical aspects

The technical aspects of the implementation of the TLS-layer into the HEAT have to cover several topics. Most importantly, as described in section 3.1, the EFTECS and therefore the HEAT should be easily extensible. The technical design of the TLS-class has to be divided into one basic class that will define general EHP-elements and methods and several specialised classes that will then extend the basic class with the specific EHPs and methods for the different TLSs. If a new TLS needs to be implemented into the HEAT, it is necessary only to implement the specialised class based on the general TLS-class (cf. section 4.8).

Additionally, the linking of the TLSs has to be addressed specifically because the linking of the TLSs also determines the students' navigation through the material. Due to time and resource limitations during the implementation phase it was decided not to create a mouse based linking option for the author, but to use an index based approach that implements colour-coded representation of the different link-types, for example direct link, split link or join link. Table 7 illustrates the basic TLS-class.

Element	Type
xslFile	EHPInformation
Help	EHPInformation
Example	EHPInformation
ehpInfo	EHPInformation
linkInfo	LinkInformation

Table 7: Elements and methods of the basic TLS-class

Table 8 illustrates the specialised elements and methods of the Lecture-TLS-class (cf. section 3.3.2).

Element	Type
xslFile	EHPInformation
Proof	EHPInformation
Theory	EHPInformation
Example	EHPInformation
Help	EHPInformation

Table 8: Elements and methods of the Lecture-TLS-class

Furthermore, set-methods and get-methods were created for every element of the classes, but are not introduced here in detail.

4.5 EM-Layer

The EM-layer of the EFTECS will work as the frontend to the user during the authoring process of the educational material. The author will create EMs, TLSs and EHPs within the HEAT. Furthermore, the modification of EHPs within TLSs, the production of the educational material for the presentation to the student via the WWW and the usage of the stored educational material in the content space are implemented as the main HEAT working interface.

4.5.1 Design aspects

As mentioned above, it has been decided to use the implementation of the EM-layer as the main HEAT interface to the author. This results in the effect that the author is not able to distinguish between the EM-layer and the HEAT, because for him it is basically the same. Therefore, the EM-layer becomes transparent to the author.

- Creation
  The creation of a new EM is seen as being rather easy for the author. Due to the fact that the main working interface of the HEAT represents the EM-layer of the EFTECS, the author creates a new EM immediately when he creates some new educational material.

- Removal
  The removal of an EM is seen as being very easy to achieve. However, every TLS and every EHP within the EM is also removed, as long as they were not stored in the content space. However, a warning is given to the author by the HEAT.

- Linking
  The linking of different EMs is not implemented in this version of the HEAT. Every EM is regarded as a stand-alone course. However, the future work in this domain will have to address the issues of inter-EM-linking (cf. section 9.2).

The important features of content space and material production of the HEAT will be introduced in 4.6 and 4.7 respectively.

4.5.2 Technical aspects

The actual technical implementation of the EM is too complex to be discussed in detail at this point of the project because the complete HEAT workspace would have to be discussed at this level as well. However, the basic elements and methods of the EM-layer will be introduced in table 9. The set-methods and get-methods of the single elements were also implemented.

Element	Type
ehpInfo	EHPInformation
TLSVector	Vector of TLSs
addTLStoVector	TLS
removeTLSfromVector	TLS

Table 9: Elements and methods of the EM-class

To provide a visualisation of the HEAT and the implementation of the EFTECS a detailed example of how the HEAT works is given in 4.8.

4.6 Content space

The content space as defined in 3.7 is implemented into the HEAT as a prototype and will be described in the following paragraphs.

The technical solution is implemented with a relational database. This database is part of the JBuilder 3 package and implemented in Java. All the information created with the HEAT is stored in tables and can be accessed by dynamically created queries.

The insertion of new or additional material into the content space is very important for the HEAT. Several different approaches are possible, but only one has been implemented into the HEAT. This implementation adds new material to the content space every time the author produces a new EM for delivery on the presumption that such material is authored correctly. This is done by adding the information to the database that forms the technical representation of the content space for the HEAT.
Other approaches could include external interfaces, e.g. data import from other authoring systems. However, extensive research in this domain is left for future work (cf. section 9.2).

The search for already existing material in the content space is crucial if the author wants to reuse some pre-existing material. For this PhD project the search is implemented as a dynamic query search for every EHP-information described in 3.4. However, the development of more sophisticated search algorithms is left for future work (cf. section 9.2).

Once the author finds some material in the content space he can reuse this material. He can import the material he wants to reuse by selecting one item from the search list.

The controlled removal of material from the content space is considered to be out of scope for this PhD on the presumption that existing educational material is too valuable to just be deleted or removed. Additionally, it seems more interesting to invest more research into the possible rating of educational material, but this is left for future work (cf. section 9.2), too.

It was defined in 3.7 that the content space is not only growing in size with every new piece of authored educational hypermedia, but that it should also provide the following functionalities:

- The search for educational material should be fast and easy.
  This demand is fulfilled by the implemented functionalities of the HEAT content space, for example search and query functionalities based on EHP-information (cf. section 4.8).

- The reuse of educational material should be possible.
  This demand is also fulfilled by the HEAT at this point of the PhD project, e.g. after the author has searched the content space for TLSs or EHPs he can import specific TLSs or EHPs into his own EM and therefore reuse existing material.

Finally, it has to be stated that several research topics concerning the content space are out of scope for this PhD. For example, it could be investigated whether the linking between single TLSs of an EM in the content space allows insights into the authored material and its reusability in another EM. These topics will have to be addressed in the future.

4.7 Material delivery

The final step in the authoring process is the delivery of the educational material to the student. Up to this point, this PhD project has dealt with the separation of the educational and the technical content in educational hypermedia. It becomes now important to know how the educational material is actually delivered and how this is done technically.

First of all, the author creates the educational material he wants to deliver as described in 4.8. When the author produces the authored EM, it is automatically stored in the content space and the educational material is specifically transformed into a WWW based format.

Depending on the EM created by the author, a start page is created which functions as an entrance point for the student to begin his way through the module. Additionally, the student's further navigation through the EM is supported by the created material based on the linkage of the material in the HEAT.

To achieve the needed transformation of the educational material into the WWW based form it was necessary to undertake the following technical implementation. The connection of XML files with XSL files is one of the important developments of this PhD. The implementation had to address these issues:

- The XML file had to be interpreted and displayed to the student by Internet Explorer.
- The specialised XSL files had to be created.
- The functionality of the Java Script within the XSL files had to be implemented.
- Whenever the material is accessed the XSL files are interpreted by the web browser and displayed to the student.
- The XSL files can be programmed in various ways that meet exactly the specific requirments for the correct presentation of the respective material to the student. This is a further proof of the successful application of the

concept of separation of educational and technical content in educational hypermedia.

- The XSL files can be inserted into the HEAT/XEML-framework dynamically. This guarantees the further extensibility of the framework.

Some examples of the XLS files developed during this PhD project can be reviewed in Appendix A.5.

After the material is delivered to the user via a material delivery interface, interactions of the user with the material delivery system can be saved and analysed. Using the results of this analysis the educational material can be adapted to the student's needs. The information about the student's preferences can even be transferred between educational systems using a n-dimensional framework [176].

However, this last step is regarded as out of scope for this PhD.

4.8 Detailed example

For a better illustration of the functionality of the HEAT, it is important to give a first example of its working scope. The following example will show how a tutorial is designed, built and distributed.

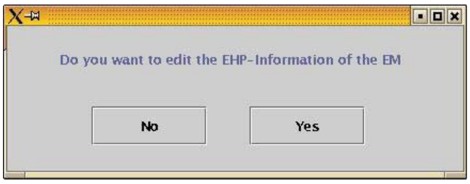


Figure 2: HEAT - Startup

During the startup procedure of the HEAT the author of the educational material is asked in a dialogue if he wants to enter the EHP-information of the EM (figure 2). However, this is not compulsory for the author. He can enter the information later or change the entered information. The EHP-information of the EM can be inherited for every TLS and EHP the author creates in the EM.

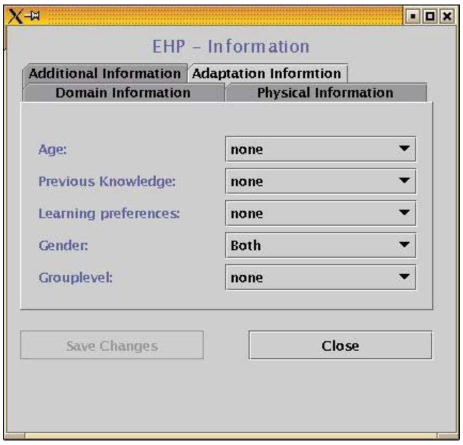


Figure 3: HEAT - Startup - EM EHP-information

Figure 3 shows the EHP-information of the new EM. The different elements of this dialogue box represent the educational information of the EM and can be modified by the author.

Figure 4 shows the HEAT after the initial startup phase. The author has the following options:

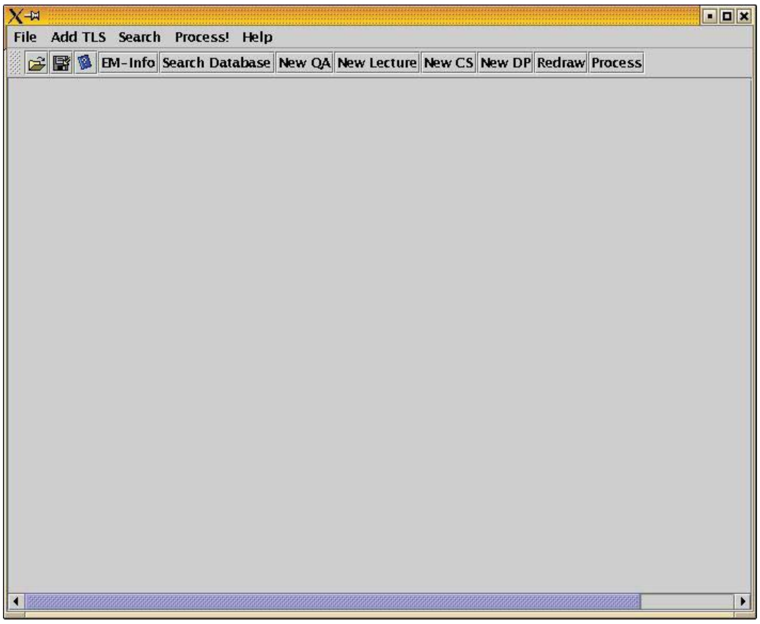


Figure 4: HEAT - Startup - Empty EM

- Add a new QA-TLS.
- Add a new Lecture-TLS.
- Add a new Case-Study-TLS.
- Add a new Drill-and-Practice-TLS.
- Search the Content Space for pre-used material.

To demonstrate the functionality of the HEAT, a demonstration walkthrough of several steps is now given:

The first step during the authoring process of an EM is to create an initial TLS. It is not necessary that the TLSs are created in the order they have to be in during the presentation phase. The actual presentation order is given by the linking information of the individual TLSs. Figure 5 shows a new EM with a first TLS selected for insertion into the EM. In this case it is a QA-TLS, which can be identified by the "Question & Answer" at the top of the TLS selection box.

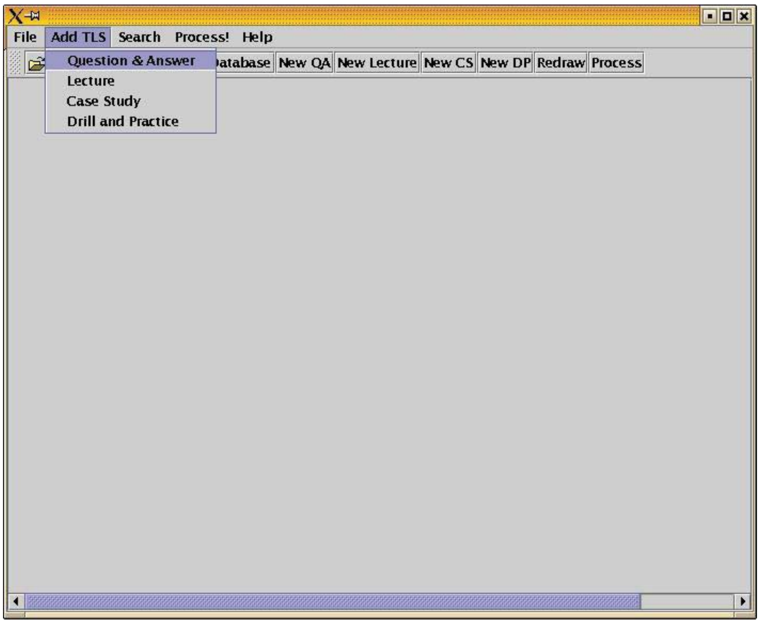


Figure 5: HEAT - Add QA-TLS

Figure 5 also illustrates the selection of a QA-TLS from the main menu of the HEAT. Alternatively, the TLS could be created by selecting the appropriate shortcut button in the toolbar of the HEAT.

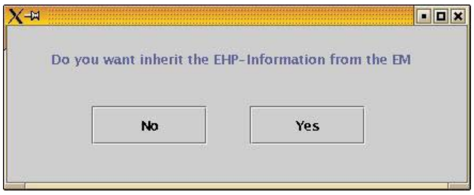


Figure 6: HEAT - Inherit EHP-information

Figure 6 shows a dialogue box that allows the author to inherit the complete EHP-information of the EM. The author can either accept or reject the inheritance. If the author accepts, the EHP-information of the EM will be copied into the EHP-information of the TLS and all the subsequent EHPs of the TLS. However, the author always has the option of changing the information or can type it in manually after rejecting the inheritance of the EHP-information of the EM.

Figure 7 shows the HEAT after a first QA-TLS was inserted into the EM. Additionally, the indexmarker of the TLS is given in brackets. This index is needed for

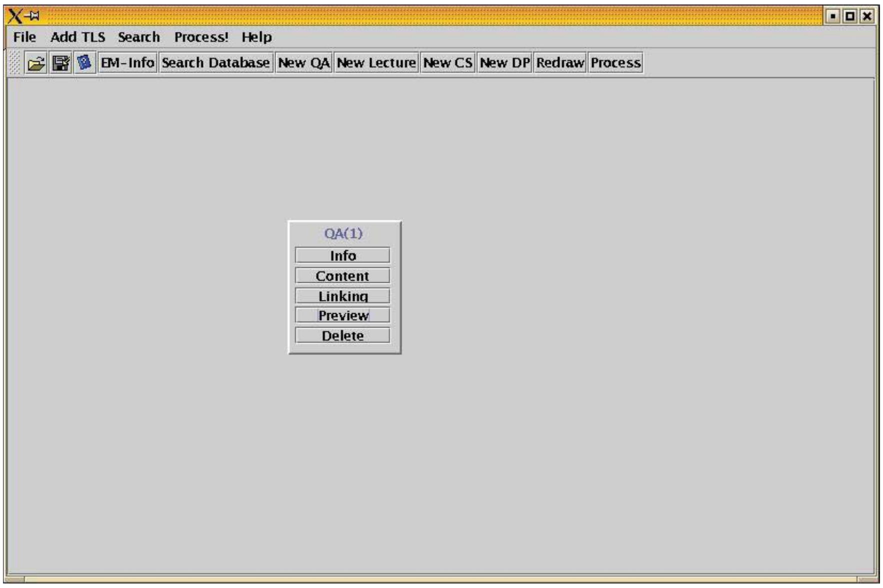


Figure 7: HEAT - QA-TLS

the linking and presentation order of the TLS within the EM. The author has now several options: he can insert another TLS, edit the EHPs of the QA-TLS, search the content space or produce the EM for display via the WWW. In this example the TLS will now be modified. First of all, the information of the QA-TLS will be modified.

Figure 8 shows the info dialogue of the QA-TLS. The author has the options of selecting the wanted TLS-style for the later presentation of the TLS. Furthermore, the author can enter an example or a help EHP. Additionally, the author can modify the EHP-information of the TLS as well as the EHP-information of the example or help information of the TLS.

Figure 9 shows the QA-TLS after the content button of the TLS has been pressed (cf. figure 7). The author has the opportunity to enter the actual content of the QA-EHPs in this dialogue. The mediatype of every single EHP can be set as well as the EHP-information of every single EHP. In this case, a QA-TLS, the author can also specify which of the answers is a correct one by selecting it in the QA-TLS.

Figure 10 illustrates the HEAT after another TLS has been added to the EM. The Lecture-TLS was added in a similar way to the QA-TLS, either by the appropriate

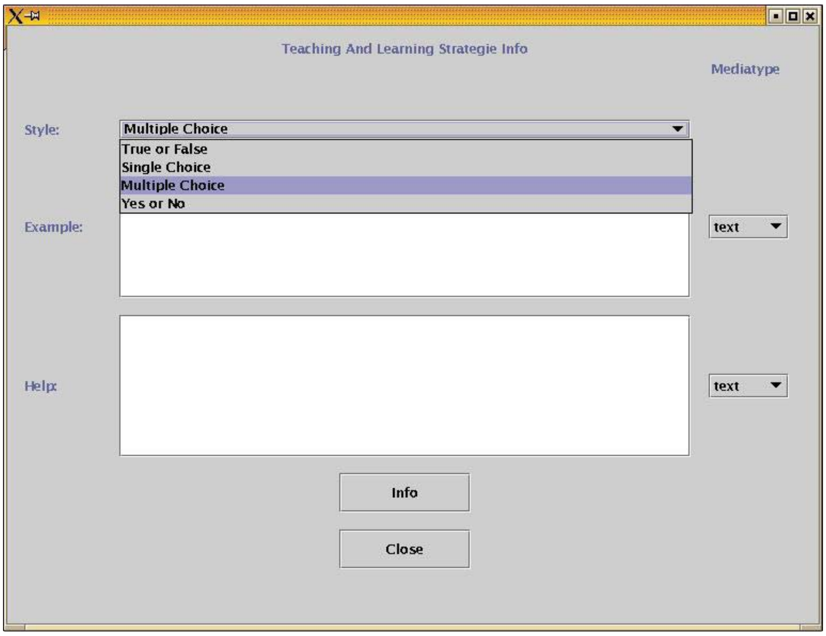


Figure 8: HEAT - QA-TLS Information

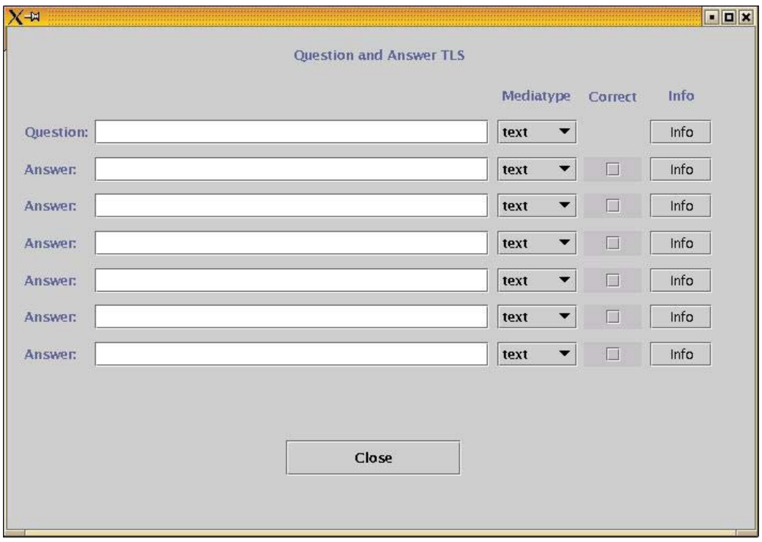


Figure 9: HEAT - QA-TLS Content

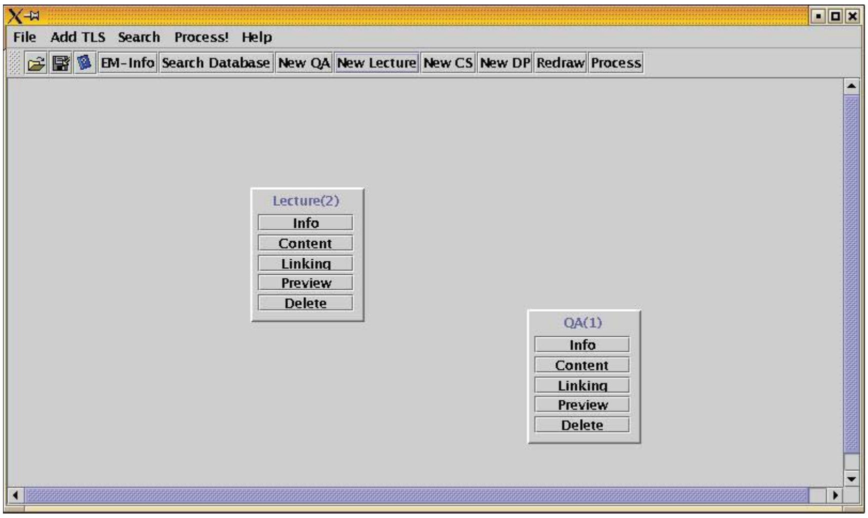


Figure 10: HEAT - Add Lecture-TLS

button or via the menu bar of the HEAT. The additional TLS is needed to illustrate the linking of the different TLSs.

Figure 11 shows the linking information dialogue of the Lecture-TLS. The author can set up to five different links to other TLSs and each of them can be one of several different linking types. The number of possible links was set to a maximum of five due to reasons of implementation resources. Theoretically, an unlimited number of links could have been implemented.

Every link can have a destination to another TLS which is selected by its individual index. In the example the Lecture-TLS is linked directly to the QA-TLS with the index 1.

The different link types can and will be presented differently during the presentation of the EM to the student.

Figure 12 shows the created link and its representation within the HEAT. To improve the overview of the TLSs and the connecting links, it is possible to turn the display of the links on and off by pressing the right mouse button. Additionally, the TLSs can be moved around and structured in the EM with a drag and drop functionality.

If the author wants to add additional TLSs he can do so by using the process

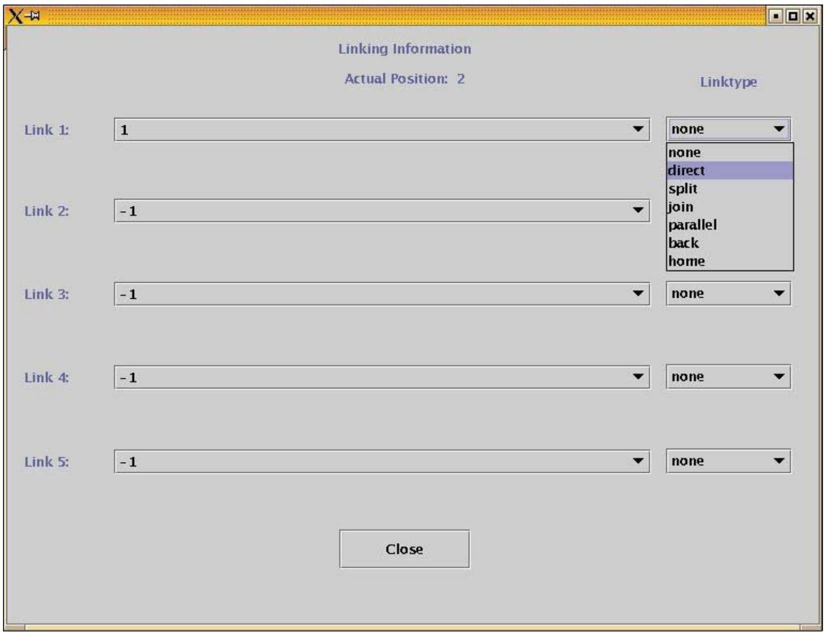


Figure 11: HEAT - Linking TLSs

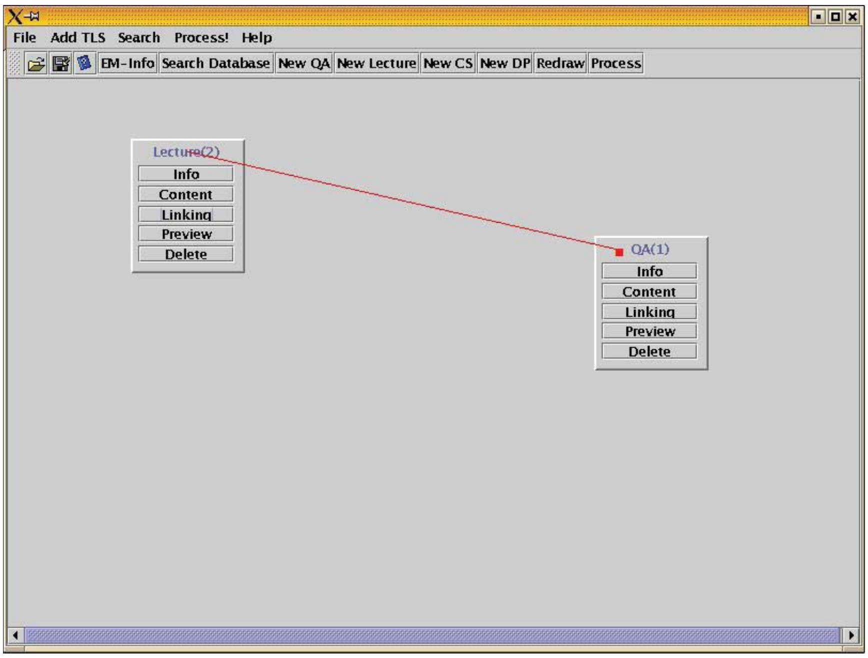


Figure 12: HEAT - Linked TLSs

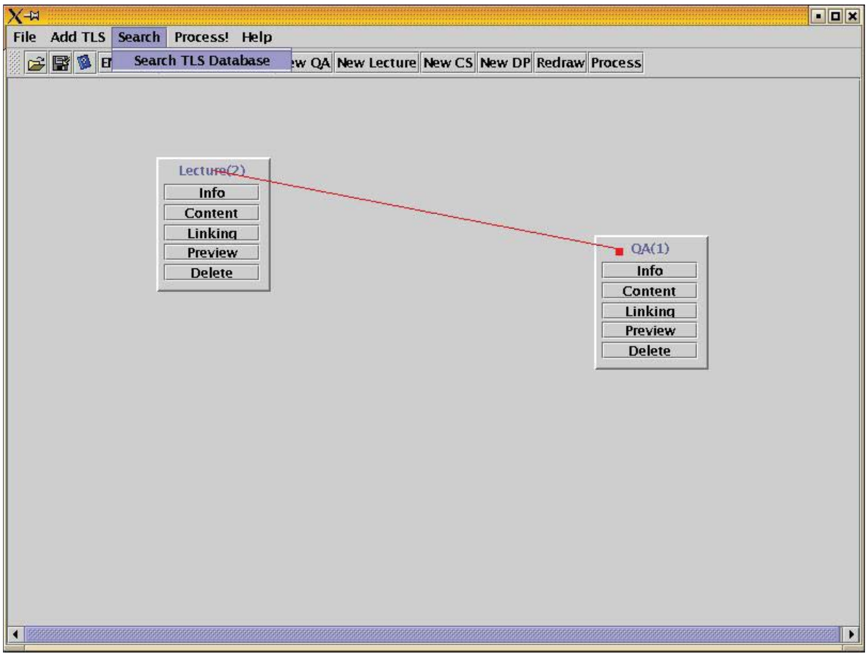


Figure 13: HEAT - Search Content Space

introduced above. However, the author of the educational material will probably reuse some existing material from the content space. Figure 13 shows how the search engine for accessing and searching the content space is activated. One or more TLSs can be added to the EM by searching the content space and importing existing material from it.

Figure 14 shows the dialogue for the content space query. The query can be designed to search for every single EHP-information stored in the content space. The results of the executed query can then be navigated element by element and the author has the option of viewing the content of the found EHPs and TLSs. If the author finds some material he wants to use for his EM, then he can insert the TLS into the EM.

Once the author has finished the creation of the EM he can start the production of the educational hypermedia material for the WWW. Figure 15 illustrates how the production process is started from the HEAT. The first step is the selection of "Start XML Creation" in the menu.

Figure 16 shows the dialogue used to process the educational material. The author

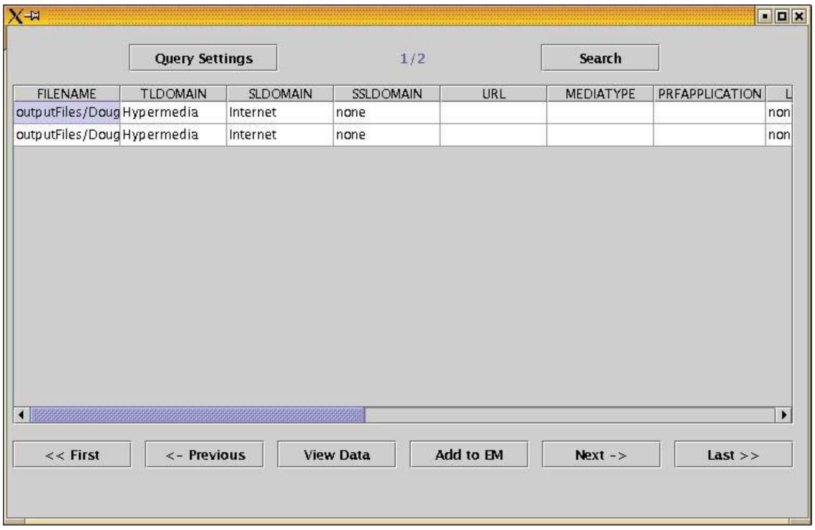


Figure 14: HEAT - Query Content Space

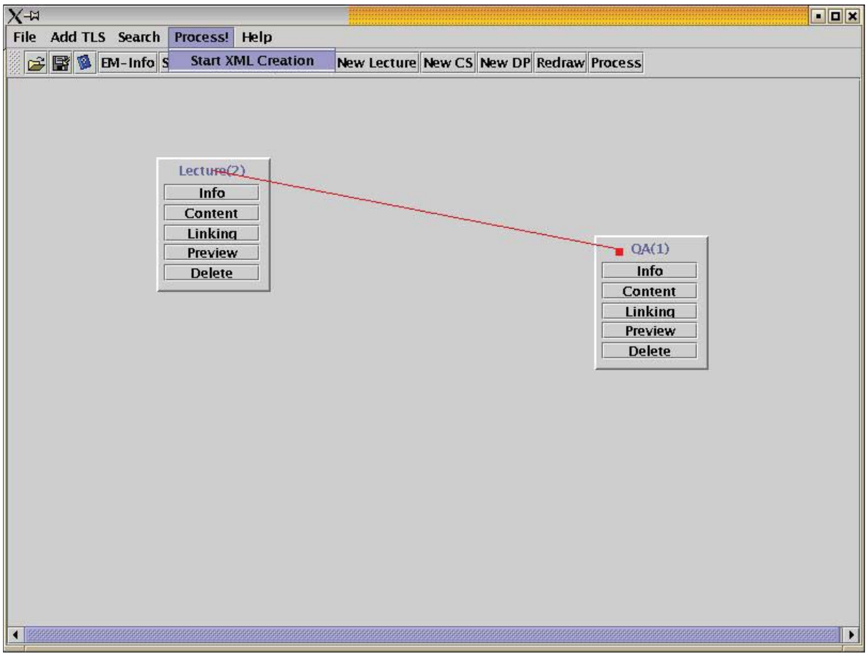


Figure 15: HEAT - Start XML processing

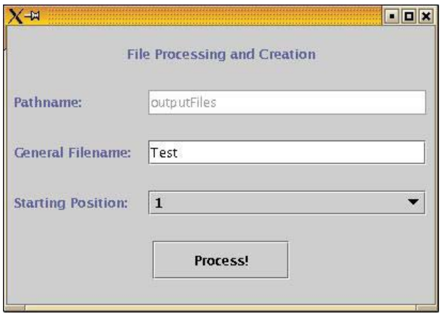


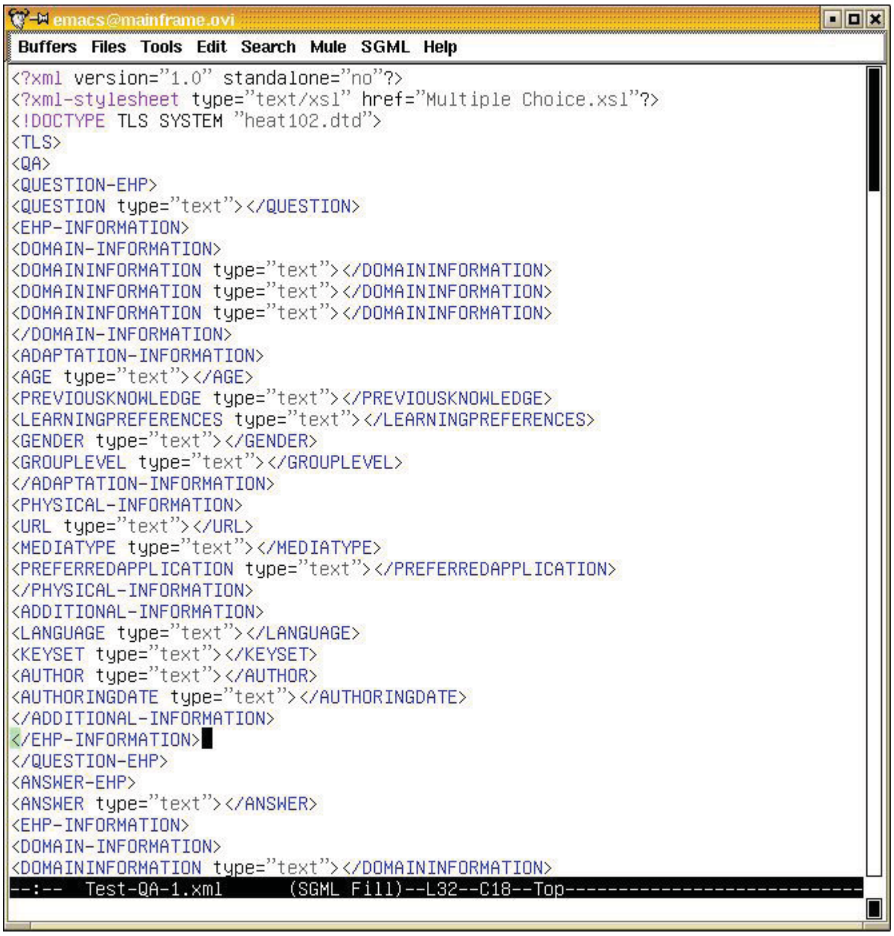
Figure 16: HEAT - XML creation information

is asked to name the path and general filename so that the created files can be stored. They can be directly stored on a webserver, where the material can be immediately put online.

The dialogue also asks the author to specify the index of the TLS which will be the student's starting point of the navigation through the material.

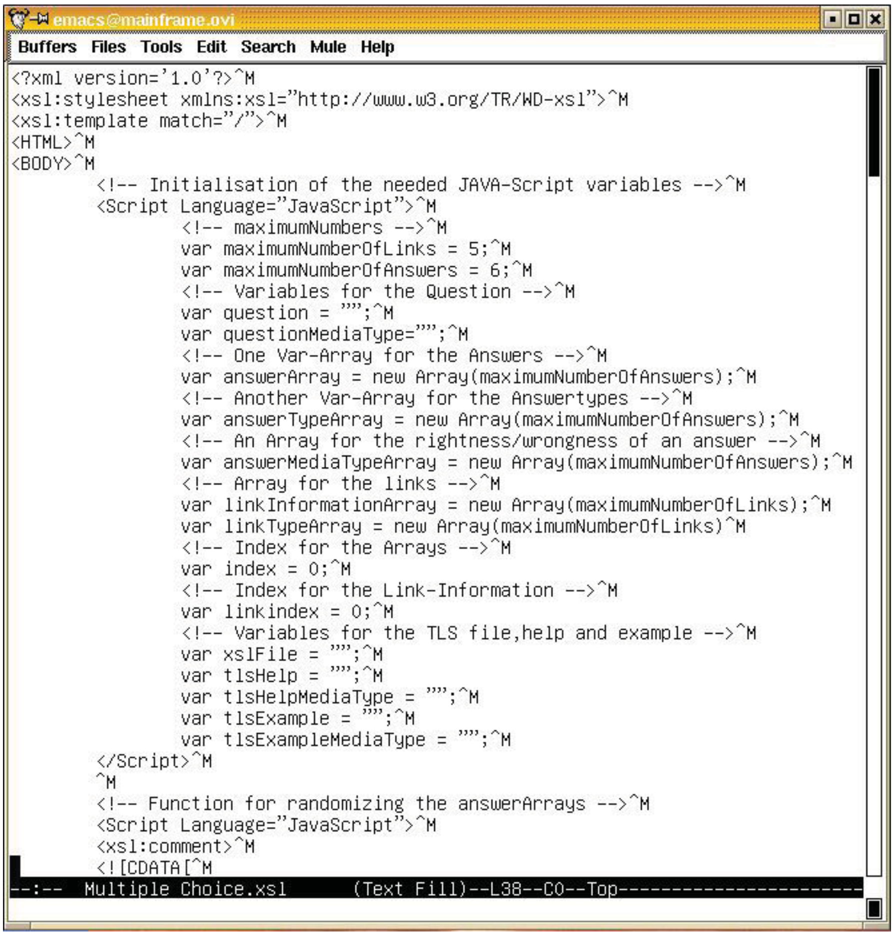
Finally, the production of the material is started by pressing the "Process"-button.

Figure 17 shows an example of the produced QA-TLS material in the XML file format. The XSL file needed for presenting the QA-TLS to a student is shown in figure 18.



```
emacs@mainframe.ovi
Buffers Files Tools Edit Search Mule SGML Help
<?xml version="1.0" standalone="no"?>
<?xml-stylesheet type="text/xsl" href="Multiple Choice.xsl"?>
<!DOCTYPE TLS SYSTEM "heat102.dtd">
<TLS>
<QA>
<QUESTION-EHP>
<QUESTION type="text"></QUESTION>
<EHP-INFORMATION>
<DOMAIN-INFORMATION>
<DOMAININFORMATION type="text"></DOMAININFORMATION>
<DOMAININFORMATION type="text"></DOMAININFORMATION>
<DOMAININFORMATION type="text"></DOMAININFORMATION>
</DOMAIN-INFORMATION>
<ADAPTATION-INFORMATION>
<AGE type="text"></AGE>
<PREVIOUSKNOWLEDGE type="text"></PREVIOUSKNOWLEDGE>
<LEARNINGPREFERENCES type="text"></LEARNINGPREFERENCES>
<GENDER type="text"></GENDER>
<GROUPLEVEL type="text"></GROUPLEVEL>
</ADAPTATION-INFORMATION>
<PHYSICAL-INFORMATION>
<URL type="text"></URL>
<MEDIATYPE type="text"></MEDIATYPE>
<PREFERREDAPPLICATION type="text"></PREFERREDAPPLICATION>
</PHYSICAL-INFORMATION>
<ADDITIONAL-INFORMATION>
<LANGUAGE type="text"></LANGUAGE>
<KEYSET type="text"></KEYSET>
<AUTHOR type="text"></AUTHOR>
<AUTHORINGDATE type="text"></AUTHORINGDATE>
</ADDITIONAL-INFORMATION>
</EHP-INFORMATION>
</QUESTION-EHP>
<ANSWER-EHP>
<ANSWER type="text"></ANSWER>
<EHP-INFORMATION>
<DOMAIN-INFORMATION>
<DOMAININFORMATION type="text"></DOMAININFORMATION>
--:--  Test-QA-1.xml      (SGML Fill)--L32--C18--Top---------------------------
```

Figure 17: HEAT - Created QA XML file




```
<?xml version='1.0'?>^M
<xsl:stylesheet xmlns:xsl=”http://www.w3.org/TR/WD-xsl”>^M
<xsl:template match=”/”>^M
<HTML>^M
<BODY>^M
        <!-- Initialisation of the needed JAVA-Script variables -->^M
        <Script Language=”JavaScript”>^M
                <!-- maximumNumbers -->^M
                var maximumNumberOfLinks = 5;^M
                var maximumNumberOfAnswers = 6;^M
                <!-- Variables for the Question -->^M
                var question = ””;^M
                var questionMediaType=””;^M
                <!-- One Var-Array for the Answers -->^M
                var answerArray = new Array(maximumNumberOfAnswers);^M
                <!-- Another Var-Array for the Answertypes -->^M
                var answerTypeArray = new Array(maximumNumberOfAnswers);^M
                <!-- An Array for the rightness/wrongness of an answer -->^M
                var answerMediaTypeArray = new Array(maximumNumberOfAnswers);^M
                <!-- Array for the links -->^M
                var linkInformationArray = new Array(maximumNumberOfLinks);^M
                var linkTypeArray = new Array(maximumNumberOfLinks)^M
                <!-- Index for the Arrays -->^M
                var index = 0;^M
                <!-- Index for the Link-Information -->^M
                var linkindex = 0;^M
                <!-- Variables for the TLS file,help and example -->^M
                var xslFile = ””;^M
                var tlsHelp = ””;^M
                var tlsHelpMediaType = ””;^M
                var tlsExample = ””;^M
                var tlsExampleMediaType = ””;^M
        </Script>^M
        ^M
        <!-- Function for randomizing the answerArrays -->^M
        <Script Language=”JavaScript”>^M
        <xsl:comment>^M
        <![CDATA[^M
```

Figure 18: HEAT - Multiple-Choice-QA - XSL file

Finally, the student can now navigate through the produced material, study the lecture and has the opportunity to answer the question of the QA-TLS.

As an example of the final result that is presented to the student, figure 19 shows a Lecture-TLS that explains in the Theory-EHP that Berlin is the capital of the reunited Germany. The student could then navigate through the Proof-EHP and Example-EHP of the lecture by pressing the “Previous” and “Next”-Button, where the student is given additional information about Berlin and its history. In the case that the TLS is the first TLS of the EM, the “Previous”-Button will be deactivated. The same goes for the “Next”-Button at the last TLS of an EM.

If the student is confident about the information he can navigate to the next TLS by pressing the link at the bottom of the screen.

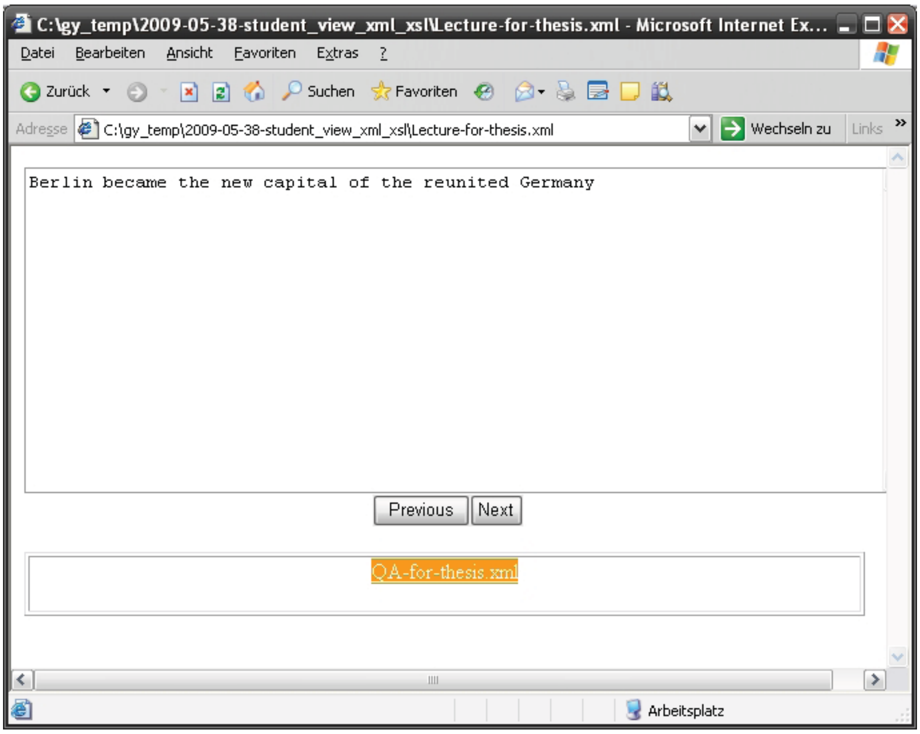


Figure 19: HEAT - Final view of a Lecture-TLS

Figure 20 illustrates a QA-TLS that is shown to the student after he has worked through the lecture material. The student is asked in this QA-TLS to answer a specific question. For this example a multiple choice presentation was selected by the author, even if there is only one correct answer. The order of the answers is mixed up during each loading process in the browser to prevent cheating.

The student has the option of getting some help by pressing the “Help”-link or he could get an example, eg. the information the author entered as an example for the QLS, by pressing the “Example”-link. He can also check if the answers he has selected are correct. This funcionality could obviously be improved, but the focus of this project was on the separation of educational and technical content in educational hypermedia, not on enhancing the technical implementation of the HEAT.

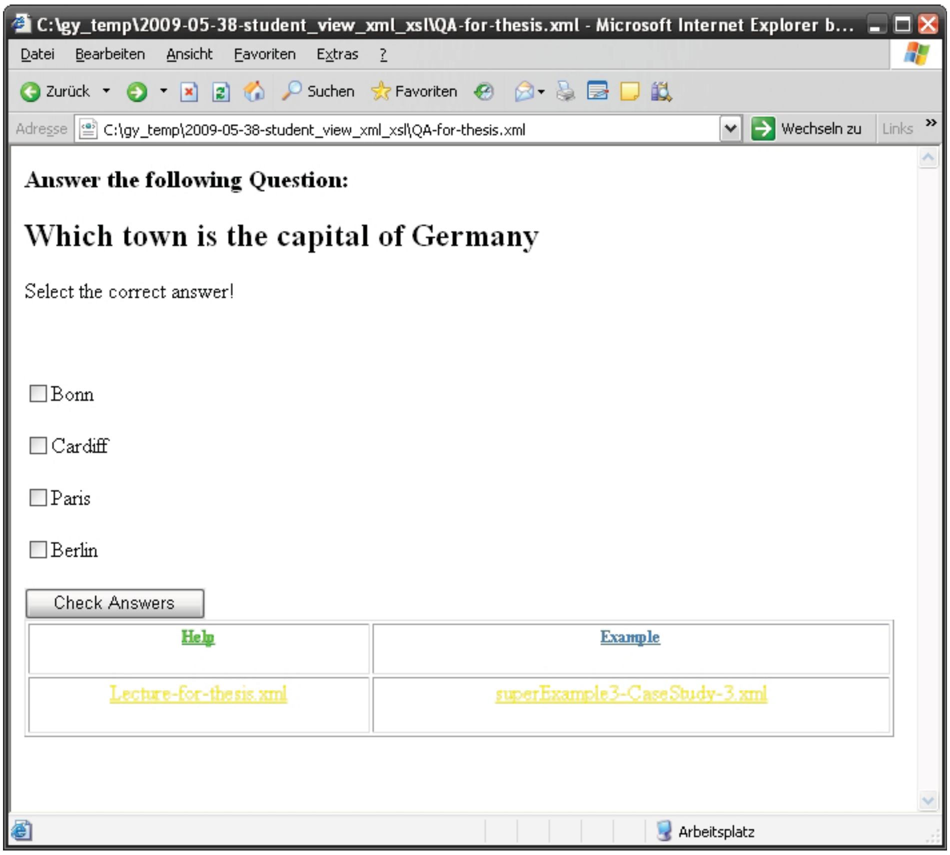


Figure 20: HEAT - Final view of a QA-TLS

Altogether, it can be stated that the separation of technical and educational content in educational hypermedia is not only theoretically possible, but also practically feasible. This statement is based on the successful conversion of the EFTECS into the HEAT and the creation of educational material with the HEAT, which is completely based on an educational framework.

However, the quality of the EFTECS and the HEAT can be evaluated only by some testing. This evaluation will be done in the interview evaluation in chapter 6 and in the practical evaluation of the HEAT in chapter 7.

4.9 Summary

This chapter introduces the HEAT and outlines the general approach used to create it (cf. section 4.1). More specifically, the implementation of the EHPs (cf. section 4.2), the EHP-Information (cf. section 4.3), the TLSs (cf. section 4.4) and the EMs (cf. section 4.5) are shown. Additionally, the content space as a basis for reusing educational material (cf. section 4.6) is specified. Furthermore, the delivery of the educational material to the students is analysed and implemented (cf. section 4.7). Finally, a detailed example of the functionality of the HEAT (cf. section 4.8) is given.

5 Evaluation methodology

This chapter will outline the methodology used during the evaluation of the EFTECS and the HEAT. Some of the possible evaluation techniques and approaches will be analysed, one will be selected for this project and then be introduced in detail.

5.1 Analysis of alternative approaches

The first step of setting up the evaluation of the 3-Layer-Model and the HEAT is to analyse the different analysis approaches. Their different advantages and disadvantages will be named and taken into consideration. The analysis and the selected approach are hereby based on the research going on in the field of software evaluation and educational system evaluation [177][178][179][180][181].

5.1.1 Group session vs. One-to-One session

The most important advantage of the group session approach is the greater number of evaluation participants. The group session approach is an excellent choice if many test subjects have to take part in the evaluation. However, this approach is not recommended if the individual members of the evaluation group must be interviewed personally. Additionally, it has to be realised that the evaluation must be designed for a large group of test subjects and therefore seems restricted in its flexibility of feedback.

5.1.2 Single session vs. Multiple sessions

Two different session styles, single session and multiple session, have to be compared to each other and one of them has been selected for this project.

Firstly, the single session approach focuses on a singular event during which the different evaluation candidates are interviewed individually.

One of the advantages of the single session approach is that it is a standardised approach. It is not too time-consuming for the test candidates and provides a high flexibility regarding the members of the evaluation group, which means that the evaluation candidates can be selected as they are needed for the evaluation. Additionally, the single session approach provides highly individualised feedback from the test candidates, due to the fact that the test candidates can be interviewed in a very individual way.

However, the structure of the evaluation must be well designed because it has to cover all the topics that are needed for the project. Therefore, the evaluation can become rather large and can take a lot of time. Besides, long-term effects cannot be tested because the single session approach takes place only once in one particular way.

Secondly, the multiple session approach has to be regarded as an option for this project.

First of all, it has to be stated that long-term effects of the project, for example a learning curve with the HEAT, can be examined only in a multiple session interview evaluation. Furthermore, the evaluation can be adapted to any problems that could possibly appear during the interviews.

However, the multiple session approach is very time-consuming and the evaluation candidates must consistently be the same to produce significant results.

5.1.3 Selected approach

For this PhD evaluation the one-to-one approach was selected. This selection was mainly based on the most important advantage of the one-to-one approach, the high flexibility during the evaluation regarding the members of the evaluation group. Another reason was that the evaluation does not aim at a large number of test subjects. Nielsen suggests around ten evaluation subjects to get significant evaluation results [182]. For this research project it was decided to undertake the evaluation with nine test participants, but to select the nine test participants from a broad range of educational domains (cf. section 6.1.2).

Furthermore, it was decided to use structured interviews during the evaluation as a way to gain a qualitative insight into the test participants' experiences.

The one-to-one approach was combined with the single session approach. There is no necessity for sequential sessions because the main goal of this evaluation was to get information about the EFTECS, the HEAT and the separation of educational and technical content on a fine-grained level (cf. section 2.13), but not the examination of long-term effects, which can be addressed in the future work (cf. section 9.2.1). However, the duration of the evaluation session was relatively long due to the many tasks that had to be covered.

Finally, the results gained from the interview evaluation are supplemented by a practical evaluation (cf. chapter 7) of the HEAT which aims at the evaluation of the HEAT and the EFTECS by creating some educational material in a real-life scenario and at the conversion of existing material and the creation of new educational material. Such a practical evaluation is necessary to test the HEAT and the EFTECS in a more real-life situation compared to the lab scenario of the interview evaluation.

In the following the design of the evaluation sessions will be introduced.

5.2 Design of the interview evaluation

After selecting the basic layout of the interview sessions, the next step was to design the interview in detail. This design will briefly be introduced in 5.2.1. Following this basic design of the evaluation methodology it was important to undertake a pilot study to evaluate the basic test design and to optimise it. The results of the test study will be explained in 5.2.2. The results of the analysis of the pilot study affected the final design of the interview session, which will be explained in detail in 5.2.3.

5.2.1 Basic design

The basic design of the interview sessions was divided into separate tasks: a manual markup task and a markup task with the HEAT. Both tasks were based on the 3-Layer-Model and the EHPs covered in the model. Therefore, it seemed necessary to explain the 3-Layer-Model to the test participants before they carried out the tasks. The basic design of the interview session covered the following aspects:

- Explanation of the 3-Layer-Model to the test candidates
- Manual markup
- Markup with the HEAT

The detailed description of the individual tasks are not given at this point, but in the description of the final interview design in section 5.2.3.

5.2.2 Pilot study

The pilot study was undertaken with two test evaluation participants. Both candidates were given the markup tasks and the explanation of the 3-Layer-Model. The test candidates completed their given tasks, however, the results of the pilot study were not as successful as hoped.

A major drawback of the interview sessions, as they were set up in the basic design, was that it was almost impossible to keep track of all the information given by the test candidates.

Furthermore, the interruptions of the given tasks which were needed to write down the information given by the evaluation candidates was described as a hinderance by the test candidates. Additionally, not all the information given during the pilot study could be written down as fast as it would have been necessary.

As a direct result of this fact it was decided to record the complete interviews on tape during the final evaluation in order to be able to analyse the data after the interview.

Another result of the pilot study was that it seemed necessary to interview the test candidates in a structured way to get meaningful data.

During the pilot study, the questions the candidates were given at the different interview stages were not structured enough to represent the information given after each task. For example, the questions about the background of the educational experts were mainly asked in the pre-test interview instead of being parts of the different interviews. Another example is the repetition of the questions about the creation of the TLSs after the manual and the HEAT markup task. In the original design, the question had only been asked once after the HEAT markup task. During the pilot study it proved necessary to get some information about the manual markup by the evaluation candidates to get insights concerning the framework and not only the HEAT.

Finally, parts of the markup tasks were re-designed to avoid the repetition of similar tasks and to fill in more, different and more significant tasks.

One decision that was made after the experience gained during the pilot study was to ask the test candidates to create several different TLSs and the corresponding EHPs. This resulted in a longer test duration but delivered a more significant insight into the usage of the framework. Another aspect that had not been included in the pilot study, but which was recommended by every pilot study test candidate is the explicit usage of the content space functionality of the HEAT.

Altogether, the pilot study was a very important step to undertake before the real interview sessions to optimise the efficiency of the final interview design. The major changes to the basic design were:

- Complete interviews were recorded on tape.
- Structured interviews were undertaken at the beginning, the middle and the end of the test to get meaningful qualitative data.
- Both markup tasks were slightly changed in order to maximise their effectiveness.

The detailed description of the single steps in the final design of the evaluation will now be explained.

5.2.3 Final design

Based on the results of the pilot study and the basic design of the evaluation, the following final design of the evaluation was created:

General objectives

The general objectives of this evaluation were:

- Evaluation by teachers from different teaching levels:
  One of the major design goals for the 3-Layer-Model was to create a framework that is usable for different teaching levels. Therefore, it was important for this study to have teachers from different teaching backgrounds, e.g. university, grammar school, and their corresponding teaching level. Furthermore, it was deemed beneficial to test the framework with teachers from different educational institutions and countries.
- Evaluation of the concept of creating useful hypermedia material from existing material:
  To evaluate the possibility of converting existing traditionally authored material or coursework into a hypermedia context, it was necessary to provide

the test candidates with some existing material. The success of the candidates converting the material can be regarded as an indicator of the degree of usefulness of the created framework.

- Evaluation of the comprehensibility of the 3-Layer-Model by teachers:
  It is important for this work that the 3-Layer-Model is comprehensible to teachers. Since the 3-Layer-Model is so crucial to this PhD project, the 3-Layer-Model and the EFTECS are used and therefore evaluated in both markup tasks.

- Evaluation of the comprehensibility of TLSs:
  One of the major aspects of the 3-Layer-Model is the concept of TLSs based on EHPs. The understanding of this concept is of high importance for the framework.

- Evaluation of the HEAT and the created output of the HEAT:
  The last general objective of this evaluation is to test the participants' understanding of the HEAT. Furthermore, their impression concerning the produced educational hypermedia content of the HEAT is regarded as important for the evaluation and discussion of the test results.

Pre-test interview

The pre-test interview was introduced in this evaluation to form a knowledge base concerning the educational background and IT-skills of the test candidates. During the interviews the teachers were asked the following questions:

- Could you please give some personal details?
  No personal details of the test candidates will be discussed in this thesis. However, the personal details were important to get a complete overview of the educational and cultural background of the test participants.

- How would you describe your educational task?
  This question was important to get an insight into the candidates' educational background, e.g. their teaching style. The information gathered here

in combination with the information about the understanding of the 3-Layer-Model allows to gain insights concerning the general application of the 3-Layer-Model.

- If you are a teacher, at what level do you teach?
  The level of teaching is important for this project because it allows conclusions about the range of accessibility of the 3-Layer-Model for teachers coming from different levels and schools.

- What computing skills do you have?
  To evaluate the influence of the participants' computing skills on their understanding of the 3-Layer-Model and the HEAT it was important to gather this kind of information.

- What specific WWW knowledge do you have?
  The participants' knowledge about the WWW in general might also have some influence on their understanding of the 3-Layer-Model and the HEAT. The more knowledge about the WWW the candidates have, the easier it should be for them to understand the 3-Layer-Model and the HEAT.

- How would you describe your thoughts about using the WWW as a tool for education?
  The more the participants are convinced of the usability of the WWW as a tool for education, the more they should like the concept of the 3-Layer-Model. Additionally, it seemed interesting to evaluate the acceptance of the WWW as a standard tool for education now and in the future.

- Do you have any experience in authoring WWW based educational material?
  If the test participants already have experience in authoring WWW based material, their understanding and their approach to the given tasks of this evaluation is of interest.

- Do you have any intention of using the WWW for educational purposes in the future?

The test participants' intention of using the WWW for education in the future will allow a prediction about the future of WWW based educational authoring tools and therefore of the HEAT.

- Do you have any external requirements to use the WWW for educational purposes in the future?
  It is also regarded as highly important to know if the test participants are or will be forced to use the WWW for educational purposes. This kind of information should also give some insight into the future prospects of the HEAT.

- Are you familiar with any educational markup projects?
  The knowledge about any educational markup projects different from the 3-Layer-Model should allow the test candidates a much easier completion of the evaluation tasks.

- Are you using any specific educational markup project?
  If the test participants are familiar with any other educational markup project it is important to know which one they know and how the markup projects they know relate to the 3-Layer-Model and the HEAT.

Each interview was undertaken as a face-to-face interview. The participants' answers were recorded on paper and on audio tape and transcribed (cf. appendix A.7.2).

The desired outcome of the pre-test interview was to determine the test participants' actual knowledge of educational hypermedia, their teaching background and their IT-skills. It was necessary for later analysis of the evaluation data to know the participants' pre-test opinion and knowledge of the topic.

After the pre-test interview, the first markup task was given to the test participants.

Evaluation of the 3-Layer-Model

To evaluate the created framework of separating technical from educational content in educational hypermedia and the 3-Layer-Model the test candidates were asked to undertake the following tasks on paper:

- Creation of a QA-TLS
  The first task the test candidates were asked to undertake was the creation of a QA-TLS on paper. The creation of the QA-TLS was seen as giving the evaluation participants a first impression of the usage of the 3-Layer-Model. The exact task and the material can be found in the appendices in Appendix A.1 and in Appendix A.2.

- Theoretical conversion of the QA-TLS from a Multiple-Choice-QA into a True-or-False-QA
  Another important issue of this evaluation was to show the participants the possibility of reusability of once authored material in different ways. This reuse was done in the simplest way by using different display styles for a specific TLS.

- Creation of another TLS (lecture)
  The next logical step of testing the framework was to ask the candidates to create a TLS by themselves. Their capability of creating TLSs individually is another important indicator of their understanding the 3-Layer-Model.

- Linking the created TLSs together
  Finally, after authoring and creating new material based on the 3-Layer-Model it was necessary to ask the candidates to link the different TLSs together to form a first EM.

After fulfilling the tasks in the manual markup part of the evaluation session the test participants were asked to give the mid-test interview so that information about the test participants' understanding of the 3-Layer-Model could be gained.

Mid-test interview

The mid-test interview is fitted into this evaluation to get a structured feedback about the manual markup task from the evaluation candidates. During the mid-test interview the participants were asked the following questions:

- How would you grade the 3-Layer-Model in a sense of complexity?
  It is important for the evaluation of the test results to know how the test candidates graded the 3-Layer-Model.

- What are the advantages or problems of the model?
  The identification of problems or advantages of the model is important for later improvement of the 3-Layer-Model.

- What is your understanding of the tags of the QA-TLS?
  It would be a good indicator of the quality of the 3-Layer-Model if the test participants have a good understanding of the specific tags of the QA-TLS.

- What are the advantages or problems of the QA-tags?
  It is not only important to know how the participants understood the QA-TLS, but also what they thought about the advantages and problems they discovered during their work on the manual markup task.

- What is your understanding of the tags of the Lecture-TLS?
  Understanding several TLSs of the created framework is another important aspect of this evaluation.

- What are the advantages or problems of the Lecture-tags?
  Similar to the QA-TLS it is important to know the advantages and problems of the Lecture-TLS to have the possibility of improving the framework in the future.

- How easy was it for you to tag the QA material?
  The easier the tagging process is for the test participants, the better the EFTECS works for the educational experts.

- How easy was it for you to tag the Lecture material?
  The easier the tagging process is for the test candidates, the better the optimisation of the framework is for educational experts.

- Do you have any additional comments?
  The participants were given the chance to express additional thoughts or

give their comments about the 3-Layer-Model that had not been covered by the previous questions.

The interview was undertaken as a face-to-face interview. The participants' answers were recorded on paper and on audio tape and transcribed (cf. appendix A.7.2).

The desired outcome of the mid-test interview was an evaluation of the comprehensibility of the 3-Layer-Model to the test participants and the impression they got from it. Additionally, the feedback concerning the 3-Layer-Model was separated from the feedback on the HEAT, which gave the possibility of evaluating the two tasks separately.

Evaluation of the HEAT

To evaluate the created framework of separating technical from educational content in educational hypermedia and the practical application of the 3-Layer-Model the test participants were introduced to the HEAT and a brief demonstration of the system was given to them. After this introduction they were asked to undertake the following tasks with the HEAT:

- Creation of a QA-TLS
  It was important for the evaluation of the HEAT to undertake tasks that are similar to the ones that had to be done in the manual markup tasks since then the EFTECS and the HEAT can be compared. The exact design of the tasks during the markup based on the HEAT can be found in the appendices in Appendix A.1.

- Practical conversion of the QA-TLS from a Multiple-Choice-QA into a True-or-False-QA
  To evaluate the functionality and the practicability of the HEAT it was important to test the possibility of converting material that has already been authored as easily as possible.

- Creation of a freely chosen different TLS
  It was necessary to evaluate the creation of a new TLS. It was important for the later discussion of the results to find out how easy it was for the test candidates to create new TLSs and to insert new content.

- Creation of a freely chosen complete EM
  The last step during the creation of new educational hypermedia material with the HEAT was the creation of a complete EM. An important factor during this step was the reuse of already existing material.

- Creation of the XML and XSL files and evaluation of the output
  The final step in the practical markup test was the creation of the educational content and the evaluation of the produced material.

After fulfilling the tasks in the practical markup part of the evaluation session the test participants were asked to give a post-test interview so that information about the understanding of the HEAT and therefore the 3-Layer-Model could be gained.

Post-test interview

The post-test interview was added to the evaluation to get some significant feedback about the markup task based on the HEAT. During the interview the teachers were asked the following questions:

- How easy was it for you to create an instance of a QA with the HEAT?
  This question will give some information about the design of the QA-TLS and its EHPs.

- If you had a problem with creating a QA, where and of what kind was it?
  The difficulties experienced during the creation of a QA-TLS were expected to be stated by the test participants and analysed.

- How easy was it for you to create a Lecture instance with the HEAT?
  The creation of a Lecture-TLS by the test participants and the question about how easy this creation aimed at gaining insights into the design of the Lecture-TLS.

- If you had a problem with creating the Lecture-TLS, where and of what kind was it?
  The difficulties experienced during the creation of a Lecture-TLS were expected to be stated by the test participants and analysed.

- How easy was it for you to link the TLSs together?
  The linking of the TLSs and the way the test participants experienced the difficulty of this task were expected to be stated by the candidates and analysed.

- If you had a problem with linking the TLSs together, were and of what kind was it?
  The difficulties experienced during the linking of the TLSs were expected to be stated by the test participants and analysed.

- How easy was it for you to reuse some existing material?
  The reuse of existing material is important for the success of this PhD. Therefore, it was also very important to know how the test candidates rated this functionality of the HEAT.

- How easy was it for you to create the actual WWW material?
  The ease of creating educational material for the WWW by educational experts canbe an indicator for the achievement of the research goals of this PhD. The test participants were asked to provide the necessary information about this material processing step.

- How good is the presentation of the authored material in the WWW?
  The quality of the created material was to be rated by the test candidates. The gained information was expected to give valuable insights for the further development of the HEAT.

- Did the completion of the first task help you to understand the HEAT?
  The completion of the first task should have enabled the test candidates to understand the framework upon which the HEAT is built. Therefore, the understanding of the HEAT was expected to have been easy for the test participants.

- Can you visualise how this tool could be used in preparing material for your teaching?
  If the test participants could imagine using the HEAT for their teaching and for delivering their material to their students, it would give some meaningful insights into the quality of the EFTECS and the HEAT.

The post-test interview is important for the evaluation of the HEAT based markup test. The questions asked in the interview form the basis of the later evaluation and discussion of the markup test.

Each interview was undertaken as a face-to-face interview and the participants' answers were recorded on paper and on audio tape and transcribed (cf. appendix A.7.2).

The post-test interview was designed to gain feedback on the HEAT and to give an insight into the participants' understanding of the HEAT and the EFTECS.

The designed tasksheet can be found in Appendix A.1, the worksheet in Appendix A.2 and the evaluation interviews in Appendix A.3.

5.3 Design of the practical evaluation

The interview evaluation introduced in section 5.2 had to be extended by a practical evaluation of the HEAT to create a complete evaluation of the HEAT. The practical evaluation focused on the extensive production of educational material with the HEAT.

The selection of the educational material that was converted with the HEAT had to address several issues to produce the best evaluation results.

Firstly, it was decided to convert educational material from two different topic areas. This selection was expected to provide insights concerning the influence of the author's personal knowledge of the educational material on the conversion of the educational material with the HEAT.

Secondly, it was important that one part of the educational material had already been existing in some form, for example a course book, and that the other part of the educational material was authored from scratch. This approach was expected to provide some information concerning the influence of pre-existing material on the authoring process.

Finally, the selected educational material was supposed to cover as many different TLSs as possible. Any additional TLSs needed can then be discussed and addressed in the future work.

The practical evaluation focused on the following aspects:

- Educational Material
  The selection of the educational material that was converted during the practical evaluation was selected in a way that promised the most significant results.

- EHP-layer
  The practical evaluation had to determine how the EHP-layer is applicable during the creation of educational material.

- TLS-layer
  The TLS-layer had to be tested and evaluated during the practical evalua-

tion of the HEAT. It was important to determine if any additional TLSs are needed and if the existing TLSs are sufficiently designed.

- Linking of TLSs
  The linking of the TLSs also forms the student's navigation through the EM. One goal of the practical evaluation was to gain information about the linking efficiency and possible drawbacks.

- EM-layer
  The practical evaluation of the HEAT should also provide some information about the usability of the designed EM-layer and the management of EMs in the HEAT.

- Presentation of material
  The presentation of the produced material in a web browser had to be evaluated during the practical evaluation of the HEAT.

- Ease of authoring
  The ease of material conversion or of the creation of new educational material with the HEAT is important for this project.

- Author's expertise in the domain
  It had to be determined if the author's expertise in the authored material influences the production of the educational material with the EM.

5.4 Summary

The desired outcome of the complete evaluation process was to get some meaningful information about:

- The created EFTECS framework.
- The practicability of the created framework of separating educational from technical content in educational hypermedia.
- The practical usability of the created framework.

The results of the evaluation sessions are analysed and discussed in detail in the following chapters.

The results of the interview evaluation will be introduced in chapter 6 and the results of the practical evaluation in chapter 7. Finally, the results of both evaluations will be discussed in chapter 8.

6 Interview evaluation

The interview evaluation that was designed and introduced in section 5.2.3 was undertaken and the gained results will now be analysed and evaluated. Based on the fact that the results of the interview evaluation should mirror the experience and insights of educational and technical experts it was decided that the evaluation of the results would be done in a qualitative way, i.e. the answers of the evaluation participants would be recorded and transcribed. It has to be stated that all the questions in this evaluation were open questions, i.e. the test participants could answer them individually and express their opinions freely. After the interviews the given answers were clustered, analysed (cf. chapter 6) and discussed (cf. chapter 8).

Additionally, nine test participants were selected covering a broad range of experience in the educational or technical fields.

To achieve the best evaluation results possible, the five parts of the interview will be analysed individually and the results of the analysis overall will be discussed in chapter 8.

An overview of the specific results of the interviews can be found in Appendix A.4. The transcripts of the evaluation interviews can be found on the appended CD (cf. appendix A.7.2).

6.1 Analysis of the pre-test interview

The purpose of the pre-test interview was to determine the candidates' abilities in the teaching and computing areas. The aim was to build a relatively representative test group covering the complete scale going from educational experts with almost no computing knowledge to technical experts with almost no teaching experience.

Firstly, the interview will be analysed. Secondly, the information gathered by this analysis will be summarised.

6.1.1 Personal details

Following the Data Protection Act [183], no personal data will be published in this thesis. However, what can be said at this point of the analysis is that nine candidates took part in the evaluation. The age of the candidates was between 27 and 48 years and every single person had at least some part-time teaching experience. Furthermore, it was possible to have test candidates of three different nationalities: British (66%), German (22%) and French (11%) (cf. table 10 on page 257). This international aspect gives additional insight into the application of the 3-Layer-Model in different educational systems.

6.1.2 Educational task and level of teaching

Another important aspect that has to be considered when building an objective test field was the educational task of the test candidates and the level at which the test candidates teach. One aim of the study was to cover a range of different teachers from different institutions as well as different teaching subjects. 66% of the evaluation candidates were teaching at university level whereas 33% were teaching at college or secondary school level (cf. table 13 on page 257). Such a broad range of teaching experience should provide some test results that are relatively representative of teachers in general and not only of one special group, for example university lecturers in computing science for final year students.

66% of the test candidates were full-time teachers either at university or college level, the rest of the participiants were part-time teachers at university level (cf. table 11 on page 257). The teaching subjects of the candidates include software-engineering, criminology, English, French, history, operating systems, programming and social sciences. This broad field of subjects will allow some conclusions about the generic usefulness of the 3-Layer-Model.

Altogether, the selected group of test candidates covers a big range of different subject areas in different educational systems in different countries and different age-levels. An objective analysis of the 3-Layer-Model and the HEAT should therefore be feasible.

6.1.3 Computing skills

The candidates' computing skills are another important factor that has to be considered during the evaluation. A good knowledge of computational techniques should be helpful in comprehending the 3-Layer-Model and in using the HEAT. However, a teacher with only limited computing experience should be able to understand and use the 3-Layer-Model based on the teaching experience the test candidate has.

The test group can basically be divided into three sub-groups. 22% of the participants can be regarded as teachers with a strong technical background. Their main education and experience covers computing and teaching in computing science. This group will be addressed from now on as "technical experts".

44% of the test candidates can be classified as teachers without any major computing skills, with their main focus on teaching. The members of the second group also teach mainly in non-computing subjects. This group will be addressed as "educational experts".

33% of the test candidates can be regarded as members of both groups, having degrees in educational computing and some significant background in computer based training (cf. table 12 on page 257).

Additionally, every test candidate possesses at least some basic computational knowledge and skills like word processing or e-mail (cf. table 14 on page 258).

Concerning the participants' computing skills, the test group represents a good mixture of educational experts and technical experts, which should provide relevant results concerning the 3-Layer-Model and the HEAT.

6.1.4 Specific WWW knowledge

Due to the fact that the 3-Layer-Model and the HEAT are based on hypermedia the knowledge of the test candidates about the WWW needs to be known. During the interviews of the candidates the following picture arose:

All members of the evaluation group have some basic knowledge about the WWW. Every participant is capable of using e-mail, search engines and the WWW as a resource for their teaching. However, HTML, XML, Java, Java Script, programming and authoring skills on the web were not present for 77% of the evaluation group. Only 22% of the group had some limited web-authoring experience (cf. table 15 on page 258). Additionally, it has to be observed that the technical expert group had more technical background in Internet technologies than the educational experts group.

6.1.5 Thoughts about using the WWW as a tool for education

It was observed that 88% of the members of the evaluation group were convinced that the WWW will play a major role in education in the future. 11% of the evaluation group were not absolutely convinced that the WWW will play a dominant role for education in the future (cf. table 16 on page 258). The general opinion was that the WWW will mainly be a support tool for teachers and students to deliver the educational content to the student.

However, there were also some concerns regarding the WWW and computer based learning. None of the test candidates could imagine that traditional teaching and learning can be replaced completely by computers. 33% of the evaluation group stated that the students must be guided and instructed to use the WWW properly as an educational tool. Another 33% were convinced that the WWW as a tool for education will mainly be used to support standard teaching methods (cf. table 17 on page 258).

33% of the evaluation group gave no specific comment.

Altogether, the WWW is regarded as a good opportunity to improve teaching and learning, but in the participants' opinion, it still needs a lot of development.

6.1.6 Experience of authoring WWW based educational material

It could be observed during the pre-test interview that 33% of the test candidates had some previous knowledge about authoring WWW based educational material, but only as a medium for delivering files, for example a presentation. The remaining 66% of the test candidates were highly interested in this specific topic, but did not have the time to acquire the needed skills (cf. table 18 on page 258).

6.1.7 Intention to use the WWW for educational purposes

88% of the test candidates expressed the desire to use the WWW as a tool for education in the future (cf. table 19 on page 259). However, the candidates also wanted to use professional tools that supported them in this task. This statement supports the concept of having a specialised authoring tool for the educational experts as argued in chapter 4.

6.1.8 External requirements to use the WWW for educational purposes

55% of the test candidates stated that there was already pressure building up to use the WWW more often for education. 33% of the test candidates could foresee this pressure in the future (cf. table 20 on page 259). They also commented that there were economic reasons that would drive distance learning more and more forward in the future.

6.1.9 Educational markup projects

88% of the members of the evaluation group had no knowledge about any existing educational markup projects, but 11% had heard about one project (cf. table 21 on page 259). However, 100% of the group had no practical experience in working with specific educational markup projects (cf. table 22 on page 259).

6.1.10 Summary of the pre-test interview

The pre-test interview of this evaluation was undertaken to determine the position of the evaluation candidates in the research area of this PhD. The analysis of the pre-test interview resulted in the following situation:

- The evaluation group can be divided into a group of "educational experts" and a group of "technical experts". The members of the technical experts group have at least some educational experience.
- The computing skills of the technical experts were significantly higher than the computing skills of the educational experts.
- All group members are convinced that the Internet and the WWW will become a major factor in education in the future.
- Neither group had any experience with educational markup projects.

Based on the results of the pre-test interview, it can be expected that the selected evaluation group should provide significant results regarding the 3-Layer-Model and the HEAT.

The next step is now to analyse the manual markup task of the interview evaluation.

6.2 Analysis of the manual markup task

It was not only the interviews of the test candidates that provided insight into the 3-Layer-Model and the created framework, but also the candidates' observations during their work on the markup tasks (cf. section 5.2).

The first markup task, the manual markup of the provided material, produced the following results.

6.2.1 Provided material

It was observed that the provided material was not immediately comprehensible to the test candidates. This problem was mainly based on the fact that the material was provided by another person and from an unfamiliar knowledge domain. The problems were more of a content based kind than of an educational type.

In general it can be said that it was difficult for the test candidates to markup material that existed on paper and which had not been created by themselves in the first place.

6.2.2 EFTECS and 3-Layer-Model

It was necessary for most of the test candidates to get a second explanation of the 3-Layer-Model during their first steps through the markup tasks. The educational concept of the 3-Layer-Model was not immediately comprehensible to the candidates. However, after a second explanation of the 3-Layer-Model and the framework every candidate of the evaluation was able to carry out the given tasks as designed in section 5.2.

6.2.3 Educational experts

The educational experts seemed to have no major problems with the given markup tasks. After a short while they felt very confident about the given tasks and worked right through them. However, it was observed that every educational expert put the material together in a very individual way, either linking it differently together or taking different information for the different TLSs.

6.2.4 Technical experts

The technical experts had more problems at the beginning with understanding the educational context of the markup tasks than the educational experts. Additionally, the technical experts tackled the tasks more from a technical point of view, for example they were more interested in the detailed concept of the EHPs than the educational experts, who accepted this concept faster.

6.3 Analysis of the mid-test interview

6.3.1 3-Layer-Model

During the mid-test interview the test candidates stated their opinion about the complexity, the advantages and the problems of the 3-Layer-Model. It could be observed that the members throughout the educational experts group graded the 3-Layer-Model as rather complex (cf. table 23 on page 260). They were able to understand the chosen terminology of the tags based on their pedagogical education, however, most of them needed two or more explanations of the 3-Layer-Model. During the manual markup tests those evaluation candidates used their experience from education to apply the 3-Layer-Model more with a sense of logic than with real understanding of the underlying concept. The test candidates that are members of the educational experts group could not identify any problems of the 3-Layer-Model at this point of the test, but also stated that they could not see any specific purpose of the model either. Therefore, 66% of the participants stated that they could not see any specific advantages of the model at that specific moment of the test. However, 22% of the test candidates said that they could imagine that the 3-Layer-Model might help them to structure their educational content (cf. table 24 on page 260).

In contrast to the educational experts, the technical experts did not have such big problems understanding the 3-Layer-Model. They rather showed good understanding of the model. They also stated in the interview that they could not see any problems or advantages of the 3-Layer-Model at that stage of the evaluation.

One member of the whole group stated that the model was possibly not complex enough to cover all possible teaching and material situations. This person has both high educational and technical expertise (cf. table 23 on page 260) and therefore was able to consider the model from different points of view.

Furthermore, 44% of the participants stated that they did not have any specific problems with the EFTECS so far. 22% said that it was too theoretical without a supporting software tool and another 22% suggested that the model should be very flexible and extensible (cf. table 25 on page 260).

6.3.2 Using the QA-TLS

None of the test candidates had any problems with the QA-tags (cf. table 26 on page 260). 77% of the candidates were able to apply the tags on the test material immediately. 22% candidates needed some explanation, but the information needed was about the educational material not the tags themselves (cf. table 28 on page 261).

Additionally, 33% of the evaluation participants, who were mainly from the educational experts group, stated that the tags of the QA-TLS correlated with their practical teaching experience (cf. table 27 on page 261).

The answers of the members of the evaluation group regarding the tags of the QA-TLS showed that the concept of the tags was understandable and applicable by the whole group.

6.3.3 Using the Lecture-TLS

All the test candidates stated that they did understand the tags of the Lecture-TLS well (cf. table 29 on page 261). However, they also said that they were more complex than the tags of the QA-TLS.

The different lecture strategies, for example deductive or inductive, did not cause any difficulties at this point of the evaluation.

77% of the participants did not see any specific advantages of the tags, but 22% stated that the introduced tags were very realistic (cf. table 30 on page 261).

Furthermore, 33% did not experience any difficulties with the tags, but 66% had either problems with the unknown material that had to be tagged or with applying the Lecture-tags to the unknown content (cf. table 31 on page 261).

6.3.4 Ease of QA material tagging

During the mid-test interview all the test candidates stated that the tagging of the QA material with the QA-tags was straightforward and not difficult (cf. table 32 on page 262). The candidates of the educational experts group as well as those of the technical experts group were confident about the task and could complete it without major problems. Minor problems occurred, but were mainly based on the fact that the candidates had difficulty in understanding the educational material (cf. appendix A.7.2).

6.3.5 Ease of lecture material tagging

Members of both expert groups stated that the tagging of the Lecture material with the Lecture-tags was not difficult (55%). However, asked how they would compare the grade of difficulty of tagging the Lecture and tagging the QA, 44% of the candidates stated that it was more difficult to tag the Lecture material than the QA material (cf. table 33 on page 262). It was also stated that a possible reason for that higher degree of difficulty was the way the material was presented to the candidates in the first place.

6.3.6 Additional comments

Most of the evaluation candidates did not have any additional comments at the end of the mid-test interview. Nevertheless, 44% stated that a general understanding of the 3-Layer-Model had not been fully established after the manual markup task (cf. table 34 on page 262). Furthermore, the evaluation candidates did not see or could not predict how the 3-Layer-Model would work in a real-life teaching and learning situation.

22% of the participants were interested in seeing the framework used in a practical situation with an authoring tool (cf. table 34 on page 262).

6.3.7 Summary of the mid-test interview

The mid-test interview of this evaluation was undertaken to analyse the comprehensibility of the 3-Layer-Model. The analysis of the mid-test interview results in the following situation:

- The educational experts graded the 3-Layer-Model as a lot more complex than the technical experts.
- The tagging of the Lecture material was more difficult than the tagging of the question and answer material.
- At the end of the mid-test interview most of the evaluation candidates did have a good but not complete understanding of the 3-Layer-Model. However, they were interested in a practical application of the model.

6.4 Analysis of the HEAT based markup task

Similar to the situation described in 6.2, the analysis of the test candidates' observations during their second markup task can potentially give additional insights into the HEAT and the EFTECS.

6.4.1 HEAT

There were some problems observed during the candidates' work with the HEAT. None of them were problems that led to an interruption of the evaluation, but the candidates could not use the HEAT immediately and easily. One reason for those problems were based on the fact that the HEAT was in a prototype phase of development. Another problematic issue was the fact that the HEAT had been developed in JAVA and that the test environment was set under a Linux environment, not giving the test candidates a typical Microsoft Windows look and feel environment (cf. table 36 on page 263).

Although most of the candidates were comfortable with the system after the first minutes working with the HEAT, it has to be mentioned that a later conversion of the XEML and the HEAT should also offer a Windows version. Most users prefer an environment that corresponds with their usual software interaction interface, for example the Windows environment (cf. table 35 on page 263 and table 37 on page 263).

All of the test candidates did complete the HEAT based markup task and no member of the evaluation group considered stopping the task due to complexity reasons. This fact suggests that the EFTECS and the framework are feasible and comprehensible in general.

6.4.2 EFTECS and 3-Layer-Model

After having completed the first markup task (cf. appendix A.1) with the provided material the test candidates did not have any problems with the 3-Layer-Model concept during the second, HEAT based markup task.

Furthermore, it was observed that the few problems the evaluation subjects had during the manual markup tasks did not come up during the HEAT based markup task. None of the evaluation subjects needed another explanation of the EFTECS and the 3-Layer-Model, but focused primarily on the creation of the educational material.

6.4.3 Educational experts

At the beginning, the educational experts had some problems with the HEAT software. They were quite confident about the tasks they were given, but needed more time to get confident with the HEAT than the technical experts.

However, it was observed that once the difficulties in using the unknown HEAT were solved, the educational experts were using the TLSs and the included EHPs almost naturally. Furthermore, the presentation of educational content via EHPs was no problem for the educational experts.

Additionally, the educational experts were using the linking functionality between the TLSs in a way similar to the way they linked the contents during the manual markup task, i.e. very individually. This can be regarded as a successful conversion of the EFTECS into the HEAT as the linking with the HEAT represents the semantic linking of the TLSs.

6.4.4 Technical experts

The technical experts were very confident about the HEAT after a short time. The experts from this group did not have the starting problems the educational experts had.

However, the technical experts did not so much focus on the educational side of the HEAT, but on the technical realisation of the EFTECS. Especially the content space and the reuse of the educational material was of high interest to the technical experts.

Finally, all of the technical experts were able to successfully create the educational material of the HEAT markup task (cf. section 5.2). This also shows that the selected approach did not only work for educational experts, but also for technical experts. This is especially important because of the further development of the HEAT that will have to be done by technical experts.

6.5 Analysis of the post-test interview

6.5.1 Using a QA-TLS in the HEAT

The creation of an instance of the QA-TLS with the HEAT was graded as easy by all the test candidates (cf. table 35 on page 263). 44% of them did not have any problems. However, some of the candidates (22%) stated problems like the presentation of the software, which differs from the standard Microsoft Windows presentation styles. A similar problem that was stated was the unusual look and feel of the software. Furthermore, 22% of the evaluation candidates had initial orientation problems with the software (cf. table 36 on page 263).

6.5.2 Using a Lecture-TLS in the HEAT

All the test candidates of both groups said that the creation of a Lecture-TLS instance was easy with the HEAT (cf. table 37 on page 263). It was also stated that the already structured content from the manual markup task helped a lot during the HEAT task (cf. table 37 on page 263). The fact that there was no possibility to convert HTML content or MS Power Point slides directly into the HEAT was identified as a possible problem of the HEAT at this point.

However, the integration of pre-existing material is already envisaged in the XEML. The implementation of the functionality in the HEAT was not done for the prototype, due to the focus on the separation of technical and educational content, e.g. the framework.

Finally, 77% of the evaluation group did not state any specific problems with the given tasks and only 22% stated that some problems occured during the learning phase of the HEAT (cf. table 38 on page 264), e.g. the JAVA environment.

6.5.3 Linking of TLSs

It was stated by 88% of the evaluation candidates that the linking of the TLSs was a rather difficult task or more difficult than the tagging task (cf. table 39 on page 264). It was observed that the members of the educational experts group had even bigger problems solving the linking task than the members of the technical experts group. One major problem was the representation of link source and link destination by indexes.

As a solution to this linking problem 33% of the evaluation group suggested an approach that included a drag and drop representation of the links (cf. table 40 on page 264).

Furthermore, 66% of the candidates stated that the linking was not self-explanatory and that most of them could not have solved the task without additional help (cf. table 40 on page 264).

Moreover, it has to be taken into consideration that the linking of educational material could also be regarded as a technical barrier. A possible solution would be to offer the author of the educational material some guidance or templates for the creation of courses and to free him of the linking task.

6.5.4 Reuse of material from the content space

The reuse of the existing material was regarded as an excellent and easy to use approach by 77% of the evaluation group. Furthermore, 22% said that reusability of educational material could save a lot of time for the author of educational material (cf. table 41 on page 264).

However, the test candidates also stated that the usability of the tool has to be improved and furthermore addressed several additional issues (cf. table 42 on page 265) that would have to be taken into consideration during any further development of the HEAT:

- Copyright issues of the material will have to be addressed in the future.
- Filters, queries and even better text-search possibilities through all the files are needed.
- The database could become too big and have redundant content areas.
- Students must not have the same access rights as the teachers.

- Traditional teachers protect their material in one way or the other. They are partly afraid of their material having errors and they do not want to be humiliated.
- A "quid pro quo" approach is preferred over a pay system for material exchange.

6.5.5 Processing the created material for the WWW

The actual creation of the WWW based material was considered to be very easy by both expert groups (88%) (cf. table 43 on page 265). It could also be observed that the educational experts were pleased with the ease of material production (cf. appendix A.7.2).

6.5.6 Quality of processed material

77% of the evaluation candidates stated that the presentation of the authored material was improvable, but not good. Members of both expert groups mentioned that the graphical representation was not state-of-the-art. However, two members of the educational experts groups (22%) with no technical background were satisfied with the produced material (cf. table 44 on page 265).

6.5.7 Manual markup vs. HEAT

77% of the test candidates stated that the manual markup of the educational material helped them to understand the HEAT. 22% said that the HEAT was self-explanatory (cf. table 45 on page 266). However, several candidates also explained that in a real-life situation they would not bother to undertake the manual markup task. They stated that they would enter the material directly into the HEAT.

6.5.8 Vision of practical application of the HEAT

Most of the test candidates stated that they would like to see and test a more developed version of the HEAT (compare to table 46 on page 266). Additionally, the following improvements were suggested by the candidates:

A print functionality for the created material was suggested, to hand out the material to students without an Internet connection. Furthermore, an option for direct communication between the teacher and the student was expressed as a wish for an improved HEAT.

The creation of a print functionality based on the chosen approach will not be a problem, if addressed in the future. This is based on the fact that the educational material is tagged and can easily be converted into a printable format (cf. section 9.2).

The direct communication between the teacher and the student would have to be implemented within the HEAT, but is regarded as out of scope for this project.

6.5.9 Summary of the post-test interview

The post-test interview of this evaluation was undertaken to determine the usability of the HEAT. The analysis of the post-test interview results in the following situation:

- The creation of educational material was not difficult. The creation of the Lecture-TLS was not more difficult than creating a QA-TLS.
- The linking of the different TLSs was considered to be difficult at the beginning.
- The reuse of existing material from the content space was regarded as a good invention.
- The presentation of the material was judged as satisfactory for a prototype, but improvements were recommended.

- Most of the test candidates would welcome a system like the HEAT.

Before the results of the interview evaluation will be discussed in chapter 8, the practical evaluation of the HEAT has to be analysed.

6.6 Summary

This chapter outlines the interview evaluation of this research work. Firstly, the pre-test interview is analysed (cf. section 6.1). Secondly, the manual markup task undertaken by the test candidates is introduced (cf. section 6.2). Thirdly, the results of the mid-test interview are shown (cf. section 6.3). Furthermore, the HEAT based markup task and the answers given by the test candidates are outlined (cf. section 6.4). Finally, the post-test interview is presented (cf. section 6.5).

7 Practical evaluation

To evaluate the EFTECS and the HEAT it was necessary to undertake some face-to-face interviews and evaluation to get significant results from educational experts. This was successfully completed and presented in chapter 6.

The interview evaluation of the HEAT resulted in several insights into the feasibility of the created EFTECS framework. The interviews with the test candidates showed that the HEAT could be used to create educational material for online delivery on a more fine-grained approach than other existing research projects, e.g. LOM [137]. Additionally, the interview evaluation not only suggested the theoretical basis of this PhD, but also helped to identify some problems within the EFTECS and the HEAT.

Furthermore, it was discovered during the interview evaluation that more insights into the EFTECS and the HEAT could be gained if an additional evaluation on a more practical level was undertaken.

To achieve this additional goal it was decided to create some new educational material and to convert some existing material with the HEAT. Due to the complexity and estimated long duration of these two tasks it has been decided that they had to be done by the author. The problems connected with this decision will be addressed in section 8.3.

7.1 Design

It was necessary to apply the HEAT and the functionality of the HEAT to a broader range of educational material. In order to get more information about the capabilities of the HEAT it was important to create and convert some educational material which is used in a real educational scenario.

However, a complete conversion of large educational modules, for example a complete course book, is not regarded necessary as long as some significant parts of it are created with the HEAT.

7.1.1 Educational material

The selection of the educational material that was to be converted with the HEAT had to address several issues to produce the best evaluation results.

Firstly, it was decided to convert educational material from two different topic areas. This choice was expected to provide insights concerning the influence of the author's personal knowledge of the educational material on the conversion of the educational material with the HEAT.

Secondly, it is important that one part of the educational material is already existing in some form, for example a course book, and the other part of the educational material will be authored from scratch. This approach will provide some information concerning the influence of pre-existing material on the authoring process.

Finally, the selected educational material should cover as many different TLSs as possible. Any additional TLSs needed can then be discussed and addressed in the future (cf. section 9.2).

7.1.2 Aim of evaluation

The aim of the practical evaluation of the HEAT was to address the following issues during the process of converting existing and creating new educational material:

- EHP-layer
  The practical evaluation will show whether the designed EHPs are usable and feasible in the conversion of existing educational material and whether there are any limitations in working with the EHPs or if additional EHPs are needed.
- TLS-layer
  It was important to determine if any additional TLSs are needed and if the existing TLSs are sufficiently designed.
- Linking of TLSs
  The linking of the TLSs represents the students' navigation through the EM.

One goal of the practical evaluation was to gain information about the linking and possible drawbacks.

- EM-layer
  The practical evaluation of the HEAT should also provide some information about the usability of the designed EM-layer and the management of EMs in the HEAT.

- Presentation of material
  The presentation of the produced material in a web browser had to be evaluated during the practical evaluation of the HEAT to get some insights into the quality of the material.

- Ease of authoring
  The ease of material conversion or of the creation of new educational material with the HEAT is important for this project. Especially for non-technical experts as defined in chapter 2 and 3 it is crucial to have an easy to use authoring system.
  Therefore, it was an important goal of the practical evaluation to gain information about the ease of authoring of educational material with the HEAT.

- Author's expertise in the domain
  It had to be determined if the author's expertise in the authored material influences the production of the educational material with the EM.

- General insights
  Additionally, any other issues concerning the HEAT or the EFTECS that came up during the practical evaluation are analysed accordingly.

The results of the practical evaluation will now be introduced in 7.2 and 7.3. Finally, a summary of the evaluation results will be given in 7.4.

7.2 Existing material

According to 7.1.1 it was decided to use some existing material for this part of the practical evaluation. Furthermore, it has to be noted that the author is not an educational expert in the domain of the selected material:

- Entrepreneurship and Opportunity Recognition [184]
- Small Enterprise Resourcing [185]

The content is mainly text based, but also includes some graphical illustrations, some mind maps and some case studies. However, the quantity of the material is far too big to be converted completely in this PhD project. Therefore, only selected parts of the material were authored with the HEAT.

The following results were gained during the evaluation.

7.2.1 EHP-Layer

From the author's point of view the EHPs that are implemented in the HEAT turned out to be satisfactory for the conversion of the material as long as only the implemented TLSs are considered. Figure 21 illustrates the EHPs of a Lecture-TLS created for the practical evaluation with the HEAT based on *Small Enterprise Resourcing* [185].

It was also observed that in some cases new TLSs would have been needed in order to convert the educational material. In this situation it would have been a necessity to design new EHPs that would have allowed the creation of the new TLS. An example of such a new TLS could be a Mind-Map-TLS which would have been needed to convert the educational material with the HEAT.

7.2.2 TLS-Layer

From the author's point of view it turned out during the conversion of the two course books that a lot of the material could be converted with the existing TLSs

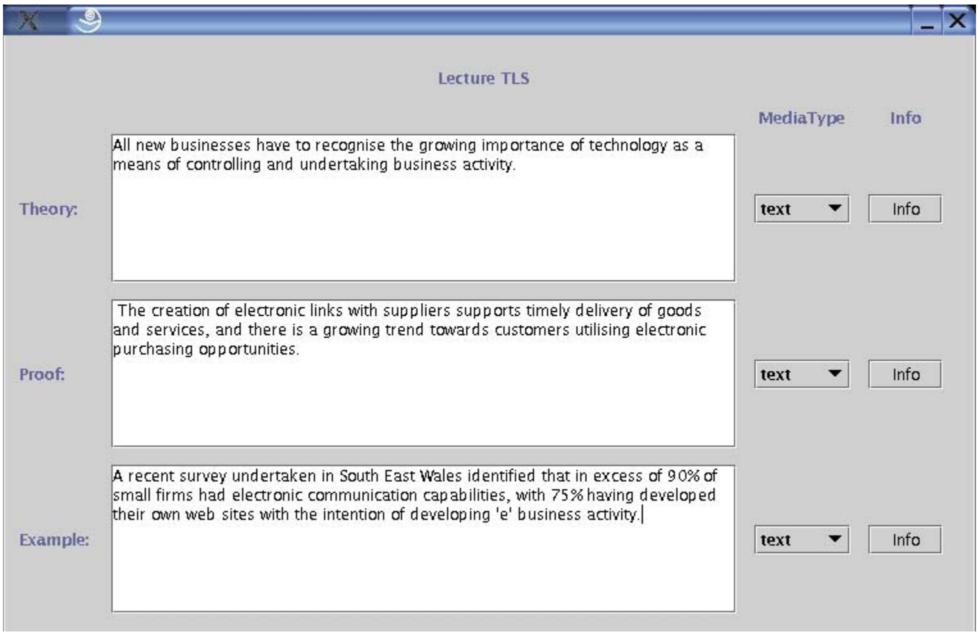


Figure 21: Lecture-TLS of existing material

and EHPs. The application of the developed TLSs and the corresponding EHPs allowed the conversion of most parts of the selected educational material.

However, it was not possible to convert all the material, for example the 'Monthly Cash Flow Forecast' in [185] could not be converted. Additionally, there are a lot of mind maps used in [184] which could not be converted directly, but had to be converted into linked Lecture-TLSs. If the complete course book needed to be converted, it would be necessary to create a special Mind-Map-TLS and the corresponding EHPs for this TLS.

Altogether, it can be stated that the HEAT approach is working at the TLS-layer, although additional TLSs will be needed in the future.

7.2.3 Linking of TLSs

The linking of the TLSs worked without any problems. Figure 22 on the following page shows an early stage of the conversion of the educational material. Several TLSs had already been created and linked at that stage. The linking of

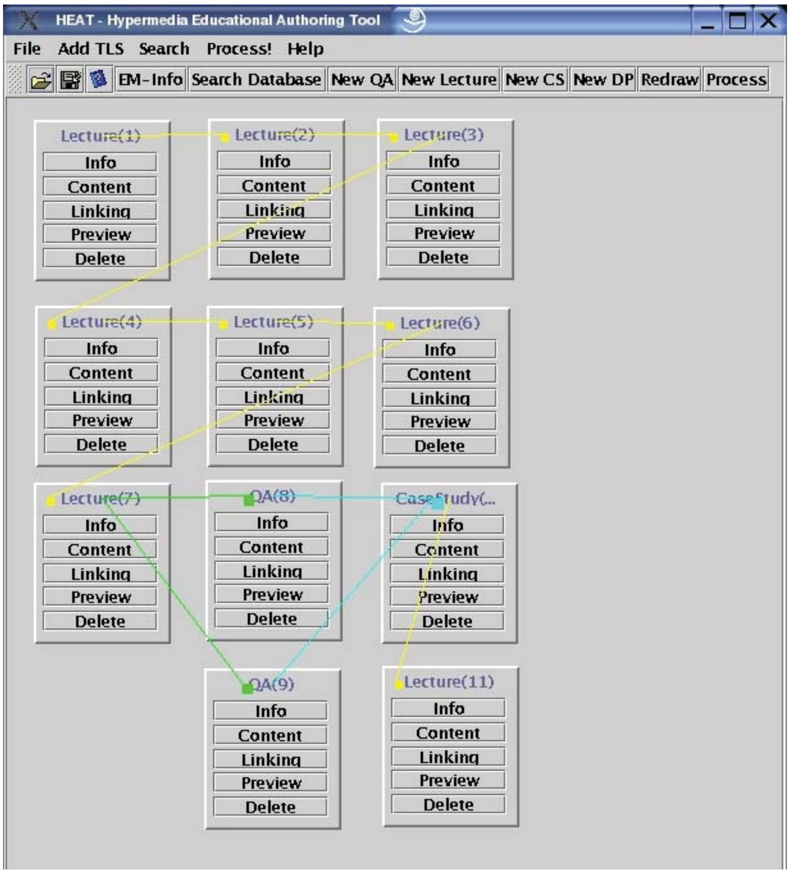


Figure 22: Educational module with linked TLSs

the converted material appeared to be straightforward because the existing course material is structured in a book style.

However, in order to get an in-depth evaluation of the linking of TLSs and the navigation through the educational material, it was decided to choose a more complex domain for the creation of a new EM in 7.3.

7.2.4 EM-Layer

During the practical evaluation it was observed that the conversion of a complete course book takes a lot of time and produces an enormous EM. The screenshot of figure 22 shows a stage of the conversion of the educational material where already several TLSs have been created and linked in an EM.

Therefore, it would be good if the HEAT allowed the division of a complete course book into several EMs, e.g. one EM for every chapter of a course book. Unfortunately, at the moment the HEAT supports only one EM at a time.

This also results in very large EMs which become more and more difficult to manage in the HEAT. Therefore, it seems important to implement the simultaneous management of several EMs in the HEAT during future work (cf. section 9.2).

As already mentioned in chapter 6, the linking of the different TLSs in the EM, the linking of different EMs and the identified problems will be discussed in chapter 8.

7.2.5 Presentation of the material

The presentation of the material after its production for the WWW was functional and free of errors. The navigation through the created content also worked correctly, but was fairly straightforward due to the fact that the converted educational material was based on a book and therefore reflected a book like structure.

However, as it was already identified during the interview evaluation in chapter 6, the graphical presentation of the material is not perfect and will have to be addressed in future work (cf. section 9.2).

7.2.6 Ease of authoring

From our point of view the conversion of already existing material into the HEAT was challenging in many respects.

First of all, all the educational material had to be typed in by hand. An electronic format of the material was available in MS Word format, but the HEAT does not support the import of external material at the moment. Therefore, it seems very important to create several import and export interfaces for accepted formats, like for example MS Word or XML.

Furthermore, the more TLSs were authored and fitted into the EM, the more difficult it became to identify the specific TLSs. The different TLSs within an EM are only identified by their index. A first step to solve this problem could be to implement a title-display for every TLS. However, further research will have to be undertaken to solve this problem.

7.2.7 Author's expertise

We possessed no expertise in the domain of the material selected for this part of the practical evaluation. Several conceptional problems and a slow conversion speed of the material can be regarded as direct results of the missing expertise. Our technical expertise did not help to simplify the authoring process.

Therefore, it was decided to select some material from our educational expertise field for the next part of the practical evaluation of the HEAT.

7.3 New material

During the authors' work as a part-time lecturer at the University of Applied Sciences in Regensburg, we taught the module 'Grundlagen der C/C++ Programmierung - Programming in C/C++'. This is a module for the first year of a bachelor's or master's degree in software engineering. There is no course book existing and we can be regarded as an educational expert in this domain.

Furthermore, it was decided not to create the educational material for a complete year, but to focus on the basic concepts of the C programming language.

7.3.1 EHP-Layer

The developed EHPs worked fine during the practical evaluation of the HEAT. The creation of new EHPs was not necessary, because there was no need for the creation of new TLSs. However, if a new TLS had been needed, it would have been necessary to add more EHPs to the EFTECS and the HEAT.

7.3.2 TLS-layer

The designed TLSs were applicable to the creation of new educational material with the HEAT. During the authoring process of the material, it was also noticed that a large part of the material could be covered and converted with the existing TLSs.

However, it was observed that for specific situations, e.g. the demonstration of how a code works during the run-time of a C-programme, a specialised TLS would be needed. Such a specialised TLS for programming languages promises great opportunities for future work (cf. section 9.2) in this area.

7.3.3 Linking of TLSs

The linking of the TLSs was straightforward. Due to the fact that we tried to implement all the different TLSs provided by the HEAT, the linking became very

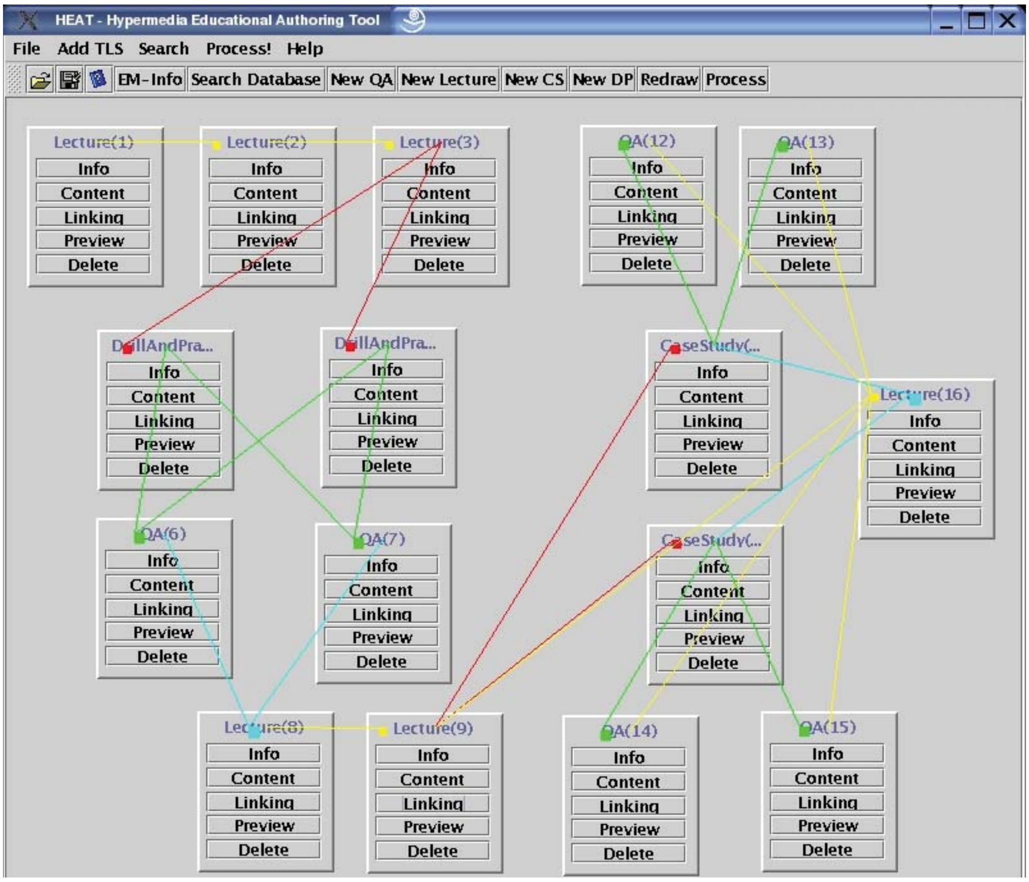


Figure 23: Educational module with new material

complex compared to the material authored in 7.2. The complexity of the linking grew with every new TLS inserted into the EM. Figure 23 illustrates the complexity of the EM module after the creation of several TLSs, e.g. the different colours of the links represent the different linking styles needed by the different TLSs.

However, this problem was already identified during the interview evaluation and the first part of the practical evaluation and will be addressed in detail in chapter 8.

7.3.4 EM-Layer

Due to the complexity of the linking and the problems discovered in 7.2.4 it was decided to create several single EMs to properly structure the different topics of the educational material.

This step resolved the problem of too complex EMs, but the creation of several EMs to avoid one large EM directly resulted in another problem. The HEAT does not support inter-EM-linking at the moment. The possibility of linking one EM directly to another EM will be crucial in the future, if a large quantity of educational material should have to be converted into several small EMs.

7.3.5 Presentation of the material

The production of the material and its presentation via the WWW was working as expected, but within the known limitations found in the interview evaluation and the first part of the practical evaluation, i.e. it has potential for improvement.

This means that the presentation of the material should be improved in the future. This improvement should not only focus on the graphical issues identified, but also on the technical representation of the content, especially for multimedia files, like video or audio files.

7.3.6 Ease of authoring

The authoring of the educational material was easier than in the first part of the practical evaluation. This experience was based on the fact that firstly we were an educational expert in the domain of the educational material. Secondly, we had no pressure to convert all of the educational material.

However, some limitations found in the first part of this evaluation were also applicable at this point of the evaluation (cf. section 7.2.6).

7.3.7 Author's expertise

The authoring of the new material in this part of the practical evaluation was not as difficult as in the first part. This could be explained by the fact that the material was not pre-existent and that there were no given limiting borders. Therefore, we could concentrate on the creation of the educational material. Furthermore, the ease of authoring can also be explained by the fact that we can be regarded as an educational expert in the selected domain and that the pre-existing expertise in the domain was beneficial during the authoring process.

Altogether, these observations support the thesis that the author's expertise in the domain of the educational material can have an influence on the usage of the HEAT and the quality of the created educational material.

7.4 Summary

Before the results of the interview evaluation and the results of this practical evaluation will be discussed in the next chapter, a brief summary of the results of the practical evaluation will be given.

7.4.1 EHP-Layer

During the practical evaluation study of this project the EHPs and therefore the EHP-layer of the EFTECS worked within the expected boundaries and without any major problems. The only limitations found were that new EHPs will have to be designed if new TLSs are needed. This creation of additional EHPs has to be done thoroughly, because they have to fit into the created framework and support the prerequisites established in chapter 3.

However, the EFTECS is designed to exactly fulfil this requirement.

7.4.2 TLS-Layer

Generally, it can be stated that the TLSs already implemented in the HEAT covered most parts of the educational material.

However, it was discovered that for specific material new TLSs are needed. Those new TLSs must be researched in detail and new EHPs implemented accordingly. For example, during the conversion of existing educational material with the HEAT, a Mind-Map-TLS would have been necessary, whereas during the creation of new material a Programming-Code-TLS was suggested.

Altogether, the possibility of introducing new TLSs into the EFTECS framework is built into the framework and therefore is no problem as long as the corresponding EHPs are properly designed.

Obviously, the TLSs would also have to be implemented into the HEAT, but this is regarded as a pure implementation problem and would not have to be addressed during research work in the future.

7.4.3 Linking of TLSs

The linking of the TLSs was not a problem during the practical evaluation of the HEAT. However, depending on the complexity of the educational material authored the linking structure can become increasingly complex. This complexity was especially observed during the creation of educational material that has not a book like structure.

The linking mechanisms implemented in the HEAT worked as foreseen, but the actual realisation of the implementation did not work ideally. For example, the problem of indexed linking that was already identified during the interview evaluation should be addressed in the future (cf. section 9.2).

7.4.4 EM-Layer

Two major problems with the EM-layer were discovered in the practical evaluation.

Firstly, the HEAT is can not of work with several EMs at the same time. Depending on the educational material that needs to be converted, rather large EMs must be created. Furthermore, the bigger an EM gets the more difficult it is to manage the single TLSs.

Secondly, the possibility of inter-EM-linking is not provided currently by the HEAT.

However, both problems are a not a design problem of the EFTECS, but an implementation problem of the HEAT which can be solved in future work (cf. section 9.2).

7.4.5 Presentation of the material

During the practical evaluation of the HEAT it was found that the presentation of the created and produced material has potential for improvement. Several issues concerning the presentations were found, for example the presentation of the

EHPs themselves or the implementation of multimedia files within the produced material. However, the basic functionality is given and is working error free.

During the future work the presentation of the produced material will have to be addressed and improved (cf. section 9.2).

7.4.6 Ease of authoring

The ease of authoring and the author's expertise in the domain of the educational material seem to be directly related to one another. The proficiency of an author in the educational material seems to have an influence on the difficulty of the authoring process.

In general, within the given restrictions of its prototype character, the HEAT offers an authoring environment that is expected to provide the user with an easy to use authoring tool for educational hypermedia.

7.4.7 Author's expertise

The results found during the interview evaluation already suggested that educational experts are quite able to produce good educational material with the HEAT. Additionally, the insights gained through the practical evaluation of the HEAT points into the direction that educational experts in a specific domain can create good material with the HEAT.

Altogether, it can be stated that the HEAT and EFTECS approach is working within its actual existing boundaries. The HEAT worked as expected during the conversion and creation of the educational material in technical respects, for example there were no system crashes and no database problems. Some problems, e.g. the conversion of existing material outside the author's educational domain (cf. section 7.2), were discovered which had not occured in the previous evaluation of the framework, but this allows some deeper insights for the whole project. These problems cannot all be solved by this PhD, but possible solutions can be pointed out and described.

The information gained during the interview evaluation and the practical evaluation of the HEAT and the EFTECS will be discussed in chapter 8.

8 Discussion

The insights gained during this research will now be discussed and analysed.

First of all, the EFTECS and the HEAT will be discussed based on results of the interview and the practical evaluation. Furthermore, any additional issues discovered during the evaluation phases will be discussed. An analysis of the selected methodology (cf. section 5) and a critique of the study (cf. section 8.3) will follow.

Finally, the work that will have to be addressed in the future and open research questions will be introduced.

8.1 Review of the EFTECS

The EFTECS and the underlying 3-Layer-Model have been evaluated in the interview and the practical evaluation study. The gained information will now be discussed.

8.1.1 Design of the EFTECS

One of the most important research objectives of this PhD project was to build a framework for the separation of educational and technical content in educational hypermedia. The selected approach was to concentrate on the fine-grained elements of teaching and learning strategies, the EHPs in cooperation with TLSs and EMs. These three layers formed the basis of the EFTECS (cf. chapter 3).

The design of the EFTECS was evaluated during the interview evaluation. The answers given during the first part of the interviews (cf. section 6.3) suggested that the educational experts did not have any diffculties in using the EFTECS to tag the given material during the manual markup task.

The technical experts were also able to use the EFTECS to solve the given tasks. However, their feedback after the manual markup task indicated that it was not as easy for the technical experts as it was for the educational experts (cf. section 6.3).

This observation can be explained by their lack of educational background compared to the educational experts. It had been expected that they were not as fast as the educational experts at understanding the concepts of the 3-Layer-Model and the EFTECS. This was observed during the interview evaluation in section 6.2, where the technical experts stated that they had difficulties during the first steps working with the EFTECS. However, at the end of the manual markup task the technical experts said that they were able to use the EFTECS to tag the given material.

All the members of the evaluation group stated that they did not have any problems using the EFTECS once they had understood the underlying principles.

However, during the manual markup task some problems did occur and were pointed out by the whole evaluation group. Those problems did not regard the EFTECS but the material that had to be tagged during the manual markup task. For example, it was stated that the tagging of pre-existing material was perceived as more difficult than the creation and tagging of the test subjects' own material.

Altogether, it has been shown that the 3-Layer-Model and the EFTECS were comprehensible and usable by both educational and technical experts.

8.1.2 Content separation

The separation of the educational content from the technical content was shown in the interview and in the practical evaluation. The educational experts stated in the interview evaluation (cf. section 6.3) that they could use and apply the EFTECS without any problems. However, this could be the effect of their educational background, because they are used to working with the educational paradigms used in the EFTECS.

Therefore, it is also necessary to take the results of the technical experts into consideration for the evaluation of the EFTECS.

The technical experts also stated that they were able to use the EFTECS without any problems after they had been given some information about the educational background of the material they had to author.

Altogether, this means that one of the major goals of the project has been achieved, because the separation of educational and technical content was feasible within the EFTECS and the HEAT paradigm.

8.1.3 Reusability of material

The reusability of the created material in other EMs was one of the requirements of this PhD. Only if existing material can be reused, will it be beneficial to educational experts in their work. As it was shown in the interview evaluation and the practical evaluation, educational material has to exist in the content space before it can be reused. This is a basic principle of IT applications, which usually need work input before they can support the users.

However, once the material is authored it can be stored in the content space (cf. section 4.6) and further on can be reused by other authors. This reusability of material was confirmed in the interview evaluation (cf. chapter 6) as well as in the practical evaluation (cf. chapter 7) and it was regarded as a major advantage of the EFTECS. Additionally, the search functions based on EHPs were especially useful to the members of the evaluation group (cf. section 6.5.4). After an author has searched and found some educational material, he can insert it into his EM.

Altogether, it was shown that material authored with the EFTECS and the HEAT can be reused.

8.1.4 Presentation and communication

The 3-Layer-Model and the EFTECS focus on the creation of educational material based on teaching and learning strategies. The EFTECS model provides the option of using different presentation technologies via the physical information layers, but leaves the actual realisation of additional functions to the HEAT or any other technical solution based on the EFTECS.

For example, communication between the teacher and the students could be established by the creation of a special communication TLS and its implementation within the HEAT. This implementation of a communication TLS could also cover synchronous or asynchronous update of the educational material, for example via an AJAX approach.

However, this functionality would have to be implemented into the HEAT in the future.

8.1.5 Extensibility of the EFTECS

The EFTECS was designed as an extensible framework for the separation of educational and technical content in educational hypermedia.

It was stated in chapter 3 that only a basic set of EHPs and TLSs was designed and implemented to prove the general approach of this PhD, for example the QA-TLS with its several QA-types.

If the created EHPs and TLSs have to be extended, the following steps will have to be undertaken.

After the need for a new TLS has been discovered, the TLS has to be analysed and the needed EHPs for that TLS have to be designed. Give the design of the EFTECS, several EHPs should be reusable, for example the HELP-EHP as described in section 3.4. The work that is necessary to achieve this reusability depends on the wanted TLS and its functions.

Another task is to implement the functions of the TLS in its corresponding XSL file. This task must not be underestimated since it is the more challenging one and requires a technical expert with some experience in programming XSL and Java Script. However, the technical solution could be realised with some other technology, too, as long as the EHP and TLS information are regarded and implemented.

Additional functions, for example the evaluation of tests or the navigation through the content based on the preferences of the learner as described in 3.4 would have to be implemented into the HEAT by some additional implementation work on the HEAT, but were regarded as out of scope for this work.

Based on the experiences gained during the creation of the EFTECS and the HEAT, we estimate that the amount of work for the creation of one TLS, its EHPs and the creation of the necessary XSL file is approximately 10 to 15 workdays, depending on the complexity of the TLS. However, this estimate is based on the author's personal programming skills and can vary accordingly.

8.2 Review of the HEAT

The conversion of the EFTECS, a theoretical framework, into a hypermedia authoring system was important for the evaluation of the EFTECS. Therefore, the creation of the HEAT - Hypermedia Educational Authoring Tool - was undertaken to prove the feasibility of the EFTECS.

The HEAT and its functionalities was introduced in detail in chapter 4 and it worked without any problems during the interview evaluation and the practical evaluation. Most of the test candidates stated that they would welcome a system like the HEAT for their work.

However, the implementation of the EFTECS into the HEAT showed some problem areas which were based on technical restrictions.

First of all, the usability of the HEAT was not regarded as ideal by the members of the evaluation group. The test group explained that this was the result of the implementation of the HEAT within the Unix context. The users reported that they were used to working in a Microsoft Windows context.

Secondly, only four TLSs were implemented due to the complexity of the implementation of a TLS. However, this number of TLSs was sufficient for a comprehensive evaluation of the EFTECS and the HEAT. The implementation of additional TLSs in the future is a matter of available resources as explained in section 3.1.

Finally, due to the complexity of the implementation only text elements were implemented within the different XSL files. The implementation of other mediatypes would be possible, but due to restrictions of resources it is considered as out of scope for this PhD.

Altogether, the conversion of the EFTECS into the HEAT can be regarded as a success within the given restrictions introduced above.

8.2.1 Conversion of the EFTECS into the HEAT

The conversion of the EFTECS and its underlying 3-Layer-Model into an authoring tool was a central task of this PhD project. This conversion resulted in the creation of the HEAT.

The HEAT was described in detail in chapter 4 and it can be claimed that all the aspects of the EFTECS (cf. chapter 3) have been built into the HEAT.

Firstly, the basic principles of EMs, TLSs and EHPs were implemented. The authors using the tool can create those instances of the 3-Layer-Model with the HEAT. During the interview evaluation this was successfully done by the evaluation candidates (cf. chapter 6).

Secondly, the linking of the TLSs and therefore the representation of the navigation through the educational material was implemented into the HEAT.

Thirdly, the HEAT offers a first implementation of the content space to provide the authors with the opportunity to reuse educational material.

However, as was discovered in the interview and the practical evaluation the HEAT has potential for further optimisation in the future. For example, it should be able to support more than one EM and EHPs with media types other than text.

Finally, the candidates of the interview evaluation used the HEAT to complete their practical markup task and did not have any problems regarding the representation of the EFTECS or the 3-Layer-Model within the HEAT.

Therefore, the conversion of the 3-Layer-Model and the EFTECS into the HEAT can be regarded as a success.

8.2.2 Basic functionality

During the interview evaluation (cf. section 6.3) most of the test candidates stated that the manual markup of the educational material helped them to understand the HEAT. However, several candidates also said that in a real-life situation they would not bother to undertake the manual markup task. They explained that they would enter the material directly into the HEAT.

Additionally, the test candidates were able to convert the educational content authored during the manual markup task with the HEAT in the second markup task.

Therefore, it can be claimed that the produced educational material was completely separated from the technical implementation no matter if it was authored with pen and paper or with the HEAT. This means that the basic functionality of the HEAT is given.

8.2.3 Existing material

The aim of the practical evaluation was to gain additional insights into the functionality of the EFTECS and HEAT.

The first part of the practical evaluation of the HEAT was designed to convert some pre-existing educational material. The selected material included parts of two different course books as described in chapter 7. Basically, all the material could be converted, which can be regarded as a proof of the functionality of the HEAT. However, the conversion of the material with the HEAT proved to be not as straightforward as it had been expected to be.

Therefore, the evaluation provided some valuable information about the limitations of the HEAT and its usage.

First of all, the author is not an educational expert in the domain of the selected material. Therefore, it was not possible to just convert the material, but the author had to understand the contents of the selected material. It can be said that the author had to acquire some knowledge about the material domain to successfully convert the material.

Additionally, the availability of only four TLSs was a restriction concerning the conversion process. As it was pointed out in section 7.2.2 more and specially designed TLSs would have been beneficial to the conversion task. A direct consequence of the lack of specialised TLSs is that the authored material had to be restructured in such a way that it could fit into the available TLSs.

Finally, the conversion of the educational material resulted in the question of mass conversion of pre-existing material. Consequently, the need for interfaces for standard file-formats like Microsoft Word or Microsoft Power Point was identified during the authoring of pre-existing material. However, these issues will have to be addressed in the future due to restrictions of time and resources within this PhD.

Altogether, the conversion of the pre-existing material revealed several problems of the HEAT. Therefore, it was decided to create some additional material from scratch to evaluate those problems and to gain some further insights into the capabilities of the HEAT.

8.2.4 New material

After the conversion of pre-existing material (cf. section 7.2) it was decided to verify the gained insights by creating some educational material from scratch.

The creation of material in a domain where the author was not only a technical expert but an educational expert as well, was successfully completed and described in section 7.3.

In comparison to the conversion of pre-existing material it was stated that it was much easier to create educational material with the HEAT if the material was taken from the author's own knowledge domain.

Since the usability of the HEAT was shown during the interview evaluation, the fact that the author's expertise and knowledge in the domain of the educational material had a direct influence on the usability of the HEAT must lead to the conclusion that the HEAT and the EFTECS are designed in a way that the educational background of the author outweighs the his technical experience. Additionally, it seems that it is easier for the author to use the HEAT and the EFTECS if he has got some expertise and knowledge concerning the educational domain.

At another point of the creation process, it was discovered that additional TLSs would be helpful to improve the usability and handling of the HEAT. The observation that additional and specialised TLSs are needed in the HEAT was also made during the practical evaluation and the interview evaluation. It can therefore be stated that future work (cf. section 9.2) will have to address the creation of such additional TLSs. The design of the EFTECS and the HEAT is expected to allow that without major problems.

Altogether, the practical evaluation of the HEAT showed that there were some minor problems which will have to be addressed in the future.

However, the design of the EFTECS and its implementation into the HEAT were proved to be successful during the practical evaluation of the study.

8.2.5 Linking of TLSs and EMs

The interview and the practical evaluation of the HEAT showed that the linking of different TLSs of an EM was not as easy as expected. Those problems were identified in section 6.5.3 and in section 7.3.3.

The first problem was the technical implementation of the linking process. It was decided to use an index approach for the HEAT, which proved to be difficult to understand for the test candidates, especially for the educational experts. This problem could be addressed by implementing the linking in a different way, for example a drag and drop approach or another visualisation technique.

The second problem is the complexity of the structure the TLSs can form within an EM. The larger the EM becomes the more complex the structure of the EM can become. A possible solution to this problem could be that the author is not being offered the option of free linking between the different TLSs. Instead, different templates could be used, for example a strict book structure with sequential navigation through the content. The work on this problem should be addressed in the future.

Finally, it has to be stated that the linking between the different TLSs is not the only problem that can occur, the limitation to only one EM at the moment can represent a problem, too. The theoretical linking between different EMs will have to be evaluated in detail. However, the EFTECS and the underlying framework is not the main issue of this problem, but their technical realisation in the HEAT.

8.2.6 Content space

The reusability of content is one of the key components of the EFTECS and the HEAT. This reusability was addressed in the HEAT by the creation of the content space as described in section 4.6. It was stated by the test candidates that the content space approach could be imagined as a great support for their daily work.

However, during the practical evaluation of the author, several problems with the content space in its current form were identified.

Firstly, as soon as some educational material is stored in the content space, the search for some specific material is not optimal. The content space needs some improved search functions and filter criteria exceeding the existing ones. This is not a major problem and should be soluble by some additional implementation within the HEAT.

Secondly, at the start of the EFTECS and the HEAT there is no material in the content space available for reuse. To avoid every single bit of educational material having to be authored with the HEAT, it will be necessary to design, implement and evaluate some import functions to allow existing educational material to be imported into the content space.

Finally, it was stated during the interview evaluation that a printing function for the created material was needed by the test candidates (cf. chapter 6). Furthermore, not only a printing function should be designed, but different export functions as well. The XML based design of the EFTECS is an optimal base for such export functions.

8.2.7 Quality of produced material

One of the goals of this PhD project is to create educational material for usage and delivery via the World Wide Web. Therefore, it is necessary to address the quality of the material produced by the HEAT.

During the interview evaluation in chapter 6 and the practical evaluation in chapter 7 it was observed that the authored material was converted into a WWW based format based on the EFTECS. This conversion step worked fine, but the quality of the converted material was relatively poor compared to the actual state of the art in web design, as far as for example the graphical design or the usage of multimedia content is concerned.

This lack of quality is based on the fact that the HEAT was designed and implemented with limited resources. The further improvement of the HEAT must address these issues and could be done during future work (cf. section 9.2).

8.2.8 Additional functionalities

Some other interesting areas of research have been discovered during the practical evaluation of the HEAT. Those areas will be introduced briefly, but are regarded as out of scope for this PhD and should be addressed during future work.

First of all, it seems highly interesting to investigate how educational material can be created automatically or semi-automatically from the material stored in the content space. A first and simple approach could be to undertake the following steps:

The author is supported by the HEAT in a first selection of useful educational material from the content space. The author would have to specify some meta-data about the material, for example subject domain and level of material. The HEAT could then suggest material and possible linking structures for the creation of a new EM. The information about the linking structures would also have to be stored in the content space. This semi-automated authoring step would allow a great reduction of the work for the author of new educational material.

Finally, an additional communication and session layer could be designed. Such an additional layer could provide several opportunities for the teacher as well as the students. For example, a session layer could store and manage the information as to where a student was in an EM before he took a break.

However, this additional layer will need some extensive research work to be done and will not have any influence on the EFTECS framework. It was therefore considered as out of scope for this PhD.

8.3 Critique of the study

The goal of this study as it was set at the beginning was to realise the separation of educational and technical content in educational hypermedia. Consequently, the major focus of this study has always been on this issue. During the work done on the project, several other issues were discovered, such as the creation, usage and management of the content space or the optimisation of the presentation of the created educational material. It would have been interesting to evaluate those issues, but this will have to be left for future research in this area.

Furthermore, problems of a more social nature, as for example the willingness of teachers to share their work and their educational material, could be analysed in depth. However, these issues will have to be addressed in further research projects.

Another aspect that has to be addressed is the possibility of an experimenter effect on the test participants as the author knew all the participants personally and explained the model (cf. section 5.2.1), provided the existing material (cf. section 5.2.3) and demonstrated the HEAT (cf. section 5.2.3). However, the answers given by the test participants during the evaluation interviews were critical and gave insight into the advantages and disadvantages of the EFTECS and the HEAT.

Furthermore, an aspect of this research project which could be criticised is the fact that the practical evaluation of the HEAT was done by the author. However, even though it is problematic that a system is evaluated by the creator of the system, in this case it was the only possible way of acquiring information about the EFTECS and the HEAT in a more real-life scenario, e.g. regarding the amount of converted data and the creation of new material with the HEAT. The insights gained from this evaluation have been critically analysed (cf. chapter 7) and discussed (cf. chapter 8). Issues which could not be addressed in this PhD project and which will have to be dealt with in future research are being pointed out in this work (cf. section 9.2).

The focus of this PhD after the interview and the practical evaluation had to lie on the EFTECS and the HEAT. All the other interesting research areas had to be defined as out of scope for this PhD.

Another aspect that has to be mentioned is the selected methodology of the evaluation. The size of the evaluation group should have been bigger for data on a more quantitative basis. However, the insights gained from the selected evaluation group can be regarded as significant on a qualitative basis. It would be ideal in future work to fully implement the HEAT and to use it in a broad field study in a real educational environment, for example a school or a university.

9 Conclusions

In this chapter the evaluation of each of the objectives of this study will be addressed in turn. The problems and issues that were discussed in chapter 8 are reconsidered in the light of the evaluation of the objectives of the study.

The chapter will conclude with suggestions for further work and research.

9.1 Research objectives

The three main objectives of this research project, as they have been identified in the literature review in section 2.13 and as they have been addressed during the evaluation and discussion chapters, have been accomplished as stated below.

9.1.1 Creation of a suitable framework for content separation

The creation of a framework for the separation of educational from technical content in educational hypermedia was suggested after the literature review and was accomplished at the beginning of this PhD project. The created 3-Layer-Model based on EHPs, TLSs and EMs resulted in the EFTECS framework and addresses the separation of educational and technical content in educational hypermedia. One of the most important issues of this work was the creation of the fine-grained EHPs of teaching and learning strategies within the EHP-layer of the framework.

This framework was developed as described in chapter 3. Further on, the EFTECS formed the basis for the XEML and the HEAT and was designed for further extensibility in the future. This extensibility allows the introduction of new EHPs and TLSs as long as the basic EHPs, e.g. HELP-EHP, are included.

The results of the interview evaluation in chapter 6, the practical evaluation in chapter 7 and the discussion in chapter 8 show that the EFTECS can be successfully and effectively used for the separation of the educational and the technical content in educational hypermedia.

However, some specific limitations of the framework were discovered especially during the interview evaluation. For example, the complexity of the framework for educational experts (cf. section 6.3) at the start of the evaluation or the existing approach of linking TLSs (cf. section 6.5.3) can be regarded as limitations of the framework, but are not an argument against the approach chosen in this project, because the problems are regarded as soluble during further research in the future. Besides, those issues are no hindrance to the separation of the educational content from the technical content.

Altogether, the first research objective formulated in the literature review in 2.13 - the creation of a framework for content separation - can be considered to be achieved within the scope of this PhD. Therefore, the main hypothesis of this work that the separation of technical and educational content is possible if it is based on a fine-grained structure of different teaching and learning strategies can be regarded as fulfilled.

9.1.2 Evaluation of the framework

The second objective of this project was to evaluate the created framework as to its application to several different TLSs and its usability on different teaching levels.

The interview evaluation with teachers, educational and technical experts from different teaching levels, teaching backgrounds and countries and the undertaken interviews showed that the EFTECS framework fulfilled the requirements of this study (cf. chapter 2).

During the interview evaluation the test subjects were asked to create educational material in two steps, a manual markup task and a HEAT based markup task. (cf. chapter 2).

During the evaluation the teachers used different EHPs to create several TLSs, for example a Lecture-TLS or a QA-TLS which they successfully put together to form an EM.

The results of the markup tasks were introduced in chapter 6 and discussed in chapter 8 and showed that the EFTECS framework is acceptable to both educational and technical experts.

Furthermore, the results gained from the practical evaluation introduced in chapter 7 also showed that the framework is applicable within given restrictions.

Altogether, it can be claimed that the EFTECS is working as specified and predicted.

9.1.3 Evaluation of the authoring tool

The third objective of this PhD was to evaluate the practical usability of the created framework. To evaluate the usability it was necessary to build a new hypermedia educational authoring tool, the HEAT, which is based on the EFTECS as described in section 3.8. The experiments with the test candidates (cf. chapter 6), the practical evaluation (cf. chapter 7) and the discussion of the experimental results (cf. chapter 8) showed the practical usability of the HEAT. Additionally, the evaluation candidates stated that the HEAT was working very well and that they would like to use it in the future, if the HEAT became available (cf. section 6.5). Moreover, the interview evaluation showed that the manual markup task helped to understand and use the HEAT (cf. section 6.2), which shows that the HEAT is a working conversion of the created EFTECS model as discussed in chapter 8.

Furthermore, the results gained from the practical evaluation in chapter 7 showed that the HEAT could be used for the creation of educational material.

At another point of this study, the reusability of educational material with the HEAT was examined. It was shown in the interview evaluation (cf. section 6.5.4) and in the practical evaluation (cf. chapter 7) that the selected approach was feasible, but will need some optimisation. The created content space (cf. section 4.6) that supports the reuse of educational material was working as expected (cf. section 6.5.4).

Furthermore, the creation of new educational material (cf. section 7.3) and the conversion of existing material (cf. section 7.2) with the HEAT were feasible. Therefore, the third research objective formulated in the literature review in 2.13 - the evaluation of the authoring tool - can be considered to be accomplished within the scope of this PhD.

Altogether, it was shown in chapter 8 that the main objectives of this PhD work have been addressed and achieved. The evaluations undertaken during this project produced enough significant results to address the objectives of this PhD.

However, it is necessary to address the problems which occurred during this research project and which could not be solved or have been defined as out of scope for this study.

9.2 Future work

The work on this PhD project also revealed several problems. Those issues provided significant insight into the topic, even if not all of them could be solved within this study.

The problems that could not be solved during this project will have to be addressed in the future.

9.2.1 Long term evaluation of the framework and the HEAT

It would have been ideal if there had been the opportunity for a long-term evaluation of the 3-Layer-Model, the EFTECS and the HEAT. Additionally, the experiments could have had even better results if there had been even more teachers from different teaching levels.

For example, the HEAT could be used at a school or a university for one or even better two years. This would allow in-depth insights into the usability of the EFTECS and the HEAT as well as the creation of a significant content space. Furthermore, the analysis and development of additional TLSs and EHPs could be undertaken in a real-life teaching scenario.

Another approach could be to use the framework and the HEAT in different teaching institutions but involving work with students from the same level. This approach could especially provide results concerning the reusability of educational content.

However, the time frame and the budget of this PhD project only allowed for the undertaken experiments.

9.2.2 Implementation of additional TLSs

The most important issue that will have to be addressed in future work is the analysis and implementation of additional EHPs and TLSs. During the interview evaluation, but especially during the practical evaluation, it was shown that the EHPs and TLSs implemented in the HEAT are not sufficient for every aspect of educational material. Since extensibility was one of the main criteria for the development of the project, the design of the EFTECS and the HEAT will allow the addition of new EHPs and TLSs without any major problems. The more EHPs and TLSs are covered within the EFTECS the more flexible and generic it will become for usage in educational hypermedia.

Four different TLSs have been analysed and implemented within the EFTECS during the work on this project: Question and Answer (cf. section 3.3.1), Lecture (cf. section 3.3.2), Case Study (cf. section 3.3.3) and Drill and Practice (cf. section 3.3.4). The experiences gained from the implementation of those TLSs and the results of the practical and interview evaluations suggest that the implementation of new TLSs should not be a problem as long as the TLSs and the EHPs implement the basic EHPs (cf. section 3.4) and the rules designed for the EFTECS (cf. section 3.8). However, if time had allowed it, it would have been most interesting to implement more TLSs and their corresponding EHPs.

For example, the creation of a specialised TLS for the creation of educational material in a software development or code production environment would potentially be very beneficial in a computing science teaching setting.

The creation of additional TLSs should be addressed during future research to optimise the usability of the HEAT.

9.2.3 Mass conversion of existing material

The conversion of pre-existing material was analysed in detail during the practical evaluation (cf. section 7.2). The results of the evaluation showed that the manual conversion of the material is very cumbersome, especially if the author is not an educational expert in the area.

Another aspect that was problematic within the scope of this PhD was the mass conversion of existing digital and paper based material. Several small tests were carried out and produced promising results (cf. chapter 7). However, the complete conversion of a whole course module for example was out of scope for this PhD. Nevertheless, the EFTECS implemented within the HEAT would allow such a conversion, after an addition of further functionalities of the HEAT.

However, there are two major challenges regarding the mass conversion or mass creation of educational material with the HEAT.

Firstly, it was discovered during the interview evaluation that the educational experts had some doubts about the willingness of teachers to share their educational material (cf. section 6.5.4). This unwilligness to share is mainly was suggested on two facts:

- The educational experts are afraid that their material is not absolutely correct and error-free. A possible solution during future work could be to introduce an anonymous account model in the content space.
- The educational experts are afraid that other teachers might not share, but only copy their created material. This problem could possibly be tackled by introducing a payment or a ratio-model into the HEAT and the content space.

Secondly, the evaluation of the EFTECS and the HEAT on a large scale would require some substantial funding. The raising of such a budget was not possible during this project, but is an issue that will need to be addressed during future work.

Altogether, for an extensive long-term test of the 3-Layer-Model it will be necessary to start a mass conversion of existing material and to use the produced material in a real-life teaching environment to overcome the existing boundaries and challenges described above.

Therefore, future work will have to address the support of the conversion of large amounts of educational material, e.g. the creation of interfaces to standard file formats and their application.

Additionally, the automatic conversion of material should be investigated in the future.

9.2.4 Improvement of the HEAT

The HEAT is still at a prototype stage of software development. The most important step for the work in the future will be to improve and optimise the HEAT to provide teachers with a tool for the authoring of educational hypermedia content which is as easy to use as possible. In order to optimise the HEAT the following issues will have to be addressed.

- Linking of TLSs
  The way of linking the TLSs was criticised in the interview and in the practical evaluation during this study (cf. section 6.5.3 and section 7.3.3). The different link-types were not the problem (cf. section 3.5), but the graphical representation of the links was unsatisfactory (cf. section 6.5.6 and section 7.3.5). Furthermore, the linking process via indexes (cf. section 8.2.5) was not as practicable as expected.
  A possible approach to overcome these problems in the future was introduced in section 8.2.5 and mainly aims at replacing the index-linking approach with a drag-and-drop approach.

- Adaptation of content
  The usage of adaptive hypermedia within the EFTECS and the HEAT should be researched during future work. The EFTECS was designed for future usage of adaptive hypermedia, but its specific implementation was out of scope for this PhD project.

- Content Space
  The improvement of the content space functionalities of the HEAT should be addressed during future work as it was discussed during the interview evaluation in section 6.5.4.

- Communication
  A major issue that needs to be addressed in the future work on the HEAT is the implementation of communication options between students and teachers. These communication options should include offline and online communication, for example e-mail or chat functionalities
  Furthermore, the communication between the TLSs and the EMs should be investigated in detail. The better the integration of the TLSs within an EM is designed the easier the creation of new educational material should be. Fur-

thermore, if the TLSs, the EMs and the communication between them were improved, the reusability of the educational material could be maximised.

- Collaboration
  It seems important to investigate how the collaboration between teachers could be improved by the HEAT. At the moment the educational experts are only supported by the content space and the reusability of authored material. A first step towards collaboration between teachers could be the usage of peer-to-peer sharing concepts, for example the Bittorent-network [186].

- HEAT interface
  Another issue that will have to be addressed during future work is the conversion of the HEAT into a Microsoft paradigm. The educational experts in particular experienced problems during the interview evaluation with the Linux based HEAT with its JAVA interface. However, this is rather a work issue and not a conceptual problem.

- Quality of produced material
  It was discovered during the interview evaluation and the practical evaluation that the quality of the educational material generated with the HEAT is not of the highest graphical and technical quality (cf. section 8.2.7). This fact will have to be addressed during future work. However, this problem is considered to be soluble. A possible solution could be to invest some development overhead into the newest web technologies without having to change the underlying EFTECS model introduced in chapter 3.

- Domain
  It seems important to evaluate whether and how the 3-Layer-Model and the EFTECS could be extended to other domains than the educational one. If the model can be adapted to the requirements of other information domains, e.g. in a business environment or in IT-project managment, then the information gained by this research project could be reused and applied to those information domains.

Altogether, the different issues outlined above will contribute to the improvement of the HEAT and should therefore be addressed during the next steps in the future work.

Finally, the original contribution to knowledge of this PhD project will be outlined.

9.3 Contribution to knowledge

The main contribution to knowledge of this project is the creation of a framework that simplifies the creation of educational hypermedia content especially for teachers. This framework is based on the separation of educational content from technical content in educational hypermedia. Specifically, this framework has been developed with specialised meta-information tags based on teaching and learning strategies, which contributes to the field of educational hypermedia systems. Furthermore, the framework was built on the fine-grained components of teaching and learning strategies, the EHPs. This fine-grained approach of the EFTECS allows educational experts to create educational content for the WWW based on their expertise in teaching and learning strategies.

Another contribution to knowledge is made by the insights gained from the evaluation process of this project and the accomplishment of the three research objectives. The interview evaluation, the practical evaluation and the discussion of the data showed the usabilty of the EFTECS and the HEAT.

Altogether, the main conclusion of this study is that authoring tools in educational hypermedia should use the separation of educational and technical content based on different teaching and learning strategies. The usage of the EFTECS allows educational experts with low computing skills to create educational content for delivery via the World Wide Web.

Parts of the work have been presented as a poster presentation at the Hypertext99 conference [187] and as a paper at the ED-Media 2000 conference [176]. Another paper about the separation of educational and technical content in educational hypermedia is currently being written.

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A Appendices

A.1 Evaluation tasksheet

Manual Markup of educational material

In order to assess a new educational markup model, we have created a number of short tasks which look at using this model and its tagging strategy.
Please read and complete the tasks below. If you have any questions about what to do or regarding the model, please ask. We are mainly interested in how usable the model is and how it complies to your educational experiences. If there is anything unclear, it is particularly important to us to know about it. If possible, comment what you are thinking while completing the tasks.
Before you begin with the tasks, the educational markup model will be explained to you. Following that you will be given an additional work sheet. Please mark parts of the work sheet with the provided high-lighters as instructed in the single tasks.

Marking up the Question and Answer material

The first of your tasks is to mark up one Question and Answer Teaching and Learning Strategy. Please have now a look on your work sheet and mark up the different parts of the Question and Answer with the different high-lighters as stated below. Please try to comment why you choose specific parts and why not.

- Please mark the question with blue colour.
- Please mark any correct answers with green colour.
- Please mark any wrong answers with red colour.
- Please mark any possible help with yellow colour.

When you are finished with the mark up, please continue with the next step.

Select the type of Question and Answer presentation

Please select now one of the presentation styles of the Question and Answer listed below. Please justify why you selected a specific one or if you would prefer to have different styles for different situations. Encircle your choice on this sheet. Here are your possible choices:

- Multiple Choice
- Single Choice
- True or False
- Yes or No

Please don't hesitate to ask if any of the presentation styles doesn't have any meaning for you.

Marking up the lecture material

For this task please have again a look on your work sheet and mark up the different parts of the Lecture information with the different high-lighters as stated below. Please try to comment why you choose specific parts and why not.

- Please mark the theory of the lecture with blue colour.
- Please mark any proof/explanation of the lecture with green colour.
- Please mark an example of the lecture with red colour.
- Please mark any possible help with yellow colour.

Select the type of the lecture presentation

Please select now one of the presentation styles of the Lecture listed below. Please justify why you selected a specific one or if you would prefer to have different styles for different situations. Encircle your selection on this sheet. Here are your possible choices:

- Theory - Proof - Example
- Example - Theory - Proof

Please don't hesitate to ask if any of the presentation styles doesn't have any meaning for you.

Marking up the additional information

For the next task please mark up additional information on the work sheet with the high-lighters. We are looking for the following information (colours):

- Name of the author (blue).
- Authoring date (green).
- Target audience age (yellow).
- Target audience level (orange).
- Language of the educational material (red).

Select the order of the presentation

Finally, the last task of the manual mark up stage is to select the order you would like your information presented in an educational module. For this task please encircle all your Question and Answer information on your work sheet with a colour of your choice and all of the Lecture information with a different colour. Then note on the sheet the display order of your preference, for example. 1,2 or A,B.

Once you have finished this task you will be asked to give a short mid-test interview about your tasks.

Practical Test with the HEAT package

The second part of your test is to work with the Hypermedia Educational Authoring Tool (HEAT). The HEAT is a new authoring tool that was developed to ease the creation of educational material for delivery over the WWW for teachers. It is based on the same model framework you were using in the first part of this study. Therefore, this second part is also focusing on the created model and not so much on the evaluation of the software. Furthermore, this software is only a test prototype so don't worry if you get stuck, just ask for help. As in the manual markup it would be highly appreciated if you could "think aloud".

Entering the additional information

Once the HEAT is starting up, it will show up the following window.

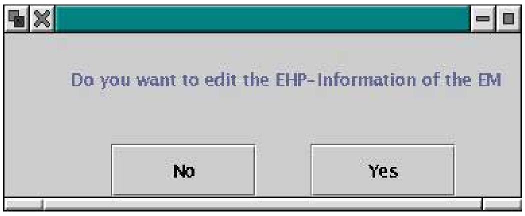

Figure 24: Startup Screen

Please answer this dialog with yes. The following screen will show up:

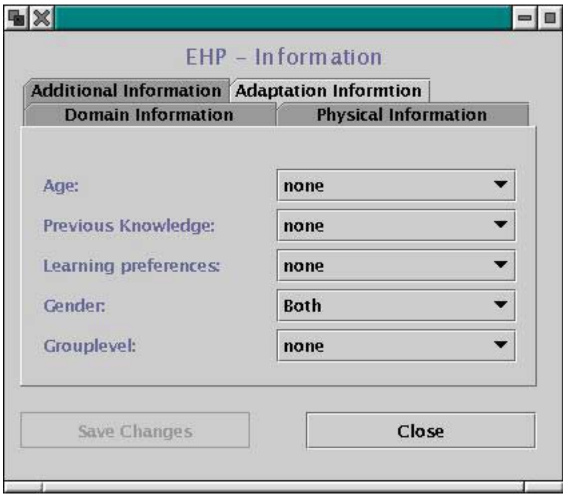

Figure 25: EHP-Information of the Educational Module

Please fill out this screen (change also the tabs on the top) with the marked up additional information from your work sheet. Once you are finished please push the “Save Changes” button, before you “Close” the window.

Creating a Question and Answer TLS

The next step of the study is to create an instance of a Question and Answer TLS. Please insert a new Question and Answer TLS into the Educational Module by selecting "New QA" from the tool bar of the HEAT.

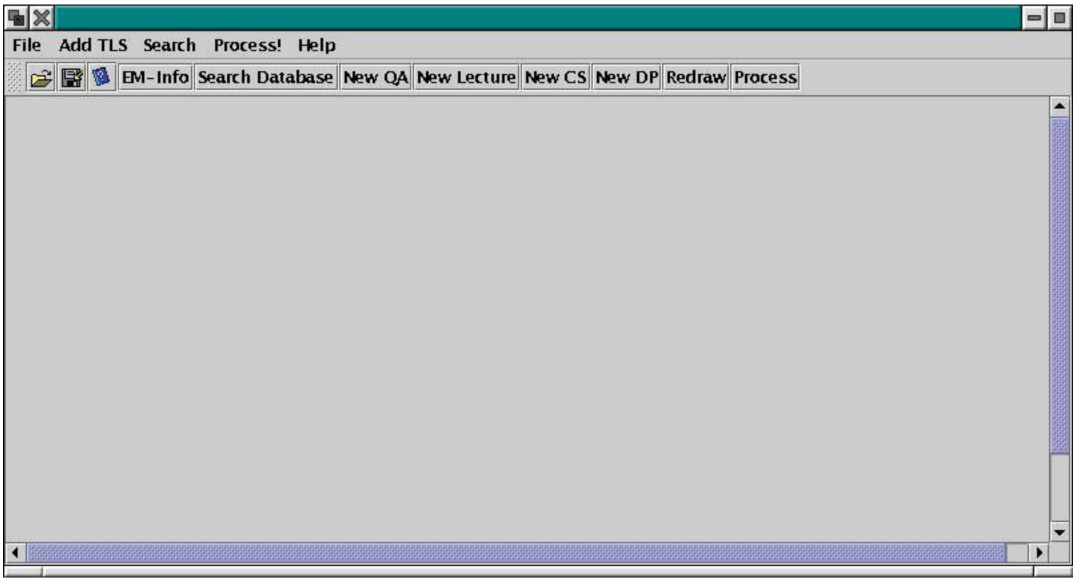

Figure 26: Empty HEAT

When you are asked if you want to inherit the EHP-Information of the EM, choose as you like (accepting the option copies the content of the additional data into the Question and Answer TLS).

The next step is to modify the content of the Q&A. Select the content option of the Q&A TLS. Please insert all your data from your work sheet (question, wrong and false answers) and then close the content window again.

If you identified some help for the Q&A or you want to select the presentation style, you have to activate the info option of the TLS. Once you are finished with modifying your data close the info window again.

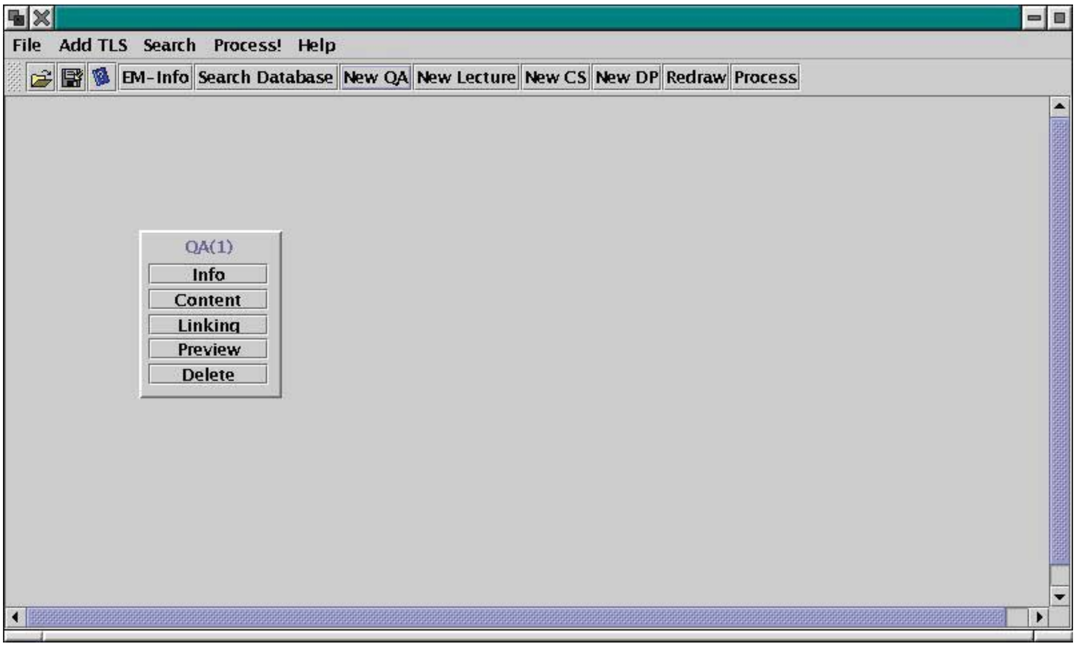

Figure 27: HEAT with QA-TLS

Creating a Lecture TLS

The next step of the study is to create an instance of a Lecture TLS. Please insert a new Lecture TLS into the Educational Module by selecting "New Lecture" from the tool bar of the HEAT. When you are asked if you want the EHP-Information of the EM, choose as you like (accepting the option copies the content of the additional data into the Question and Answer TLS).

The next step is to modify the content of the Lecture. Select the content option of the Lecture TLS. Please insert all your data from your work sheet (theory, proof, example) and then close the content window again.

If you identified some help for the Lecture or you want to select the presentation style, you have to activate the info option of the TLS. Once you are finished with modifying your data close the info window again.

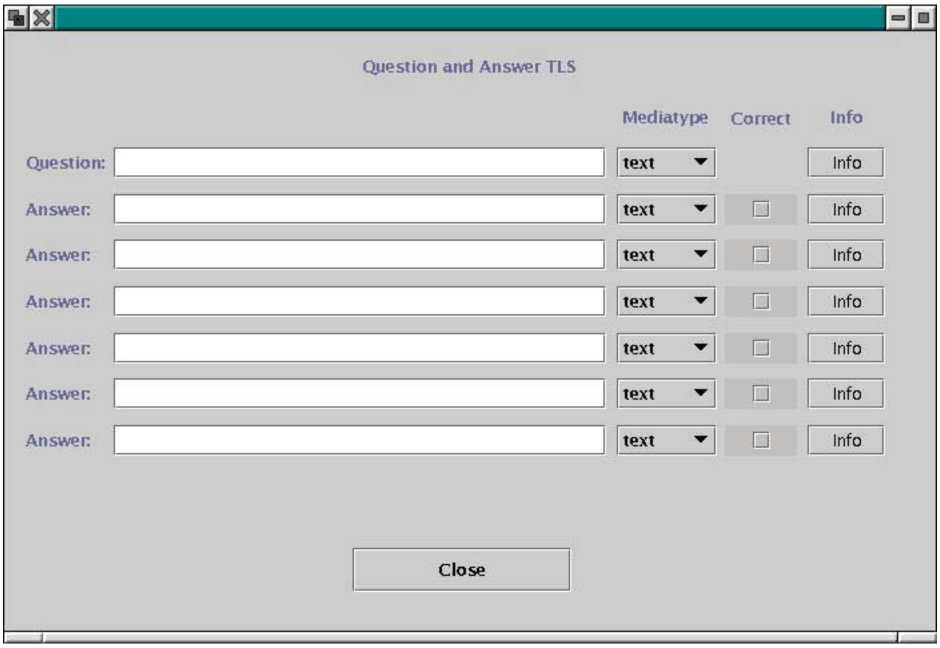

Figure 28: Content window of the QA-TLS

Reusing existing material

A big advantage of the HEAT and the 3-Layer-Model is that previously material can be easily reused. Please activate now the “Search Database” option of the tool bar. HEAT will present you with a list of available TLSs that you can insert into your module. By selecting any of the lines and pushing the “View Data” button you can preview the data of the material before inserting it into your module (“Add to EM”)

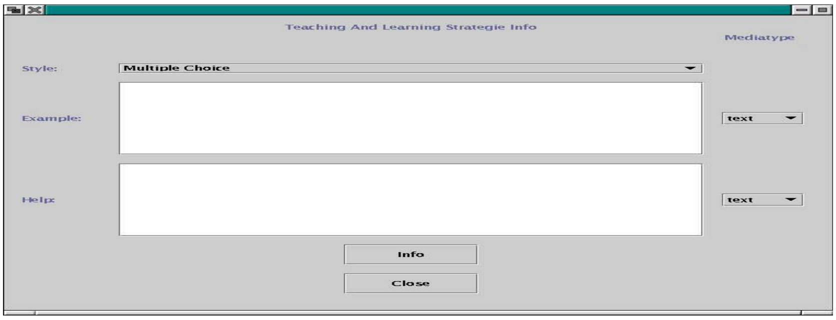

Figure 29: Info window of QA-TLS

Linking the TLSs together

Before processing the educational module now into a WWW format, you have to link the single TLSs together. To link the different TLSs you have to activate the linking option of the TLS you want to link from (the link-base or source). To link to another TLS you have to select the target TLS (indicated by reference numbers in the TLS-title) and the link type. Please select always direct links for the link types. Once you are finished entering the linking information, close the window again.

Depending on your preferences please link the TLSs now together. You can visualise the links if you click with the mouse somewhere on the HEAT background (not on a TLS).

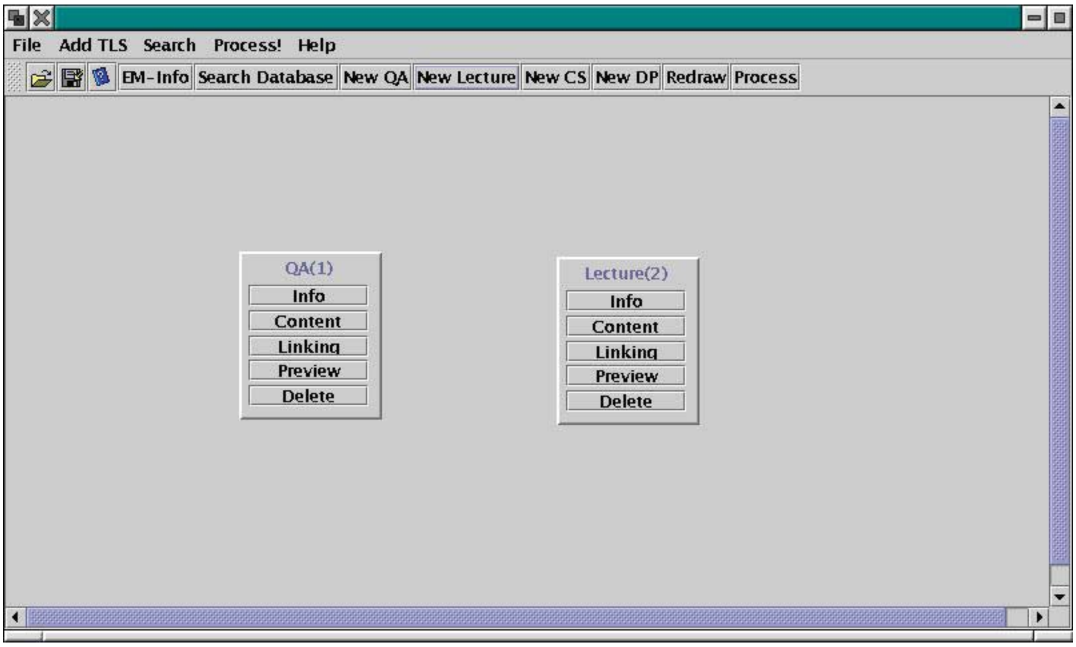

Figure 30: Educational Module with QA and Lecture

Processing the educational module

The final step in creating an educational module is to actually start the processing. Please select "Process" from the tool bar. You will be asked for a general filename: Please use your first name followed by "-EM", for example "Sam-EM". Additionally, please select the TLS you want the module to start with. Finally, press the "Process" button and close the window.

Your material is now being process and converted into an WWW format.

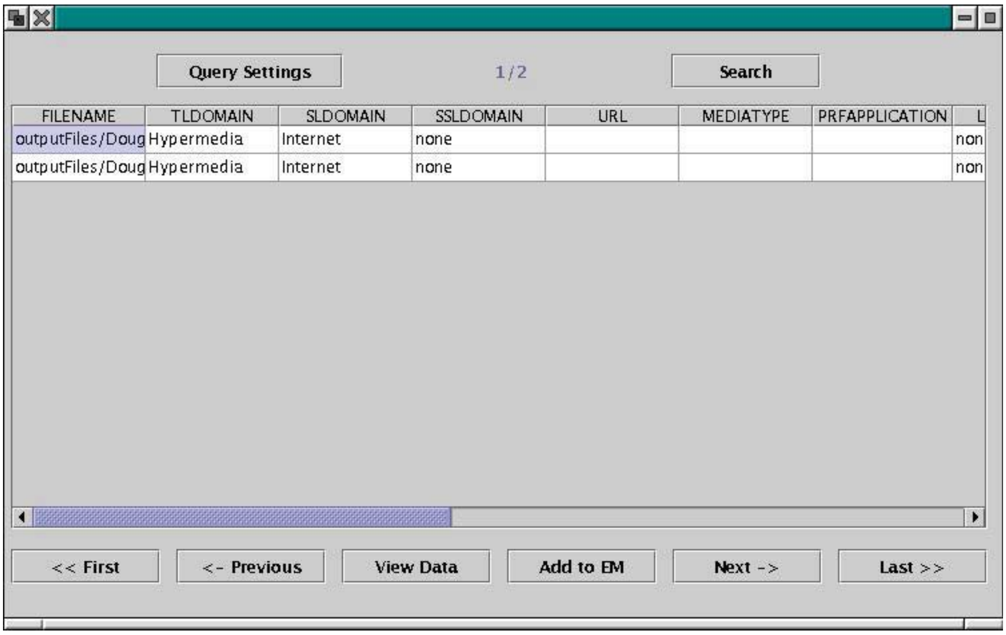

Figure 31: HEAT Database Search

Navigation through the created online material

At this point you don't have to do any more work. Just have a look at the material the HEAT produced for you. It would be appreciated if you could give comments on the produced material.

Thank you very much for your participation in this study!

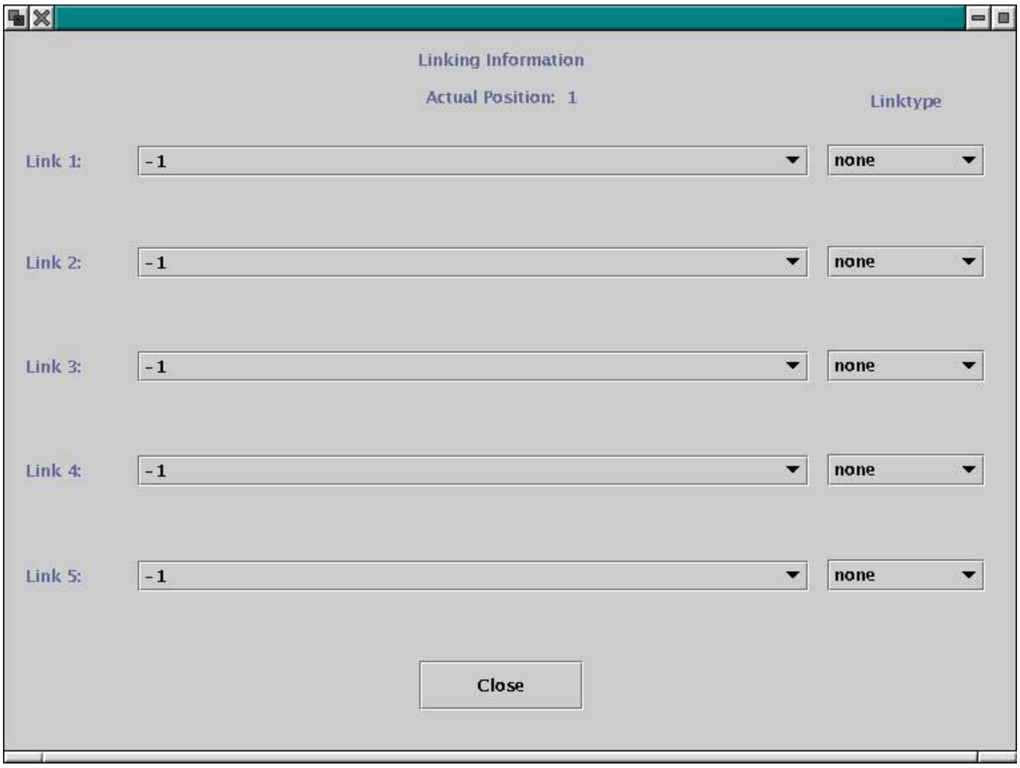

Figure 32: Linking window of the QA

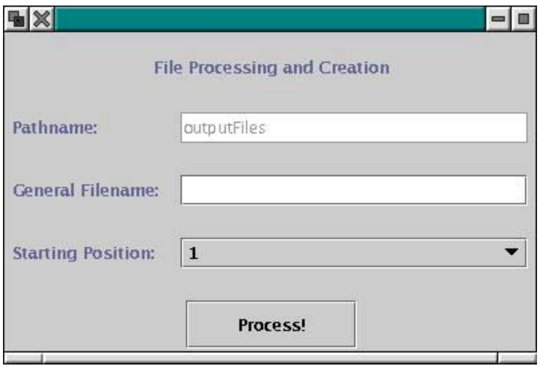

Figure 33: Processing the Educational Module

A.2 Evaluation Worksheet

Please fill the following details first.

- Name:
- Date:
- Audience-level:
- Audience-Age:
- Language:

Question and Answer markup task

Please state all the correct answers to the following question:

Which statement about the University of Glamorgan is correct?

- The University of Glamorgan was originally founded in 1902.
- The University of Glamorgan has a railway station right next to its grounds.
- The University of Glamorgan has School of Medicine.
- The University of Glamorgan identifies its buildings with numbers, e.g. First Block, Second Block.
- The University of Glamorgan has its grounds in south-west Wales near Cardiff.

Please keep in mind, that the University of Glamorgan was formerly known as the Polytechnic of Wales and changed to an University not too long ago.

Lecture markup task

The following text will give you some information about navigating on the grounds of the University of Glamorgan.

The University of Glamorgan is easy to find. It is based approximately 10 miles north of Cardiff and can be reached via train or bus connections. It has a railway station right next to its grounds. Most students think that the navigation on the University grounds is very easy.

This impression is based on the fact that the university identifies is buildings with letters, for example J-Block hosts the School of Computing. Additionally, the university placed signs all over campus pointing out specific buildings or student halls.

For example, if you want to go from the main entrance to J-Block you would be given the following instructions: Leave B-Block and go up the next flight of stairs. On your right-hand side you will see G-Block. Pass it and also pass H-Block on your right. The next building will be J-Block.

If you need any additional help about the university grounds, buildings or specific schools within the university please check out the university Homepage at http://www.glam.ac.uk

A.3 Evaluation Interviews

Pre-Test interview

- Personal Details?
- How could you describe your educational task?
- If you are a teacher, at what level are you teaching?
- What computing skills do you have?
- What specific WWW knowledge do you have?
- How could you describe your thoughts about using the WWW as a tool for education?
- Do you have any experience of authoring WWW-based educational material?
- Do you have any intention to use the WWW for educational purposes in the future?
- Do you have any external requirements to use the WWW for educational purposes in the future?
- Are you know any educational markup projects?
- Are you using any specific educational markup project?

Mid-Test interview

- How would you grade the 3-Layer-Model in a sense of complexity?
- What are the advantages or problems of the model?
- What is your understanding of the tags of the QA-TLS?
- What are the advantages or problems of the QA-tags?
- What is your understanding of the tags of the Lecture-TLS?
- What are the advantages or problems of the Lecture-tags?
- How easy was it for you to do the tagging of the QA material with the tags?
- How easy was it for you to tag the Lecture material?
- Do you have any additional comments?

Post-Test Interview

- How easy was it for you to create an instance of a QA with the HEAT?
- If you had a problem with creating a QA, where and what kind of nature was it?
- How easy was it for you to create a Lecture instance with the HEAT?
- If you had a problem with creating the Lecture, where and what kind of nature was it?
- How easy was it for you to link the TLSs together?
- If you had a problem with linking the TLSs together, were and what kind of nature was it?
- How easy was it for you to reuse some existing material (Database)?
- How easy was it for you to create the actual WWW material (Processing)?
- How good is the presentation of the authored material in the WWW?
- Did the completion of the first task (Manual tagging) help you to understand the HEAT?
- Can you visualise how this tool could be used in preparing material for your teaching?

A.4 Summary of interview results

A.4.1 Summary Pre-Test interview

Personal Details?

The evaluation group had 9 members. The youngest member was 27 years old, the oldest member was 28 years old. In average the evaluation group was 32.44 years old.

Nationality	Number	Percentage
United Kingdom	6	66,66 %
Germany	2	22,22 %
France	1	11,11 %

Table 10: Nationality of evaluation subjects

How could you describe your educational task?

Grade of occupation	Number	Percentage
Full-time teacher	6	66,66 %
Part-Time (50%) teacher	3	33,33 %

Table 11: Educational occupation of evaluation subjects

Educational expertise	Number	Percentage
Educational expert	4	44,44 %
Mixed	3	33,33 %
Technical expert	2	22,22 %

Table 12: Educational expertise of evaluation subjects

If you are a teacher, at what level are you teaching?

Teaching level	Number	Percentage
University	6	66,66 %
Grammar or College	3	33,33 %

Table 13: Teaching level of evaluation subjects

What computing skills do you have?

Computing skills	Number	Percentage
Degree in Computing Science skills, e.g. Word	5	55,55 %
Basic skills, e.g. Word	4	44,44 %

Table 14: Computing skills of evaluation subjects

What specific WWW knowledge do you have?

WWW knowledge	Number	Percentage
Basic skills, e.g. E-Mail	7	77,77 %
HTML or programming skills	2	22,22 %

Table 15: WWW knowledge of evaluation subjects

How could you describe your thoughts about using the WWW as a tool for education?

Importance of WWW for education	Number	Percentage
Important / Will become important	8	88,88 %
Not sure	1	11,11 %

Table 16: Importance of WWW for education

WWW as a tool for education	Number	Percentage
Should be controlled	3	33,33 %
Only for support	3	33,33 %
No comment	3	33,33 %

Table 17: Usage of WWW as a tool for education

Do you have any experience of authoring WWW-based educational material?

Experience in authoring educational material for the WWW	Number	Percentage
No experience	6	66,66 %
Only as a delivery medium	3	33,33 %

Table 18: Experience in WWW authoring for education

Do you have any intention to use the WWW for educational purposes in the future?

Intention of using the WWW for educational purposes	Number	Percentage
Yes	8	88,88 %
No	1	11,11 %

Table 19: Intention of using the WWW for educational purposes

Do you have any external requirements to use the WWW for educational purposes in the future?

External requirements	Number	Percentage
Yes, already existing	5	55,55 %
Yes, in the future	3	33,33 %
No requirements	1	11,11 %

Table 20: External requirements of using the WWW for educational purposes

Do you know any educational markup projects?

Knowledge of educational markup projects	Number	Percentage
No knowledge	8	88,88 %
Some knowledge	1	11,11 %

Table 21: Knowledge of educational markup projects

Are you using any specific educational markup project?

Usage of educational markup project	Number	Percentage
None	9	100%

Table 22: Usage of any specific educational markup project

A.4.2 Summary Mid-Test interview

How would you grade the 3-Layer-Model in a sense of complexity?

Complexity of EFTECS and 3-Layer-Model	Number	Percentage
Complex	4	44,44 %
Straightforward	4	44,44 %
Not complex enough	1	11,11 %

Table 23: Complexity of EFTECS and 3-Layer-Model

What are the advantages or problems of the model?

Advantages of the model	Number	Percentage
No specific advantages	6	66,66 %
Helps structuring the content	2	22,22 %
Easy to understand	1	11,11 %

Table 24: Advantages of the model

Problems of the model	Number	Percentage
No specific problems	4	44,44 %
So far only theoretical	2	22,22 %
Needs to be very flexible	2	22,22 %
Seems very complex	1	11,11 %

Table 25: Problems of the model

What is your understanding of the tags of the QA-TLS?

Understanding of the QA-TLS	Number	Percentage
Fully understood	9	100%

Table 26: Understanding of the QA-TLS

What are the advantages or problems of the QA-tags?

Advantages of the QA-tags	Number	Percentage
No specific advantages	6	66,66 %
Tags are realistic	3	33,33 %

Table 27: Advantages of the QA-tags

Problems of the QA-tags	Number	Percentage
No specific problems	7	77,77 %
Tagging in general was a problem	2	22,22 %

Table 28: Problems of the QA-tags

What is your understanding of the tags of the Lecture-TLS?

Understanding of the Lecture-TLS	Number	Percentage
Fully understood	9	100%

Table 29: Understanding of the Lecture-TLS

Comments:

- Additional tags for lectures were recommended

What are the advantages or problems of the Lecture-tags?

Advantages of the Lecture-tags	Number	Percentage
No specific advantages	7	77,77 %
Tags are realistic	2	22,22 %

Table 30: Advantages of the Lecture-tags

Problems of the Lecture-tags	Number	Percentage
Tags are difficult to apply	4	44,44 %
No specific problems	3	33,33 %
Unknown material	2	22,22 %

Table 31: Problems of the Lecture-tags

How easy was it for you to do the tagging of the QA material with the tags?

Difficulty of QA-tagging	Number	Percentage
Very easy / Easy	9	100%

Table 32: Difficulty of QA-tagging

How easy was it for you to tag the Lecture material?

Difficulty of Lecture-tagging	Number	Percentage
Very easy / Easy	5	55,55 %
More difficult then QA-tagging	4	44,44 %

Table 33: Difficulty of Lecture-tagging

Do you have any additional comments?

Additional comments	Number	Percentage
Framework not yet fully understood	4	44,44 %
Interested in practical application	2	22,22 %
No comment	2	22,22 %
Tagging of mixed educational material could be difficult	1	11,11 %

Table 34: Additional Comments of evaluation group

A.4.3 Summary Post-Test Interview

How easy was it for you to create an instance of a QA with the HEAT?

Difficulty of creating a QA-TLS	Number	Percentage
Very easy / Easy	9	100%

Table 35: Difficulty of creating a QA-TLS

Comment:

- Windows version would be preferred

If you had a problem with creating a QA, where and what kind of nature was it?

Problems with creating a QA-TLS	Number	Percentage
No specific problems	4	44,44 %
Not Windows look and feel	2	22,22 %
Instructions for HEAT were needed	2	22,22 %
Presentation styles got mixed up	1	11,11 %

Table 36: Problems with creating a QA-TLS

How easy was it for you to create a Lecture instance with the HEAT?

Difficulty of creating a Lecture-TLS	Number	Percentage
Very easy / Easy	9	100%

Table 37: Difficulty of creating a Lecture-TLS

If you had a problem with creating the Lecture, where and what kind of nature was it?

Problems with creating a Lecture-TLS	Number	Percentage
No specific problems	7	77,77 %
No Windows look and feel	1	11,11 %
Instructions for HEAT were needed	1	11,11 %

Table 38: Problems with creating a Lecture-TLS

How easy was it for you to link the TLSs together?

Difficulty of linking the TLSs	Number	Percentage
Not so easy as the tagging tasks	8	88,88 %
Very easy / Easy	1	11,11 %

Table 39: Difficulty of linking the TLSs

If you had a problem with linking the TLSs together, were and what kind of nature was it?

Problems with linking the TLSs	Number	Percentage
Linking technique needs to be modified	6	66,66 %
Drag and drop should be used	3	33,33 %

Table 40: Problems with linking the TLSs

How easy was it for you to reuse some existing material (Database)?

Advantages of the material reuse	Number	Percentage
Easy to use	5	55,55 %
Good approach	2	22,22 %
Reusability can save a lot of time	2	22,22 %

Table 41: Advantages of the material reuse

Problems of the material reuse	Number	Percentage
Copyright issues	3	33,33 %
Material sharing is critical	2	22,22 %
No specific problems	2	22,22 %
Better structure and tools needed	1	11,11 %
Pay-system is critical	1	11,11 %

Table 42: Problems of the material reuse

Comments:

- quid-pro-quo is preferred
- no copyright issues within one institutions
- no problems with sharing own content

How easy was it for you to create the actual WWW material (processing)?

Difficulty of processing the created material	Number	Percentage
Very easy / Easy	8	88,88 %
Presentation should be improved	1	11,11 %

Table 43: Difficulty of processing the created material

How good is the presentation of the authored material in the WWW?

Quality of material presentation	Number	Percentage
Improvable, not state of the art	7	77,77 %
Good	2	22,22 %

Table 44: Quality of the presentation of created educational material

Did the completion of the first task (manual tagging) help you to understand the HEAT?

Helpfulness of manual markup task	Number	Percentage
Very helpful / Helpful	7	77,77 %
HEAT was self-explanatory	2	22,22 %

Table 45: Helpfulness of manual markup task

Can you visualise how this tool could be used in preparing material for your teaching?

Potential usage of HEAT	Number	Percentage
Potential given for improved version	5	55,55 %
Potential given	4	44,44 %

Table 46: Potential of using the HEAT for creating educational material

A.5 XSL-Documents

A.5.1 Question and Answer - Multiple Choice

```
<?xml version='1.0'?>
<xsl:stylesheet xmlns:xsl="http://www.w3.org/TR/WD-xsl">
<xsl:template match="/">
<HTML>
<BODY>
<!– Initialisation of the needed JAVA-Script variables –>
<Script Language="JavaScript">
<!– maximumNumbers –>
var maximumNumberOfLinks = 5;
var maximumNumberOfAnswers = 6;
<!– Variables for the Question –>
var question = "";
var questionMediaType="";
<!– One Var-Array for the Answers –>
var answerArray = new Array(maximumNumberOfAnswers);
<!– Another Var-Array for the Answertypes –>
var answerTypeArray = new Array(maximumNumberOfAnswers);
<!– An Array for the rightness/wrongness of an answer –>
var answerMediaTypeArray = new Array(maximumNumberOfAnswers);
<!– Array for the links –>
var linkInformationArray = new Array(maximumNumberOfLinks);
var linkTypeArray = new Array(maximumNumberOfLinks)
<!– Index for the Arrays –>
var index = 0;
<!– Index for the Link-Information –>
var linkindex = 0;
<!– Variables for the TLS file,help and example –>
```

```
var xslFile = "";
var tlsHelp = "";
var tlsHelpMediaType = "";
var tlsExample = "";
var tlsExampleMediaType = "";
</Script>
<!– Function for randomizing the answerArrays –>
<Script Language="JavaScript">
<xsl:comment>
<![CDATA[
function randomiseArrays()
{
<!– Create Temporary Arrays for the randomizing process –>
var tempAnswerArray=new Array(maximumNumberOfAnswers);
var tempAnswerTypeArray=new Array(maximumNumberOfAnswers);
var tempAnswerMediaTypeArray=new Array(maximumNumberOfAnswers);
<!– Then initialise the Arrays –>
for(var i=0;i<maximumNumberOfAnswers;i++)
{
tempAnswerArray[i]= "";
tempAnswerTypeArray[i]= "";
tempAnswerMediaTypeArray[i]= "none";
}
<!– Now randomize the order of the answers –>
for(var i=0;i<maximumNumberOfAnswers;i++)
{
var entryNumber = Math.round(Math.random()*maximumNumberOfAnswers) %
maximumNumberOfAnswers;
while(tempAnswerArray[entryNumber]!="")
{
```

```
entryNumber = (Math.round(Math.random()*maximumNumberOfAnswers) % max-
imumNumberOfAnswers);
}
<!– entryPosition Found, now write into the tempArrays –>
tempAnswerArray[entryNumber]=answerArray[i];
tempAnswerTypeArray[entryNumber]=answerTypeArray[i];
tempAnswerMediaTypeArray[entryNumber]=answerMediaTypeArray[i];
}
<!– Finally assign the tempArrays to the original Arrays –>
answerArray = tempAnswerArray;
answerTypeArray = tempAnswerTypeArray;
answerMediaTypeArray = tempAnswerMediaTypeArray;
}
]]>
</xsl:comment>
</Script>
<!– Function for displaying the AnswerEvaluationButton –>
<Script Language="JavaScript">
<xsl:comment>
<![CDATA[
function displayEvaluationButton()
{
document.write("<input type=\"button\" value=\"Check Answers\" onClick=\"analyseAnswers()\"></in
}
]]>
</xsl:comment>
</Script>
<!– Function for displaying the answers –>
<Script Language="JavaScript">
<xsl:comment>
```

```
<![CDATA[
function displayMultipleChoice()
{
<!– Create a new form –>
document.write("<Form Name=\"MultipleChoiceForm\">");
for(var i=0;i<answerArray.length;i++)
{
<!– Display the answer only if it is a valid answer –>
if(answerArray[i] != "")
{
document.write("<input type=\"checkbox\" UNCHECKED ");
document.write("value=\""+answerArray[i]+"\" ");
document.write("name=\"AnswerCheckbox\" ");
document.write("onClick=\"\">");
document.write("</input>"+answerArray[i]+"<BR></BR>");
}
}
<!– Close the Form –>
document.write("</Form>");
}
]]>
</xsl:comment>
</Script>
<!– Function for displaying the answers –>
<Script Language="JavaScript">
<xsl:comment>
<![CDATA[
function displayQuestion()
{
```

```
document.write("<H3>Answer the following Question:</H3>");
document.write("<H2>"+question+"</H2>");
document.write("Select all the correct answers to the question!<BR></BR><BR></BR>");
}
]]>
</xsl:comment>
</Script>
<!– Function for analysing the answers –>
<Script Language="JavaScript">
<xsl:comment>
<![CDATA[
function analyseAnswers()
{
var correctness=true;
var arrayindex = 0;
for(var i=0;i<MultipleChoiceForm.AnswerCheckbox.length;i++)
{
<!– First position the arrayindex to the next element –>
while(answerArray[arrayindex]=="")
{
arrayindex++;
}
<!– Then check the answer –>
if(answerTypeArray[arrayindex]!=MultipleChoiceForm.AnswerCheckbox[i].checked)
{
correctness=false;
}
<!– don't forget to increment the arrayindex to the next element –>
arrayindex++;
```

```
}
if(correctness)
{
alert("Your answer was correct!");
}
else
{
alert("Your answer was wrong");
}
}
]]>
</xsl:comment>
</Script>
<!– Function for showing the navigational links –>
<Script Language="JavaScript">
<xsl:comment>
<![CDATA[
function showNavigationLinks()
{
<!– Variable for the display color –>
var displayColor="blue";
<!– Open the table –>
document.write("<table width=\"99%\" border=\"1\">");
document.write("<tr>");
<!– Insert the table date from the link array –>
for(var i=0;i<maximumNumberOfLinks;i++)
{
<!– There is a link destination stored –>
if(linkInformationArray[i] != "-1")
```

```
{
<!– Determine the color of the link –>
if(linkTypeArray[i] == "direct")
{
displayColor="yellow";
}
if(linkTypeArray[i] == "home")
{
displayColor="red";
}
if(linkTypeArray[i] == "back")
{
displayColor="green";
}
if(linkTypeArray[i] == "split")
{
displayColor="orange";
}
if(linkTypeArray[i] == "join")
{
displayColor="brown";
}
if(linkTypeArray[i] == "parallel")
{
displayColor="pink";
}
<!– Now insert the link into the table –>
document.write("<td valign=\"middle\" align=\"center\">");
document.write("<A href=\""+linkInformationArray[i]+"\">");
```

```
document.write("<Font color="+displayColor+">"+linkInformationArray[i]+"</Font>");
document.write("</A></H5></td>");
}
}
<!– Close the table –>
document.write("</tr>");
document.write("</table");
}
]]>
</xsl:comment>
</Script>
<!– Function for showing the supportive links –>
<Script Language="JavaScript">
<xsl:comment>
<![CDATA[
function showSupportLinks()
{
<!– Open the table only if there is an example or a help–>
if(tlsHelp != "" && tlsExample !="")
{
document.write("<table width=\"99%\" border=\"1\" height=\"5\">");
document.write("<tr>");
<!– Insert the table data from the content –>
<!– Determine the color of the link –>
if(tlsHelp != "")
{
document.write("<td valign=\"middle\" align=\"center\">");
document.write("<A href=\""+document.location+"#HELP\" onClick=showHelp()><H5><FONT
color=lime>Help</FONT></H5></A>");
document.write("</td>");
```

```
}
if(tlsExample != "")
{
document.write("<td valign=\"middle\" align=\"center\">");
document.write("<A href=\""+document.location+"#EXAMPLE\" onClick=showExample()><H5><FC
color=steelblue>Example</FONT></H5></A>");
document.write("</td>");
}
<!– Close the table –>
document.write("</tr>");
document.write("</table");
}
}
]]>
</xsl:comment>
</Script>
<!– Function for showing the TLS-HELP –>
<Script Language="JavaScript">
<xsl:comment>
<![CDATA[
function showHelp()
{
alert(tlsHelp);
}
]]>
</xsl:comment>
</Script>
<!– Function for showing the TLS-Example –>
<Script Language="JavaScript">
<xsl:comment>
```

```
<![CDATA[
function showExample()
{
alert(tlsExample);
}
]]>
</xsl:comment>
</Script>
<xsl:for-each select="TLS">
<xsl:for-each select="QA">
<xsl:for-each select="QUESTION-EHP">
<!– save the question Information –>
<Script Language="JavaScript">
question = "<xsl:value-of select ="QUESTION"/>";
questionMediaType = "<xsl:value-of select ="QUESTION/@type"/>";
</Script>
</xsl:for-each>
<xsl:for-each select="CORRECTANSWER-EHP">
<!– save the information of the correctanswers –>
<Script Language="JavaScript">
answerArray[index] = "<xsl:value-of select="CORRECTANSWER"/>";
answerMediaTypeArray[index] = "<xsl:value-of select="CORRECTANSWER/@type"/>";
answerTypeArray[index] = true;
index = index + 1;
</Script>
</xsl:for-each>
<xsl:for-each select="ANSWER-EHP">
<!– save the information of the answers –>
<Script Language="JavaScript">
```

```
answerArray[index] = "<xsl:value-of select="ANSWER"/>";
answerMediaTypeArray[index] = "<xsl:value-of select="ANSWER/@type"/>";
answerTypeArray[index] = false;
index = index + 1;
</Script>
</xsl:for-each>
</xsl:for-each>
<xsl:for-each select="LINK-INFORMATION">
<!– save the information of the links –>
<Script Language="JavaScript">
linkInformationArray[linkindex] = "<xsl:value-of select="DESTINATION"/>";
linkTypeArray[linkindex] = "<xsl:value-of select="DESTINATION/@type"/>";
linkindex = linkindex + 1;
</Script>
</xsl:for-each>
<Script Language="JavaScript">
<!–Read in the TLS FILE,HELP and EXAMPLE –>
xslFile = "<xsl:value-of select="XSLFILE"/>";
tlsHelp = "<xsl:value-of select="HELP"/>";
tlsHelpMediaType = "<xsl:value-of select="HELP/@type"/>";
tlsExample = "<xsl:value-of select="EXAMPLE"/>";
tlsExampleMediaType = "<xsl:value-of select="EXAMPLE/@type"/>";
</Script>
</xsl:for-each>
<!– Make a test run with all the data –>
<Script Language="JavaScript">
<xsl:comment>
<![CDATA[
randomiseArrays();
```

```
displayQuestion();
displayMultipleChoice();
displayEvaluationButton();
showSupportLinks();
showNavigationLinks();
]]>
</xsl:comment>
</Script>
</BODY>
</HTML>
</xsl:template>
</xsl:stylesheet>
```

A.5.2 Lecture - Deductive

```
<?xml version='1.0'?>
<xsl:stylesheet xmlns:xsl="http://www.w3.org/TR/WD-xsl">
<xsl:template match="/">
<HTML>
<BODY>
<!– Initialisation of the needed JAVA-Script variables –>
<Script Language="JavaScript">
<!– maximumNumbers –>
var maximumNumberOfLinks =5;
<!– Variables for the Theory –>
var theory = "";
var theoryMediaType="";
<!– Variables for the Example –>
var example ="";
var exampleMediaType="";
<!– Variables for the Proof –>
var proof = "";
var proofMediaType = "";
<!– Array for the links –>
var linkInformationArray = new Array(maximumNumberOfLinks);
var linkTypeArray = new Array(maximumNumberOfLinks)
<!– Index for the Link-Information –>
var linkindex = 0;
<!– Variables for the TLS help and example –>
var tlsHelp = "";
var tlsHelpMediaType = "";
var tlsExample = "";
var tlsExampleMediaType = "";
```

```
<!– Variable for the Lecturestyles –>
var lectureStyle = "";
var actualPosition ="";
</Script>
<!– Function for Displaying the content form –>
<Script Language="JavaScript">
<xsl:comment>
<![CDATA[
function displayLectureContentArea()
{
document.write("<Form Name=\"LectureContentForm\">");
//Display the content area
document.write("<TextArea name=\"ContentArea\" rows=\"15\" cols=\"80\" ></TextArea>");
//display the navigation button
document.write("<DIV align=center><input type=\"button\" name=\"Previous\"
value=\"Previous\" onClick=\"processPrevious()\"></input><input type=\"button\"
name=\"Next\" value=\"Next\" onClick=\"processNext()\"></input></DIV>");
document.write("</Form>");
}
]]>
</xsl:comment>
</Script>
<Script Language="JavaScript">
<xsl:comment>
<![CDATA[
function processPrevious()
{
if(lectureStyle=="inductive")
{
//first case, it is at the beginning of the lecture type
```

```
//no navigation is done, only a alert is displayed
if(actualPosition=="example")
{
alert("You are at the starting position");
}
else
{
//second case, the user is at the proof element
//the position will be set to the example element and the example content displayed
if(actualPosition=="proof")
{
displayContent(example);
actualPosition="example";
}
else
{
//third case, the user is at the theory element
//the position will be set to the proof element and the proof content displayed
if(actualPosition=="theory")
{
displayContent(proof);
actualPosition="proof";
}
}
}
}
if(lectureStyle=="deductive")
{
//first case, it is at the beginning of the lecture type
```

```
//no navigation is done, only a alert is displayed
if(actualPosition=="theory")
{
alert("You are at the starting position");
}
else
{
//second case, the user is at the proof element
//the position will be set to the example element and the example content displayed
if(actualPosition=="proof")
{
displayContent(theory);
actualPosition="theory";
}
else
{
//third case, the user is at the example element
//the position will be set to the proof element and the proof content displayed
if(actualPosition=="example")
{
displayContent(proof);
actualPosition="proof";
}
}
}
}
}
]]>
</xsl:comment>
```

```
</Script>
<Script Language="JavaScript">
<xsl:comment>
<![CDATA[
function processNext()
{
if(lectureStyle=="inductive")
{
//first case, the user is at the example element
//the position will be set to the proof element and the proof content displayed
if(actualPosition=="example")
{
displayContent(proof);
actualPosition="proof";
}
else
{
//second case, the user is at the proof element
//the position will be set to the theory element and the theory content displayed
if(actualPosition=="proof")
{
displayContent(theory);
actualPosition="theory";
}
else
{
//third case, it is at the end of the lecture type
//no navigation is done, only a alert is displayed
if(actualPosition=="theory")
```

```
{
alert("You are at the end position");
}
}
}
}
if(lectureStyle=="deductive")
{
//first case, it is at the beginning of the lecture type
//the position will be set to the proof element and the proof content displayed
if(actualPosition=="theory")
{
displayContent(proof);
actualPosition="proof";
}
else
{
//second case, the user is at the proof element
//the position will be set to the example element and the example content displayed
if(actualPosition=="proof")
{
displayContent(example);
actualPosition="example";
}
else
{
//third case, the user is at the example element
//no navigation is done, only a alert will be displayed
if(actualPosition=="example")
```

```
{
alert("You are at the end position");
}
}
}
}
}
]]>
</xsl:comment>
</Script>
<Script Language="JavaScript">
<xsl:comment>
<![CDATA[
function displayContent(content)
{
//First clear the content
LectureContentForm.ContentArea.value="";
//And then display the contet in the area
LectureContentForm.ContentArea.value=content;
}
]]>
</xsl:comment>
</Script>
<!– Function for showing the navigational links –>
<Script Language="JavaScript">
<xsl:comment>
<![CDATA[
function showNavigationLinks()
{
```

```
<!– Variable for the display color –>
var displayColor="blue";
<!– Open the table –>
document.write("<table width=\"99%\" border=\"1\">");
document.write("<tr>");
<!– Insert the table date from the link array –>
for(var i=0;i<maximumNumberOfLinks;i++)
{
<!– There is a link destination stored –>
if(linkInformationArray[i] != "-1")
{
<!– Determine the color of the link –>
if(linkTypeArray[i] == "direct")
{
displayColor="yellow";
}
if(linkTypeArray[i] == "home")
{
displayColor="red";
}
if(linkTypeArray[i] == "back")
{
displayColor="green";
}
if(linkTypeArray[i] == "split")
{
displayColor="orange";
}
if(linkTypeArray[i] == "join")
```

```
{
displayColor="brown";
}
if(linkTypeArray[i] == "parallel")
{
displayColor="pink";
}
<!– Now insert the link into the table –>
document.write("<td valign=\"middle\" align=\"center\">");
document.write("<A href=\""+linkInformationArray[i]+"\">");
document.write("<Font color="+displayColor+">"+linkInformationArray[i]+"</Font>");
document.write("</A></H5></td>");
}
}
<!– Close the table –>
document.write("</tr>");
document.write("</table");
}
]]>
</xsl:comment>
</Script>
<!– Function for showing the supportive links –>
<Script Language="JavaScript">
<xsl:comment>
<![CDATA[
function showSupportLinks()
{
<!– Open the table only if there is an example or a help–>
if(tlsHelp != "" && tlsExample !="")
```

```
{
document.write("<table width=\"99%\" border=\"1\" height=\"5\">");
document.write("<tr>");
<!– Insert the table data from the content –>
<!– Determine the color of the link –>
if(tlsHelp != "")
{
document.write("<td valign=\"middle\" align=\"center\">");
document.write("<A href=\""+document.location+"#HELP\" onClick=showHelp()><H5><FONT
color=lime>Help</FONT></H5></A>");
document.write("</td>");
}
if(tlsExample != "")
{
document.write("<td valign=\"middle\" align=\"center\">");
document.write("<A href=\""+document.location+"#EXAMPLE\" onClick=showExample()><H5><FO
color=steelblue>Example</FONT></H5></A>");
document.write("</td>");
}
<!– Close the table –>
document.write("</tr>");
document.write("</table");
}
}
]]>
</xsl:comment>
</Script>
<!– Function for showing the TLS-HELP –>
<Script Language="JavaScript">
<xsl:comment>
```

```
<![CDATA[
function showHelp()
{
alert(tlsHelp);
}
]]>
</xsl:comment>
</Script>
<!– Function for showing the TLS-Example –>
<Script Language="JavaScript">
<xsl:comment>
<![CDATA[
function showExample()
{
alert(tlsExample);
}
]]>
</xsl:comment>
</Script>
<xsl:for-each select="TLS">
<xsl:for-each select="LECTURE">
<xsl:for-each select="THEORY-EHP">
<!– save the question Information –>
<Script Language="JavaScript">
theory = "<xsl:value-of select ="THEORY"/>";
theoryMediaType = "<xsl:value-of select ="THEORY/@type"/>";
</Script>
</xsl:for-each>
<xsl:for-each select="PROOF-EHP">
```

```
<!– save the information of the correctanswers –>
<Script Language="JavaScript">
proof = "<xsl:value-of select="PROOF"/>";
proofMediaTypeArray = "<xsl:value-of select="PROOF/@type"/>";
</Script>
</xsl:for-each>
<xsl:for-each select="EXAMPLE-EHP">
<!– save the information of the answers –>
<Script Language="JavaScript">
example = "<xsl:value-of select="EXAMPLE"/>";
exampleMediaTypeArray = "<xsl:value-of select="EXAMPLE/@type"/>";
</Script>
</xsl:for-each>
</xsl:for-each>
<xsl:for-each select="LINK-INFORMATION">
<!– save the information of the links –>
<Script Language="JavaScript">
linkInformationArray[linkindex] = "<xsl:value-of select="DESTINATION"/>";
linkTypeArray[linkindex] = "<xsl:value-of select="DESTINATION/@type"/>";
linkindex = linkindex + 1;
</Script>
</xsl:for-each>
<!–Read in the TLS HELP and EXAMPLE –>
<Script Language="JavaScript">
tlsHelp = "<xsl:value-of select="HELP"/>";
tlsHelpMediaType = "<xsl:value-of select="HELP/@type"/>";
tlsExample = "<xsl:value-of select="EXAMPLE"/>";
tlsExampleMediaType = "<xsl:value-of select="EXAMPLE/@type"/>";
</Script>
```

```
</xsl:for-each>
<!– Make a test run with all the data –>
<Script Language="JavaScript">
displayLectureContentArea();
showSupportLinks();
lectureStyle = "deductive";
actualPosition = "theory";
displayContent(theory);
showNavigationLinks();
</Script>
</BODY>
</HTML>
</xsl:template>
</xsl:stylesheet>
```

A.5.3 Drill and Practice - Drill and Practice

```
<?xml version='1.0'?>
<xsl:stylesheet xmlns:xsl="http://www.w3.org/TR/WD-xsl">
<xsl:template match="/">
<HTML>
<BODY>
<!– Initialisation of the needed JAVA-Script variables –>
<Script Language="JavaScript">
<!– maximumNumbers –>
var maximumNumberOfLinks =5;
<!– Variables for the Drill –>
var drill = "";
var drillMediaType="";
<!– Variables for the Example –>
var instruction ="";
var instructionMediaType="";
<!– Variables for the Proof –>
var practice = "";
var practiceMediaType = "";
<!– Array for the links –>
var linkInformationArray = new Array(maximumNumberOfLinks);
var linkTypeArray = new Array(maximumNumberOfLinks)
<!– Index for the Link-Information –>
var linkindex = 0;
<!– Variables for the TLS help and example –>
var tlsHelp = "";
var tlsHelpMediaType = "";
var tlsExample = "";
var tlsExampleMediaType = "";
```

```
</Script>
<!– Function for showing the navigational links –>
<Script Language="JavaScript">
<xsl:comment>
<![CDATA[
function showNavigationLinks()
{
<!– Variable for the display color –>
var displayColor="blue";
<!– Open the table –>
document.write("<table width=\"99%\" border=\"1\">");
document.write("<tr>");
<!– Insert the table date from the link array –>
for(var i=0;i<maximumNumberOfLinks;i++)
{
<!– There is a link destination stored –>
if(linkInformationArray[i] != "-1")
{
<!– Determine the color of the link –>
if(linkTypeArray[i] == "direct")
{
displayColor="yellow";
}
if(linkTypeArray[i] == "home")
{
displayColor="red";
}
if(linkTypeArray[i] == "back")
{
```

```
displayColor="green";
}
if(linkTypeArray[i] == "split")
{
displayColor="orange";
}
if(linkTypeArray[i] == "join")
{
displayColor="brown";
}
if(linkTypeArray[i] == "parallel")
{
displayColor="pink";
}
<!– Now insert the link into the table –>
document.write("<td valign=\"middle\" align=\"center\">");
document.write("<A href=\""+linkInformationArray[i]+"\">");
document.write("<Font color="+displayColor+">"+linkInformationArray[i]+"</Font>");
document.write("</A></H5></td>");
}
}
<!– Close the table –>
document.write("</tr>");
document.write("</table");
}
]]>
</xsl:comment>
</Script>
<!– Function for showing the supportive links –>
```

```
<Script Language="JavaScript">
<xsl:comment>
<![CDATA[
function showSupportLinks()
{
<!– Open the table only if there is an example or a help–>
if(tlsHelp != "" && tlsExample !="")
{
document.write("<table width=\"99%\" border=\"1\" height=\"5\">");
document.write("<tr>");
<!– Insert the table data from the content –>
<!– Determine the color of the link –>
if(tlsHelp != "")
{
document.write("<td valign=\"middle\" align=\"center\">");
document.write("<A href=\""+document.location+"#HELP\" onClick=showHelp()><H5><FONT
color=lime>Help</FONT></H5></A>");
document.write("</td>");
}
if(tlsExample != "")
{
document.write("<td valign=\"middle\" align=\"center\">");
document.write("<A href=\""+document.location+"#EXAMPLE\" onClick=showExample()><H5><FO
color=steelblue>Example</FONT></H5></A>");
document.write("</td>");
}
<!– Close the table –>
document.write("</tr>");
document.write("</table");
}
```

```
}
]]>
</xsl:comment>
</Script>
<!– Function for showing the TLS-HELP –>
<Script Language="JavaScript">
<xsl:comment>
<![CDATA[
function showHelp()
{
alert(tlsHelp);
}
]]>
</xsl:comment>
</Script>
<!– Function for showing the TLS-Example –>
<Script Language="JavaScript">
<xsl:comment>
<![CDATA[
function showExample()
{
alert(tlsExample);
}
]]>
</xsl:comment>
</Script>
<xsl:for-each select="TLS">
<xsl:for-each select="DRILLANDPRACTICE">
<xsl:for-each select="DRILL-EHP">
```

```
<!– save the question Information –>
<Script Language="JavaScript">
drill = "<xsl:value-of select ="DRILL"/>";
drillMediaType = "<xsl:value-of select ="DRILL/@type"/>";
</Script>
</xsl:for-each>
<xsl:for-each select="INSTRUCTION-EHP">
<!– save the information of the correctanswers –>
<Script Language="JavaScript">
instruction = "<xsl:value-of select="INSTRUCTION"/>";
instructionMediaTypeArray = "<xsl:value-of select="INSTRUCTION/@type"/>";
</Script>
</xsl:for-each>
<xsl:for-each select="PRACTICE-EHP">
<!– save the information of the answers –>
<Script Language="JavaScript">
practice = "<xsl:value-of select="PRACTICE"/>";
practiceMediaTypeArray = "<xsl:value-of select="PRACTICE/@type"/>";
</Script>
</xsl:for-each>
</xsl:for-each>
<xsl:for-each select="LINK-INFORMATION">
<!– save the information of the links –>
<Script Language="JavaScript">
linkInformationArray[linkindex] = "<xsl:value-of select="DESTINATION"/>";
linkTypeArray[linkindex] = "<xsl:value-of select="DESTINATION/@type"/>";
linkindex = linkindex + 1;
</Script>
</xsl:for-each>
```

```
<!–Read in the TLS HELP and EXAMPLE –>
tlsHelp = "<xsl:value-of select="HELP"/>";
tlsHelpMediaType = "<xsl:value-of select="HELP/@type"/>";
tlsExample = "<xsl:value-of select="EXAMPLE"/>";
tlsExampleMediaType = "<xsl:value-of select="EXAMPLE/@type"/>";
</xsl:for-each>
<!– Make a test run with all the data –>
<Script Language="JavaScript">
document.write("<P>Drill: "+drill+"<BR></BR>DrillType: "+drillMediaType+"</P>");
document.write("<P>Instruction: "+instruction+"<BR></BR>ProofType: "+instructionMediaType+"</P>");
document.write("<P>Practice: "+practice+"<BR></BR>ExampleType: "+practiceMediaType+"</P>");
showSupportLinks();
showNavigationLinks();
</Script>
</BODY>
</HTML>
</xsl:template>
</xsl:stylesheet>
```

A.5.4 Case Study - Traditional

```
<?xml version='1.0'?>
<xsl:stylesheet xmlns:xsl="http://www.w3.org/TR/WD-xsl">
<xsl:template match="/">
<HTML>
<BODY>
<!– Initialisation of the needed JAVA-Script variables –>
<Script Language="JavaScript">
<!– maximumNumbers –>
var maximumNumberOfLinks =5;
<!– Variables for the Drill –>
var description = "";
var descriptionMediaType="";
<!– Variables for the Example –>
var viewer ="";
var viewerMediaType="";
<!– Variables for the Proof –>
var view = "";
var viewMediaType = "";
<!– Array for the links –>
var linkInformationArray = new Array(maximumNumberOfLinks);
var linkTypeArray = new Array(maximumNumberOfLinks)
<!– Index for the Link-Information –>
var linkindex = 0;
<!– Variables for the TLS help and example –>
var tlsHelp = "";
var tlsHelpMediaType = "";
var tlsExample = "";
var tlsExampleMediaType = "";
```

```
</Script>
<!– Function for showing the navigational links –>
<Script Language="JavaScript">
<xsl:comment>
<![CDATA[
function showNavigationLinks()
{
<!– Variable for the display color –>
var displayColor="blue";
<!– Open the table –>
document.write("<table width=\"99%\" border=\"1\">");
document.write("<tr>");
<!– Insert the table date from the link array –>
for(var i=0;i<maximumNumberOfLinks;i++)
{
<!– There is a link destination stored –>
if(linkInformationArray[i] != "-1")
{
<!– Determine the color of the link –>
if(linkTypeArray[i] == "direct")
{
displayColor="yellow";
}
if(linkTypeArray[i] == "home")
{
displayColor="red";
}
if(linkTypeArray[i] == "back")
{
```

```
displayColor="green";
}
if(linkTypeArray[i] == "split")
{
displayColor="orange";
}
if(linkTypeArray[i] == "join")
{
displayColor="brown";
}
if(linkTypeArray[i] == "parallel")
{
displayColor="pink";
}
<!– Now insert the link into the table –>
document.write("<td valign=\"middle\" align=\"center\">");
document.write("<A href=\""+linkInformationArray[i]+"\">");
document.write("<Font color="+displayColor+">"+linkInformationArray[i]+"</Font>");
document.write("</A></H5></td>");
}
}
<!– Close the table –>
document.write("</tr>");
document.write("</table");
}
]]>
</xsl:comment>
</Script>
<!– Function for showing the supportive links –>
```

```
<Script Language="JavaScript">
<xsl:comment>
<![CDATA[
function showSupportLinks()
{
<!– Open the table only if there is an example or a help–>
if(tlsHelp != "" && tlsExample !="")
{
document.write("<table width=\"99%\" border=\"1\" height=\"5\">");
document.write("<tr>");
<!– Insert the table data from the content –>
<!– Determine the color of the link –>
if(tlsHelp != "")
{
document.write("<td valign=\"middle\" align=\"center\">");
document.write("<A href=\""+document.location+"#HELP\" onClick=showHelp()><H5><FONT
color=lime>Help</FONT></H5></A>");
document.write("</td>");
}
if(tlsExample != "")
{
document.write("<td valign=\"middle\" align=\"center\">");
document.write("<A href=\""+document.location+"#EXAMPLE\" onClick=showExample()><H5><F
color=steelblue>Example</FONT></H5></A>");
document.write("</td>");
}
<!– Close the table –>
document.write("</tr>");
document.write("</table");
}
```

```
}
]]>
</xsl:comment>
</Script>
<!– Function for showing the TLS-HELP –>
<Script Language="JavaScript">
<xsl:comment>
<![CDATA[
function showHelp()
{
alert(tlsHelp);
}
]]>
</xsl:comment>
</Script>
<!– Function for showing the TLS-Example –>
<Script Language="JavaScript">
<xsl:comment>
<![CDATA[
function showExample()
{
alert(tlsExample);
}
]]>
</xsl:comment>
</Script>
<xsl:for-each select="TLS">
<xsl:for-each select="CASESTUDY">
<xsl:for-each select="DESCRIPTION-EHP">
```

```
<!– save the description Information –>
<Script Language="JavaScript">
description = "<xsl:value-of select ="DESCRIPTION"/>";
descriptionMediaType = "<xsl:value-of select ="DESCRIPTION/@type"/>";
</Script>
</xsl:for-each>
<xsl:for-each select="VIEWER-EHP">
<!– save the information of the viewer –>
<Script Language="JavaScript">
viewer = "<xsl:value-of select="VIEWER"/>";
viewerMediaTypeArray = "<xsl:value-of select="VIEWER/@type"/>";
</Script>
</xsl:for-each>
<xsl:for-each select="VIEW-EHP">
<!– save the information of the view –>
<Script Language="JavaScript">
view = "<xsl:value-of select="VIEW"/>";
viewMediaTypeArray = "<xsl:value-of select="VIEW/@type"/>";
</Script>
</xsl:for-each>
</xsl:for-each>
<xsl:for-each select="LINK-INFORMATION">
<!– save the information of the links –>
<Script Language="JavaScript">
linkInformationArray[linkindex] = "<xsl:value-of select="DESTINATION"/>";
linkTypeArray[linkindex] = "<xsl:value-of select="DESTINATION/@type"/>";
linkindex = linkindex + 1;
</Script>
</xsl:for-each>
```

```
<!–Read in the TLS HELP and EXAMPLE –>
tlsHelp = "<xsl:value-of select="HELP"/>";
tlsHelpMediaType = "<xsl:value-of select="HELP/@type"/>";
tlsExample = "<xsl:value-of select="EXAMPLE"/>";
tlsExampleMediaType = "<xsl:value-of select="EXAMPLE/@type"/>";
</xsl:for-each>
<!– Make a test run with all the data –>
<Script Language="JavaScript">
document.write("<P>Description: "+description+"<BR></BR>DescriptionType: "+descriptionMediaType+"</P>");
document.write("<P>Viewer: "+viewer+"<BR></BR>ViewerType: "+viewerMediaType+"</P>");
document.write("<P>View: "+view+"<BR></BR>ViewType: "+viewMediaType+"</P>");
showSupportLinks();
showNavigationLinks();
</Script>
</BODY>
</HTML>
</xsl:template>
</xsl:stylesheet>
```

A.6 XEML - eXtensible Educational Markup Language

```
<!– Hypermedia Education Authoring Tool (HEAT) - DTD –>
<!ELEMENT EM (TLS+, EHP-INFORMATION?)>
 <!ELEMENT TLS ((QA|LECTURE|CASESTUDY|DRILLANDPRACTICE), HELP-EHP, EXAMPLE-EHP, EHP-INFORMATION?, LINK-INFORMATION*)>
   <!ELEMENT QA (QUESTION-EHP, ANSWER-EHP+, CORRECTANSWER-EHP+, EHP-INFORMATION?, EXAMPLE-EHP*, HELP-EHP*)>
    <!ELEMENT QUESTION-EHP (QUESTION, EHP-INFORMATION?)>
     <!ELEMENT QUESTION (#PCDATA)>
      <!ATTLIST QUESTION type (text|audio|video|image|link) #REQUIRED>
    <!ELEMENT ANSWER-EHP (ANSWER, EHP-INFORMATION?)>
     <!ELEMENT ANSWER (#PCDATA)>
      <!ATTLIST ANSWER type (text|audio|video|image|link) #REQUIRED>
    <!ELEMENT CORRECTANSWER-EHP (CORRECTANSWER, EHP-INFORMATION?)>
     <!ELEMENT CORRECTANSWER (#PCDATA)>
      <!ATTLIST CORRECTANSWER type (text|audio|video|image|link) #REQUIRED>
  <!ELEMENT LECTURE (THEORY-EHP+, PROOF-EHP+, EHP-INFORMATION?, EXAMPLE-EHP*, HELP-EHP*)>
    <!ELEMENT THEORY-EHP (THEORY, EHP-INFORMATION?)>
     <!ELEMENT THEORY (#PCDATA)>
      <!ATTLIST THEORY type (text|audio|video|image|link) #REQUIRED>
    <!ELEMENT PROOF-EHP (PROOF, EHP-INFORMATION?)>
     <!ELEMENT PROOF (#PCDATA)>
      <!ATTLIST PROOF type (text|audio|video|image|link) #REQUIRED>
  <!ELEMENT CASESTUDY (DESCRIPTION-EHP, VIEW-EHP, VIEWER-EHP, EHP-INFORMATION?, EXAMPLE-EHP*, HELP-EHP*)>
    <!ELEMENT DESCRIPTION-EHP (DESCRIPTION, EHP-INFORMATION?)>
     <!ELEMENT DESCRIPTION (#PCDATA)>
      <!ATTLIST DESCRIPTION type (text|audio|video|image|link) #REQUIRED>
    <!ELEMENT VIEW-EHP (VIEW, EHP-INFORMATION?)>
     <!ELEMENT VIEW (#PCDATA)>
      <!ATTLIST VIEW type (text|audio|video|image|link) #REQUIRED>
    <!ELEMENT VIEWER-EHP (VIEWER, EHP-INFORMATION?)>
     <!ELEMENT VIEWER (#PCDATA)>
```

```
     <!ATTLIST VIEWER type (text|audio|video|image|link) #REQUIRED>
 <!ELEMENT DRILLANDPRACTICE (DRILL-EHP, INSTRUCTION-EHP, EHP-INFORMATION,
EXAMPLE-EHP*, HELP-EHP*)>
   <!ELEMENT DRILL-EHP (DRILL, EHP-INFORMATION?)>
    <!ELEMENT DRILL (#PCDATA)>
     <!ATTLIST DRILL type (text|audio|video|image|link) #REQUIRED>
   <!ELEMENT INSTRUCTION-EHP (INSTRUCTION, EHP-INFORMATION?)>
    <!ELEMENT INSTRUCTION (#PCDATA)>
     <!ATTLIST INSTRUCTION type (text|audio|video|image|link) #REQUIRED>
  <!ELEMENT HELP-EHP (#PCDATA)>
   <!ATTLIST HELP-EHP type (text|audio|video|image|link) #REQUIRED>
  <!ELEMENT EXAMPLE-EHP (#PCDATA)>
   <!ATTLIST EXAMPLE-EHP type (text|audio|video|image|link) #REQUIRED>
 <!– The following three tags are on the TLS-LEVEL –>
 <!– CHANGES WERE MADE AT THIS SECTION ON 09.02.2001 to improve the DTD –>
 <!– A new Section LINK-INFORMATION was created and the old link-information –>
 <!– will be used in there. Additional information about the links is now easier –>
 <!– to fit into the model –>
 <!ELEMENT LINK-INFORMATION (LINK, DESTINATION, POSITION)>
  <!ELEMENT LINK (#PCDATA)>
  <!ELEMENT DESTINATION (#PCDATA)>
   <!ATTLIST DESTINATION type (direct|split|join|parallel|back|home) #REQUIRED>
  <!ELEMENT POSITION (#PCDATA)>
 <!– The following tags are on the EHP-LEVEL, but can and will be reused on the TLS and EM
level as well–>
 <!ELEMENT EHP-INFORMATION (DOMAIN-INFORMATION+, ADAPTATION-INFORMATION+,
PHYSICAL-INFORMATION+, ADDITIONAL-INFORMATION+)>
 <!ELEMENT DOMAIN-INFORMATION (#PCDATA)>
  <!ATTLIST DOMAIN-INFORMATION level (toplevel|sublevel|subsublevel) #REQUIRED>
 <!ELEMENT ADAPTATION-INFORMATION (AGE?, PREVIOUSKNOWLEDGE?, LEARN-
INGPREFERENCES?, GENDER?)>
  <!ELEMENT AGE (#PCDATA)>
  <!ELEMENT PREVIOUSKNOWLEDGE (#PCDATA)>
  <!ELEMENT LEARNINGPREFERENCES (#PCDATA)>
  <!ELEMENT GENDER (#PCDATA)>
```

```
<!ELEMENT PHYSICAL-INFORMATION (URL?, MEDIA-TYPE?, PREFERRED-APPLICATION?)>
  <!ELEMENT URL (#PCDATA)>
  <!ELEMENT MEDIA-TYPE (#PCDATA)>
  <!ELEMENT PREFERRED-APPLICATION (#PCDATA)>
  <!– CHECK IF ONLY ATTLIST allows a CHOICE OF CONTENT –>
<!ELEMENT ADDITIONAL-INFORMATION (LANGUAGE?, KEYSET?)>
  <!ELEMENT LANGUAGE (#PCDATA)>
  <!– CHECK FOR CHOICE –>
  <!ELEMENT KEYSET (#PCDATA)>
```

A.7 Contents of CD

The following files are stored on the CD of this thesis:

A.7.1 The electronic format of the thesis

Thesis.pdf

A.7.2 The transcripts of the interview evaluation

Transcripts/1.pdf

Transcripts/2.pdf

Transcripts/3.pdf

Transcripts/4.pdf

Transcripts/5.pdf

Transcripts/6.pdf

Transcripts/7.pdf

Transcripts/8.pdf

Transcripts/9.pdf