Coupling Computer-Supported Co-operative Work- and Hypermedia Technology for Distance Education Solutions

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Abstract

Searching for highly interactive and cooperative technologies in the field of distance learning has led to the development of a novel solution. It overcomes existing deficiencies with respect to context-sensitive and individualized interaction in shared learning spaces among learners and teachers. In this contribution we present the results and benefits of integrating computer-supported-cooperative-work- and hypermedia technology at the methodological and conceptual layer, and, based on that, at the implementation level. The application of concepts, such as profiling, has led to several positive effects in practice. We also report on the problems when providing the proper technology support. However, first results from evaluation indicate an increase in usability with respect to the acceptance of electronic media for interactive learning support in distributed environments.

1. Introduction

Distance Learning/Teaching is based on the idea that learners participate in a self-managed way in knowledge transfer processes. Thereby, learners and teachers do not have to be available continuously and at a single location when interacting. However, the process of knowledge transfer is subject to (course) planning and organization, including the collaboration and interaction between learners and teachers, e.g. [8]. Traditionally, distance education is based on novel I&CT (Information and Communication Technologies) and services, such as hypermedia available via the web, and electronic support of collaboration and individual knowledge management, e.g., chats and multi-media annotations [7]. Unfortunately, the acceptance of these approaches is rather limited, as recent empricial findings reveal [16], and the National School Network Testbed initiative (http://nsn.bbn.com) has shown:

- Mentoring and supervision via tele media have not been accepted by learners.
- Existing I&CT as Internet- or web-based tools do neither support knowledge transfer nor group work effectively and efficiently.
- The production of material is time-consuming and lack operational support.
- The participants could not experience any added value due to the electronic availability and computer-supported features compared to conventional settings in education.

The problems/deficiencies listed above have been experienced, although the Internet and its services, such as the web, have turned out to be easy to handle for teachers and learners. It can be concluded that organizational hindrances or/and the ***utilization*** of I&CT for material preparation, transfer of knowledge including mentoring, interaction and collaboration has not been put on a sound conceptual basis. Recent studies on that issue, e.g. [3], have concluded that task-oriented and interpersonal interaction are the most crucial factors for the success of distance learning environments. These issues have also been addressed through principles for design and evaluation: sociability, connectivity, immersion, presence, and engagement [17]. As a consequence, in the course of the SCHOLION (SCaleable tecHnOLIOgies for teleteachiNg/learning) project (http:// instserv0.ce.uni-linz.ac.at/scholion) we had to develop a conceptually sound integration of features for collaboration and interaction based on hypermedia for education. This project should lead to higher user acceptance through increased usability than previous approaches.

In the following sections we review related work with respect to the integration of hypermedia I&CT and collaboration support (section 2). We then revisit the

SCHOLION project from a methodological and conceptual perspective (section 3). In section 4 we sketch the implementation of the proposed concepts. Section 5 evaluates the achievements against standardized principles for designing virtual educational applications. In the conclusion we summarize the objectives and results of our work, and list further research activities.

2. Related Work

Analyzing benchmark and evaluation studies, e.g. [11], it turned out that a sound migration of hypermedia concepts with features for collaboration or vice versa has not been performed so far. However, there exists a variety of approaches toward the extensive use of hypermedia for distance education: In the TeleTeaching project Mannheim-Heidelberg (http://www.informatik.uni-mannheim.de/informatik /pi4/projects/teleteaching) multimedia learning material has been enriched with telecommunication features for human-computer interaction in distance education. Students might learn at home synchronously and asynchronously. So far, no features have yet been developed to support social needs in the course of knowledge transfer, such as publicly available annotations. The „Authoring-on-the-fly"(AOF)-concept [2] also focuses on hypermedia course material rather than on collaboration support. The same statement holds for other development, such as Socratenon [14], and the IRI (Interactive Remote Instruction) System developed at the Old Domino University (http://www.cs.odu.edu/ODUCS /brochure/rcnr.html#irit). The latter targets toward distributed hypermedia course material through the provision of high speed networking, television, and computer technologies over the Internet. In a virtual classroom learners experience identical learning situations at geographically dispersed colleges.

I-CARE (Cyberspace Assisted Responsive Education) (http://wwwpride-i2.poly.edu/I-CARE/icarefl. html) has been developed at PRIDE (Polytechnic Research Institute for Development & Enterprise). The project does not only target toward the provision of hypermedia course material but also toward sociability, namely responsiveness to learner needs, albeit exploiting the Internet as a medium and source of support tools. I-CARE subsumes (i) tools for communication, such as e-mail, telnet, ftp and chat, (ii) tools for group work, e.g., group calendar, bulletin board, appointment books, (iii) tools for information (search engines, on-line databases and dictionary), and (iv) further Internet resources like reference documents, FAQ-files and links.

WebCT (http://www.homebrew1.cs.ubc.ca/webct) enables the development of educational web-pages and corresponding environments. Besides a set of tools that can be applied to any course development, it provides administrative tools that assist the educator in the task of course administration. Tools for communication comprise video conferencing, chat and e-mail. There are no dedicated tools for collaboration. Evaluation tools capture on-line self-testing, automatically marked quizzes, and content-related multiple choice questions. Additionally, a searchable image archive, a course calendar tool, a linkable glossary database, collaboration and presentation areas, content annotation, course navigation, indexing and searching tools, as well as account administration tools are available.

Besides the technology-driven development of hypermedia for distance education (resulting in systems as listed above), in the field of Computer-Supported Cooperative Work the early recognized need for socially adaptive technologies, e.g. [4], has led to an established tradition of empirical and conceptual investigations. It has been found out that the lack of socially responsive developments can be caused by isolated use of tools [10]. These results require revisiting of technology with respect to the dual role of technology [15], and identifying concrete design requirements, as e.g. done by Kristoffersen et al. [9] for the management of collaborative sessions. Unfortunately, up to now, collaborative hypermedia environments for distance education have not incorporated conceptual and empirical findings to an extent that teachers and learners could have experienced an added value when using these technologies.

3. Methodological and Conceptual Design

The SCHOLION developments emphasize the intertwining of hypermedia and collaboration technology in a distributed educational setting. Thus, it should overcome the limitations of existing approaches of distance learning through the provision of the following features [6]:

- to allow learners to individualize and annotate multi- and hypermedia course material in a way similar to the way they use to make notes in traditional course material
- to provide situation- and context-sensitive interaction between learners and teachers
- to support browsing and navigation through the material according to individual annotations,
- to be open to existing data formats and solutions
- to provide an organizational model for teaching, including the preparation of presentations.

The required software systems seem simple in function, but become complex in operation, since users cannot only be supported in an idiosyncratic, personally customized way, e.g., through individualized learning material (figure 1, arrow 1).

Teachers and learners have also to be supported through shared knowledge spaces, equipped with sophisticated features for interaction to enable socially acceptable interactivity. Collaborative hypermedia environments replace conventional education material and knowledge transfer processes. Hence, they require that they can be used simultaneously for both personal use and social coordination. These dual function of collaborative hypermedia introduce new challenges and opportunities for interpersonal communication (figure 1, arrow 2). Additionally, collaborative hypermedia might publicly display the use of course material and the features for annotation and manipulation. This enrichment has implications for both individual users and the function of the software system in the organization more broadly. In the effort to make knowledge transfer and collaboration more effective and efficient, distributed collaborative hypermedia indirectly affect much more fundamental issues of knowledge sharing and temporal coordination. In this critical position, the social environment and technology co-evolve and co-adapt (figure 1, arrow 3).

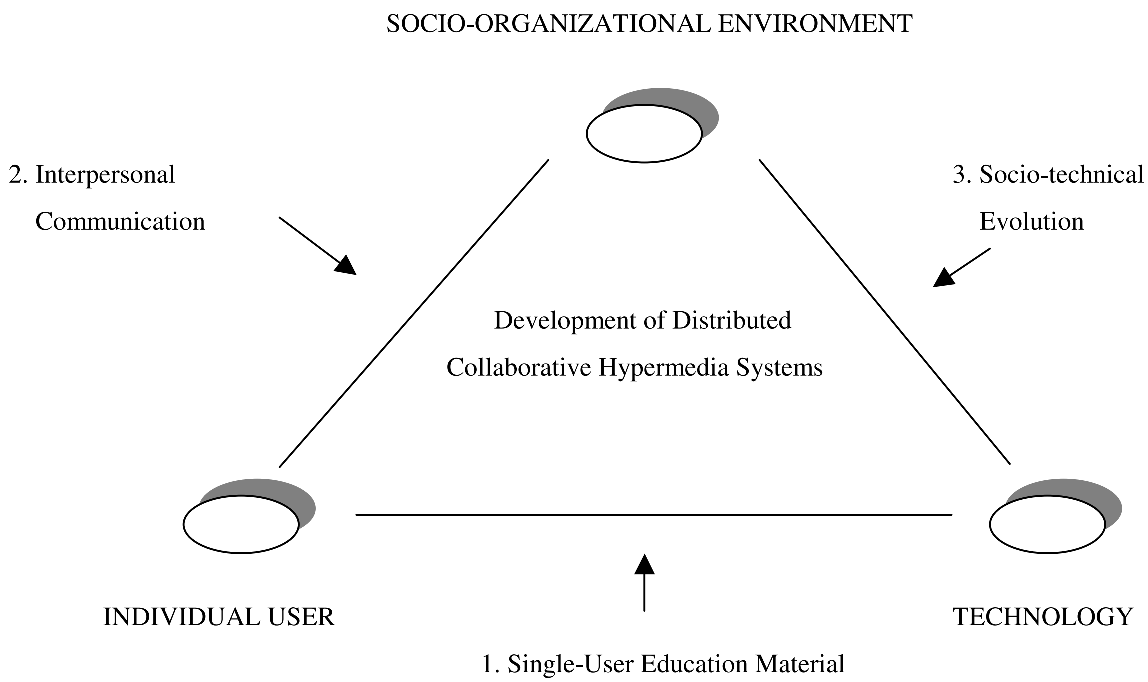

Figure 1. Convergent Perspectives on Distributed Collaborative Hypermedia Systems

	Windows NT	Windows95/98	UNIX
FEATURES TO BE SUPPORTED			
Stability	Yes	Yes	Yes
Networking-ability	Supports TCP/IP	Supports TCP/IP	Supports TCP/IP
Graphical User Interface	Yes	Yes	Yes
Data types			
.html, .htm	Yes	Yes	Yes
.txt, .doc, .rtf	.txt, .doc, .rtf	.txt, .doc, .rtf	.txt, .rtf
.gif, .jpg, .tif, .xbm	.gif, .jpg, .tif, .xbm	.gif, .jpg, .tif, .xbm	.gif, .jpg, .tif, .xbm
.wav, .mpg	.wav, .mpg	.wav, .mpg	.mpg
.mov, .avi	.mov, .avi		
.class	.class	.class	.class
.css	.css	.css	.css
.aam, .aas	.aam, .aas	.aam, .aas	
.dir, .dcr, .dxr	.dir, .dcr, .dxr	.dir, .dcr, .dxr	
Other Functions	Yes	Yes	Yes

Table 1. Analyzing conventional platforms

	Principles to be Supported			
	Openness	**Platform independence**	**Support of plugins**	**Interface specification**
Status with Respect to Requirements	Need to have	Nice to have	Need to have	Need to have
CBIquick Authoring System	N/A	N/A	N/A	N/A
HyperGASP	Yes , import and export HTML	Mac	No	No
CourseBuilder	No	Mac	No	No
StorySpace	Export text and html, but not completely	Mac, Windows 3.1, 95, 98	N/A	No

Table 2. Assessing authoring tools

Table 1 shows some results of the platform analysis that has been performed to meet the objective for openness. Table 2 shows part of the assessment of existing authoring systems. The principles applied in that analysis have also been selected and rated with respect to the requirements listed above.

As SCHOLION targets towards a non-profit use, additional constraints had to be met with respect to the last mile: low-bandwidth PC-connections without permanent online connection should suffice for communication. Knowledge consumers should not have to provide broadband communication or video equipment to interact with SCHOLION. Public domain software should be used whenever possible for presentation.

The starting point of the design phase of the SCHOLION software system has been the specification of a process model. The entire organization of a course has been captured through specifying user roles, organizational constraints, data, activities including their temporal relationships to complete certain tasks. The second major activity in the design phase was the development of a flexible hypermedia scheme for the representation of course material, i.e. a linked structure of slides or text pages, including graphics, animation, spoken text, and video. It is supposed that a course material can be provided by several authors (i.e. teachers, knowledge providers, trainers etc.) or by institutions (i.e. schools, universities, companies etc.). The course material itself has to be a hypermedia document. This hypermedia document may comprise hyperlinks to graphics, animation (for example programmed in Java), spoken text or videos. Conceptually, a SCHOLION course material consists of various slides (similar to HTML pages in the WWW), in order to provide an easy to grasp and flexible structure of the course material.

Figure 2 shows a part of the SCHOLION data model, capturing the structure of course material and the profile concept. In the following table names are starting with capital letters written in *italics*. Attributes are also written in *italics.* Once a learner opens a *CourseMaterial*, he/she invariably opens a *Profile* of a certain *CourseMaterial*. Changes or adaptations (e.g. *Markups*) are always created within this *Profile* and never in the *CourseMaterial* itself.

Each user keeps several *Profiles* for a certain *CourseMaterial*. The *Profile's* attributes are a *profileNr* (which is generated by the system (primary key)), a *title* and a date (*creationdate*) when the *Profile* has been stored for the first time. A *Profile* may be global (*isGlobal*) if the user wants to make a specific *Profile* available to other users.

The underlying structure of the feature to add notes and *Markups* to a *CourseMaterial* is the Markup object. It is the parent element to the following child elements:

- *Annotation*: additional note of a learner
- *Link*: additional link to any object (within SCHOLION to a link target or to a WWW Site)
- *Question*: special kind of note which refers to an entry in a *Discussion*
- *Layout*: a layout change of an offset within the *CourseMaterial* (highlight or underline).

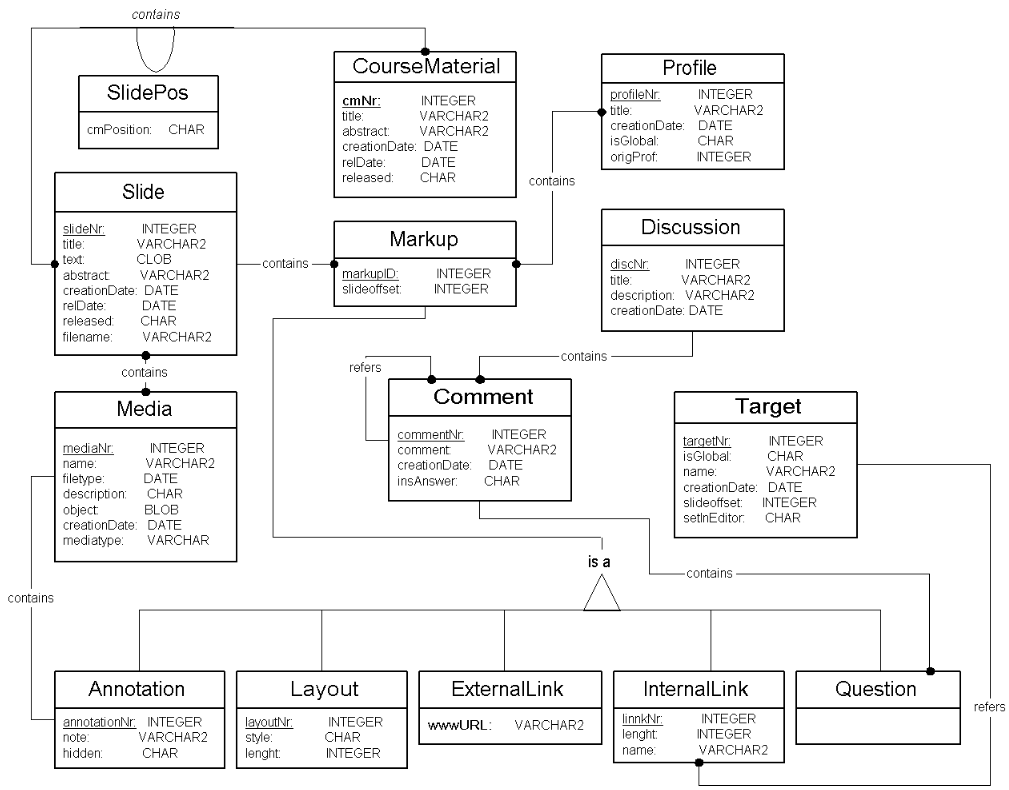

Figure 2. Part of the SCHOLION data model (profiling)

An *Annotation* is a *Markup* used for adding *notes* to a *CourseMaterial*. Notes can be text, pictures or even videos, audio's or exe-files. For textual notes a facility has been provided to show the *note* on the screen permanently, or to hide (*hidden*) it by adding an icon. The latter leads to a GUI-dialog containing the actual text of the note when clicking on it. A *Layout* is a *Markup* used to emphasize parts of a *CourseMaterial*. The user has the possibility to underline or to highlight (*style*) a certain range, beginning at the *slideoffset* position, stored in the *Markup* according to the *length*. A *Question* is a *Markup* representing a link referring from a specified position in a *Slide* (*slideoffset*) to a *Comment* or a *Discussion*. Structuring the data this way enables the straightforward implementation of the above mentioned features for individualization of multimedia course material and collaborative knowledge transfer.

Figure 3 shows a browser-window with the different kinds of annotations available in SCHOLION. A profile can be explained best with a metaphor. It can be compared to a transparency that is laid over a course material. All annotations are part of that transparency. Users might also use empty ones and start a new series of annotations. They might also remove them, move it to a public place to be used by other users, or copy a public one for private use and append own annotations (see figure 4). A symbolic description of copying and publishing profiles is given in figure 5.

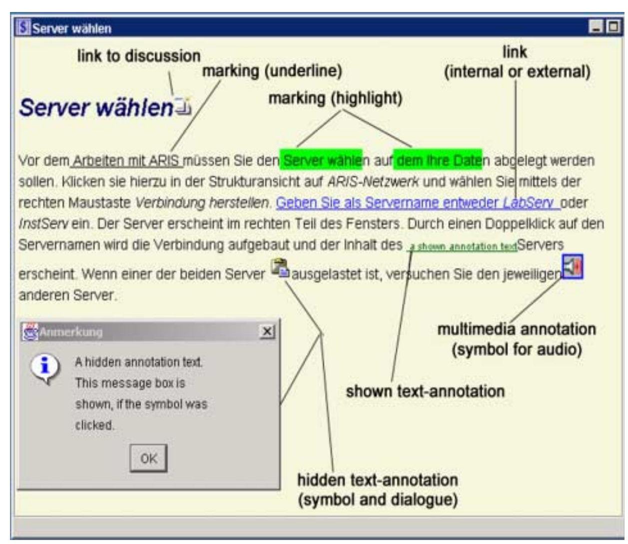

Figure 3. Annotation types in SCHOLION

The profile concept enables traditional as well as novel ways of learning based on digital content: a text marker for marking important passages, a pencil for making annotations in the text and for making references to additional content information in other documents or knowledge spaces.

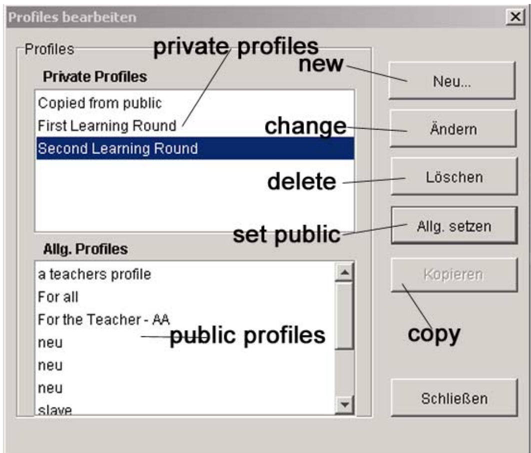

Figure 4. The profile dialog in SCHOLION

For collaboration ***cascaded profiling*** is considered to be the key concept**.** Profiles can be set public. Public profiles are available for each user: A user can open a material applying views (annotations, considerations) of another user. Thus, users might learn from each other. If a user selects a public profile, he/she can copy it to the private ones and append individual annotations (see figure 5 – *set public, copy to private*).

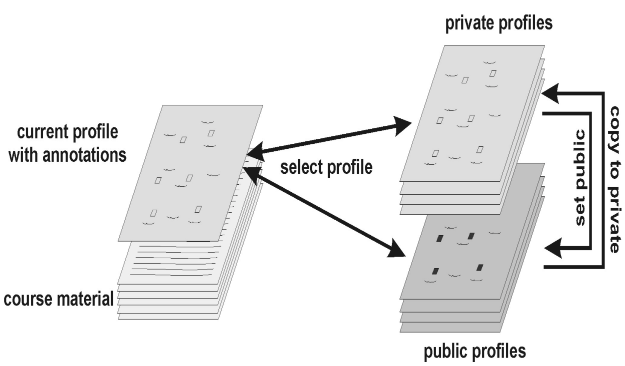

Figure 5. Cascaded profiling

The profile concept is also crucial for achieving acceptable performance. It reduces the amount of data to be transferred in the course of learning and collaborating: When opening a course material, the user selects his/her currently preferred profile (see figure 4: *private and public profiles* in the list). After a course material has been loaded to the client, only the currently chosen profile will be transferred to the client computer. This way, merely user- and session-specific information instead of content has to be transferred. The resulting increase in performance is higher the larger materials are.

The requirement for the support of collaborative content handling is met through two features of the profile concept: (i) User groups may work within identical profiles. Hence, group members might not only have an individual account, but also an account that is assigned to a group exclusively (with actually identical content linked to a profile). However, annotations, internal and external links, links to the discussion board and markings can be handled by each group member; (ii) Virtual teams can also communicate through the discussion board. They can create their own discussion forum for handling specific topics or a common project. SCHOLION´s profile concept allows to set links directly from the course material into the discussion board (see figure 3 - *link to discussion*). These links are visualized through discussion symbols. If the user clicks on this symbol, not the discussion board itself, but the contributions (question, answer, remark) linked to the content item are displayed in the discussion-browser window. This way, different comments can be linked to content items in a context-sensitive way.

As already mentioned, a profile can be set public as well. Each user is allowed to make private profiles public. If a user, e.g. a teacher, wants to control the deployment process of content, e.g., the progress of the students/trainees in learning, he/she can view the public profiles and the annotations to receive feedback this way (see also figure 5).

4. Implementation

SCHOLION is a client/server system. It is based on a ORACLE 8 database-server capturing all data (including all media files and slides stored in BLOBs). In figure 6 the general architecture of the SCHOLION system is shown. The main components are the SCHOLION Browser, the SCHOLION Editor, the SCHOLION Discussion Manager (discussion board), the SCHOLION Server Application and the database system. The SCHOLION Editor provides the functionality to design course materials and enables the import of .html, .htm, .rtf and .txt or other text files. The course material is stored in the ORACLE database system. The SCHOLION Server manages the database administration. The SCHOLION Browser enables the display of content. Media files are displayed or played by external applications such as the MS-Windows Media Player [13]. Browser (plugin)-dependent files, such as macromedia [12] files, are opened using a www-browser with the corresponding plugin. Pdf-files are opened with Acrobat [1]. The connection between the client application and the database server is established via a TCP/IP connect through JDBC data access.

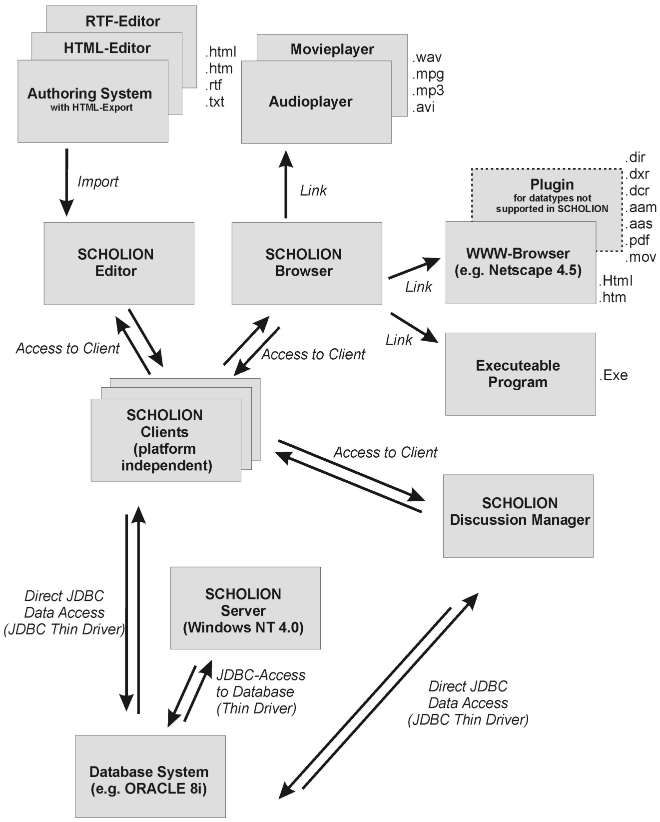

Figure 6. General architecture of SCHOLION

Testing has been performed with respect to correct functioning and task completeness. The latter has been facilitated through the process definitions (already mentioned in section 3), since those provide the basis for task-driven test cases. In addition, in SCHOLION each process corresponds to a GUI dialog. Each sub-process corresponds to an entry to a new (cascaded) dialog (e.g., a menu entry that opens a new dialog for adding an annotation).

5. Evaluation and User Experiences

The SCHOLION developments have been evaluated according to the following procedure:

- Functional testing according to the test cases derived from the process definitions (see previous section)
- Usability Testing. This part has been split into checking the environment against the state-of-the-art principles in web engineering, and an explorative field trial in a course on information systems.

Checking against principles. SCHOLION has been evaluated according to the 24 state-of-the-art principles given in [17] (p.63), ranging from sociability and connectivity to the size of virtual learning environments. With respect to the effectiveness and efficiency of individualization features and corresponding collaboration support the following principles have been checked:

- *sociability and connecitivity* addressing the multi-user capability of the software
- *veridicality* describing the degree of accuracy with respect to mapping the reality of the learning environment to the artefact
- *engagement* denoting the depth of user involvement when interacting
- *reconfigurability* concerning the modifiability of an environment
- *responsiveness* capturing performance data in terms of minimizing the time between user input and system output
- *robustness* also addressing performance, this time in terms of functioning under different conditions
- *viewpoint* meaning the usage of content under multiple user perspectives
- *representation of the user* requiring the visual (re)presentation of users in the environment
- *input/output bandwidth* concerning the amount of information that can be transmitted from/to the user within the environment
- *multisensory requirements* bringing in the diversity of channels involved in human-computer interaction
- *interactivity* comprising the entire spectrum of features for selection, modality-switching, and navigation for control and content manipulation
- *autonomy* denoting the modularity of the software system
- *locus of control* targeting an organizational issue, namely who is in charge of creating and controlling the virtual learning environment
- *choice of representation* questioning the separation of content and presentation, namely, in how far content can be (re)presented through different media and forms
- *calibration and customization* focusing on the capabilities of adapting the environment to the individual needs of learners and teachers.

Since not all of the listed principles could be measured in a straightforward way we had to find items and parameters for concrete evaluation. The required parameters and items have been found in web-engineering frameworks and related usability-engineering techniques, such as [5]. The items found have been assigned to one or more categories listed above. In addition, the concerned roles have been identified for structured evaluation, as shown for interactivity in the table below.

Interactivity - Navigation

Instance of interactivity	TTS should provide several possibilities to navigate through a course material. The learner should be able to select from possible paths through proper instructions. The finally selected path should correspond to the learner's preferences and level of experience.
Concerned role	Learner
Instance of interactivity	On each page in a course material it should be possible to go to the main page, the start page and to select the way of navigating through a course material. This way, learners determine their own path through the course material and/or through the program.
Concerned role	Learner
Instance of interactivity	In TTS the user should be able to exit the program at any time.
Concerned role	Learner, knowledge producer, domain expert, tutor, teacher

After the operational definitions have been found, the items have been applied according to the scenarios of use (role models). Four usability experts checked the SCHOLION environment. Then the data have been analyzed. It turned out that the following criteria have been met successfully:

- *sociability and connectivity* - users can communicate and interact at any time anywhere they have Internet access;
- *engagement* due to the context-sensitivity of the items for collaboration;
- *reconfigurability* due to the openness;
- *responsiveness* - the required data transfer has been minimized according to the profile concept;
- *viewpoint* - profiling supports different perspectives on course materials;
- *input/output bandwidth* and *multisensory requirements* due to the variety of codalities of information and media for presentation
- *interactivity* for selection and navigation
- *autonomy* due to the modular software structure
- *locus of control* – a specific organizational model has been developed;
- *calibration and customization* through annotations and profiling.

Some of the other principles have not been implemented so far: *representation of the user*, *choice of representation*. The remaining principles (together with the ones already checked conceptually) have been checked in the field trial.

User Experiences. SCHOLION has been tested in the field. 6 teachers and 35 students participated in the trial. One of the teachers had extensive experience in teaching (over 10 years), one about 4 years, and the others about one year. The test setting was a 2-hours/week course on information systems within the business informatics curriculum at the University of Linz. The course is held in the first year of studies, mainly for beginners in business information systems. The course is composed of a theoretical, lecture-style part, and a practical part with student projects. The teachers had their original materials either in MS-Word- or html format. Their first task was to import the material into the SCHOLION editor. Their second task was to enhance the imported material with multimedia content. Finally, the organization of the course had to be handled in SCHOLION, namely to allow interactive access to the material in a certain period of time (usually 6 months) through a certain set of students. Then, during that period (in our test case from February – July 2000) the teacher were on ‘online’-duty coaching the students, giving lectures and evaluating projects. It has to be noted that for each course a discussion board is generated. This board is publicly available for all students and has to be edited by the teacher. Since in SCHOLION a three-layer architecture for discussions has been implemented (question-answer-remark) editing by teachers means linking items that refer to each other or are in mutual relationship from the content point of view. Editing also means to answer questions and to refer to items in the course material that are relevant, either to understand a problem fully or to illustrate an answer or a comment.

The experiences of the *teachers* were as follows: First of all, generating electronic course material requires to revisit the structure of the original course material. In most of the cases, the logical structure of documents has to be redesigned in terms of the SCHOLION data model, based on slides and the concepts for active knowledge transfer. The experiences show that SCHOLION can be used both, for lecture-style teaching over the Internet, and for providing course material for remote studying. Secondly, the enrichment of course materials with multimedia elements requires planning and media competence. The embodiment of different media has to follow didactic guidelines. 4 out of the 6 teachers needed assistance, since it was their first time tuning text, images, and video. From the technical perspective, it turned out, that the import of existing documents into SCHOLION might be cumbersome, since a html parser has to scan the data for elements, such as nested tables used for the layout of pages, that cannot be processed in the course of collaboration. Overall, a total amount of 3 hours (on an average) per slide has to be calculated to make contents available in SCHOLION.

The experiences of the *students* confirmed the data from the conceptual analysis described previously. We followed the recommendations for recording the Quality-of-Service parameters as given in [16]. SCHOLION performed outstanding with respect to responsiveness and input/output bandwidth even under high workload (high network traffic, amount of data to be transmitted, complex database transactions). Hence, we could also give proof of concept for robustness. With respect to veridicality students experienced troubles in mapping their realities to the features of the artefact. In particular, it took some time for learners to actually use the features for collaboration, since they have been skeptically in the beginning that the context of interaction is actually being kept by the software system. Once the context-sensitivity of discussions has been experienced, learners became confident and relied on the electronic version of the course material for collaborative learning.

Lessons Learnt. The results from the conceptual analysis (first step of usability tests) have been confirmed in the field trial. However, due to the novel coupling of content to interaction and collaboration features, a novel culture of coaching in the course of active knowledge transfer will evolve in long term use of such environments.

6. Conclusion

Collaborative distance learning/teaching hypermedia systems should support learners to participate actively in the transfer of knowledge in a self-managed way, but still in the ambiente of a learning community. SCHOLION has been developed to overcome existing deficiencies to that respect through the provision of novel features for

- Mentoring and supervision via tele media
- Effective and efficient knowledge transfer
- Effective and comfortable operational support for producing electronic hypermedia-course material.

The achievements indicate that learners can experience added value in terms of enlarging their individual learning/knowledge space in a reliable and satisfying way. The crucial concept of SCHOLION is the profile concept which integrates the view concept known from database theory with flexible link management. Beside functional improvements performance improvements have been achieved, since the required amount of data to be transmitted in the course of knowledge transfer has been reduced to a minimum.

Future work will focus on individual feedback loops through self testing, and monitoring features to detect hot spots in materials that might need further explanations and guidance. Finally, the SCHOLION systems will be re-implemented to develop a web-application in terms of Java-applets or browser plug-ins.

References

[1] Adobe: http:// www.adobe.com, 1999.

[2] Ch. Bacher, R. Müller et al.: Authoring on the Fly. A New Way of Integrating Telerepresentation and Courseware Production, in: Proceedings ICCE'97, 1997.

[3] Z.L. Berge: Interaction in Post-Secondary Web-based Learning, in: Education Technology, Vol. 31, pp. 263-300, 1999.

[4] S.F. Ehrlich: Strategies for Encouraging Successful Adoption of Office Communication Tools, in: ACM Transcations on Office Information Systems, Vol. 5, No. 4, pp. 340-357, 1987.

[5] ElLearn: Electronic Learning: Criteria and Standards Used in Evaluating Web-Based Instruction and Delivery Guidelines,http://www.electroniclearning.edu/certification/checklist.html, 08.03.2000.

[6] B. Froschauer, W. Ortner et al.: SCHOLION- Scaleable Technologies for Telelearning, in: Proceedings Symposium in Applied Computing, ACM, pp. 141-146, 2000.

[7] L. Harasim: A Framework for Online Learning: The Virtual University, in: IEEE Computer, Vol. 32, No. 9, p. 44-49, 1999.

[8] P.A.M. Kommers, D.H. Jonasson et al. (eds): Cognitive Tools for Learning, Springer, Berlin , 1992.

[9] St. Kristoffersen, F. Ljungberg: An Empirical Study of How People Establish Interaction: Implications for CSCW Session Management Models, in: Proceedings CHI'99, ACM, pp. 1-8, 1999.

[10] M.L. Markus, T. Connolly: Why CSCW-Applications Fail: Problems in the Adoption of Interdependent Work Tools, in: ACM Proceedings CSCW'90, pp. 371-380, 1990.

[11] Marshal University: Comparison of Online Course Delivery Software Products, Center for Instructional Technology, http://multimedia.marshal.edu/cit/webct/ compare/comparison.html, 2000.

[12] Macromedia: http://www.macro-media.com, 1999.

[13] Microsoft: http://www.microsoft.com, 1999.

[14] N.V. Nikolic, M.V. Trajkovic et al.: Socratenon – a Web-based Training System with an Intellect, in: Proceedings 33rd Hawaii Int. Conference on System Sciences, IEEE, 2000.

[15] W. Orlikowski: The Duality of Technology: Rethinking the Role of Technology in Organizations, in: Organization Science, Vol. 3, No. 3, pp. 398-427, 1992.

[16] A. Sears, J.A. Jacko: Understanding the Relation between Network Quality of Service and the Usability of Distributed

Multimedia Documents, in: Human-Computer Interaction, Vol. 15, No. 1, pp. 43-68, 2000.
[17] R. Stuart: The Design of Virtual Environments, McGraw-Hill, New York, 1996.

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