Adaptive Educational Hypermedia: From Generation to Generation

Peter Brusilovsky
School of Information Sciences, University of Pittsburgh
Pittsburgh, PA 15260, USA
peterb@pitt.edu

SUMMARY
Adaptive hypermedia is a relatively new direction of research on the crossroads of hypermedia and user modeling. Adaptive hypermedia systems build a model of the goals, preferences and knowledge of each individual user, and use this model throughout the interaction with the user, in order to adapt to the needs of that user. Educational hypermedia was one of the first application areas for adaptive hypermedia and is currently one of the most popular and well-investigated. The goal of this presentation is to provide a subjective historical overview of research in adaptive educational hypermedia and summarize the current state of the art.

KEYWORDS: *adaptive hypermedia, Web-based Education, Intelligent Tutoring System*

INTRODUCTION

Adaptive hypermedia is an alternative to the traditional "one-size-fits-all" approach in the development of hypermedia systems. Adaptive hypermedia systems build a model of the goals, preferences and knowledge of each individual user, and use this model throughout the interaction with the user, in order to adapt to the needs of that user (Brusilovsky, 1996). For example, a student in an adaptive educational hypermedia system will be given a presentation that is adapted specifically to his or her knowledge of the subject (De Bra & Calvi, 1998), and a suggested set of the most relevant links to proceed further (Brusilovsky, Eklund & Schwarz, 1998). An adaptive electronic encyclopedia will personalize the content of an article to augment the user's existing knowledge and interests (Milosavljevic, 1997). A virtual museum will adapt the presentation of every visited object to the user's individual path through the museum (Oberlander et al., 1998).

AH systems can be useful in any application area where a hypermedia system is expected to be used by people with different goals and knowledge and where the hyperspace is reasonably big. Users with different goals and knowledge may be interested in different pieces of information presented on a hypermedia page and may use different links for navigation. AH tries to overcome this problem by using knowledge represented in the user model to adapt the information and links being presented to the given user. Adaptation can also assist the user in a navigational sense, which is particularly relevant for a large hyperspace. Knowing user goals and knowledge, AH systems can support users in their navigation by limiting browsing space, suggesting the most relevant links to follow, or providing adaptive comments to visible links.

In this presentation, I attempt to provide a review of past and present research on adaptive educational hypermedia. I have tried to classify the variety of known work into generations and research directions. I hope that this work will help both experienced researchers and newcomers understand this field. This review is based on my personal (and probably subjective) view of the field based on my own work on adaptive hypermedia for more than 10 years. Over these years my view of adaptive hypermedia and my understanding of it has broadened quite significantly. I was fortunate to work on adaptive hypermedia problems with several teams that were driven by different goals. I think it has helped me consider adaptive educational hypermedia from several prospects and avoid a narrow and pragmatic view to it. To make my current prospect and viewpoint clearer to a reader, I deliberately choose to present the overview of the field in two parallel streams. One stream attempts to provide more objective overview of a whole generation of research, while another stream presents my own research work that falls in the same generation of research.

ADAPTIVE EDUCATIONAL HYPERMEDIA: THE FIRST GENERATION

The research on adaptive navigation support in hypermedia can be traced back to the early 1990's. At that time, several research teams had recognized the problems of static hypertext in different application areas, and had begun to explore various ways to adapt the behavior of hypertext and hypermedia systems to individual users. A number of teams addressed the problems related to navigation in hypermedia (such as the problem of inefficient navigation or the problem of being lost) that had been discovered when the field of hypertext reached relative maturity at the end of the 1980's (Hammond, 1989). Other teams addressed the problems related to presentation (such as the need to present different information on a hypermedia page to different users). Within a few years, a number of technologies for *adaptive navigation support* (Böcker, Hohl & Schwab, 1990; Brusilovsky, Pesin & Zyryanov, 1993; de La Passardiere & Dufresne, 1992; Kaplan, Fenwick & Chen, 1993) and *adaptive presentation* (Beaumont, 1994; Böcker et al., 1990; Boyle & Encarnacion, 1994; Boyle & Teh, 1993) were proposed. The adaptive navigation support technologies introduced by early adaptive hypermedia systems were later classified as *direct guidance*, *sorting*, *hiding*, and *annotation* (Brusilovsky, 1996).

It is quite natural that educational hypermedia was one of the first application areas for AH. In educational context users with alternative learning goals and knowledge on the subjects require essentially different treatment. It is also in educational hypermedia where the problem of "being lost in hyperspace" is especially critical. A number of pioneer adaptive educational hypermedia systems were developed between 1990 and 1996. These systems can be roughly divided into two research streams. The systems of one of these streams were created by researchers in the area of intelligent tutoring systems (ITS) who were trying to extend traditional student modeling and adaptation approaches developed in this field to ITS with hypermedia components (Beaumont, 1994; Brusilovsky et al., 1993; Gonschorek & Herzog, 1995; Pérez, Gutiérrez & Lopistéguy, 1995). The systems of another stream were developed by researchers working on educational hypermedia in an attempt to make their systems adapt to individual students (Böcker et al., 1990; De Bra, 1996; de La Passardiere & Dufresne, 1992; Hohl, Böcker & Gunzenhäuser, 1996; Kay & Kummerfeld, 1994).

I entered the field of adaptive hypermedia from ITS side. During my Ph.D. years at the at the Moscow State University I was working on *adaptive sequencing* of educational material, i.e., intelligent technologies that can select the most relevant readings, examples, and problems for the given student at the given time. I have developed several innovative sequencing algorithms (Brusilovsky, 1992a) that were implemented in ITEM/IP system (Brusilovsky, 1992b). After my graduation, as an adjunct professor at the Moscow State University I directed several graduate student projects focusing on elaborating adaptive sequencing technologies and applying them to different subjects from geometry to geography. Two of these projects – ITEM/PG (Brusilovsky & Gorskaya-Belova, 1992) and ISIS-Tutor (Brusilovsky & Pesin, 1994) attempted to go beyond the original sequencing: we suggested what we called *adaptive hypermedia* for personalized student's access to educational content (Brusilovsky et al., 1993). By introducing adaptive hypermedia we attempted to add some flexibility to classic adaptive sequencing allowing students to participate in selecting the most relevant educational objects. We considered adaptive navigation support in educational hypermedia as "best of both worlds". Choosing the next task in an ITS with sequencing is based on machine intelligence. Choosing the next task in traditional hypermedia is based on human intelligence. Adaptive navigation support is an interface that can integrate the power of machine and human intelligence: a user is free to make a choice while still seeing the opinion of an intelligent system. Following this vision we considered adaptive hypermedia as a necessary *component of every ITS* (Brusilovsky et al., 1993) and developed a specific authoring approach and a toolkit for developing adaptive hypermedia components for ITS (Brusilovsky, 1997).

Our main focus was *adaptive navigation support,* currently one of the major AH technologies. We explored several ways of adaptive navigation support in the ITEM/PG (Brusilovsky et al., 1993) and ISIS-Tutor (Brusilovsky & Pesin, 1994) projects. We introduced a specific adaptive annotation technology that classifies pages with educational material with regard to the user's current knowledge and goals. With regard to goals/interests a page can be relevant or not relevant. With regard to knowledge, it can be a page with no new concepts, a page with new and ready to be understood concepts, or a page that is not yet ready to be learned. Based on this classification ISIS-Tutor and ITEM/PG systems color-coded the links to presentation and problem pages as "ready", "not-ready", and "already learned". Adaptive link annotations in this context guide the users to the most appropriate pages. This technology was later extensively evaluated and is known to reduce navigation efforts, the time it takes to achieve the goal, while increasing learner retention and quality of learning (Brusilovsky & Eklund, 1998; Brusilovsky & Pesin, 1998; Eklund & Brusilovsky, 1998; Weber & Specht, 1997). It has been re-used since in many adaptive systems. We also explored direct guidance in the form of "teach me" button that provides a one-click access to the next best task. In one of the versions of ISIS-Tutor we also used adaptive link removal to remove all links to not-ready pages.

ADAPTIVE EDUCATIONAL HYPERMEDIA: THE SECOND GENERATION

Despite the number of creative ideas explored and evaluated in the early educational AH systems, it was not until 1996 that this research area attracted attention of a larger community of researchers. There are two main factors that might account for this growth of research activity. The first factor is the accumulation and consolidation of research experience in the field. It is clearly visible that research in adaptive hypermedia performed and reported up to 1996 provided a good foundation for the new generation of research. As we noted above, early researchers were generally not aware of each other's work. The early papers provided no (or almost no) references to similar work in adaptive hypermedia, and described original methods and techniques. Almost all systems reported by 1996 were laboratory systems developed to demonstrate and explore innovative ideas. In contrast, many papers published since 1996 are clearly based on earlier research. These papers cite earlier work, and usually suggest an elaboration or an extension of techniques suggested earlier. In addition, a large number of systems developed since 1996 are either real world systems, or research systems developed for real-world settings. This is indicative of the relative maturity of adaptive hypermedia as a research direction.

The second and arguably most important factor is the rapid increase in the use of the Word Wide Web. The Web, with its clear demand for adaptivity served to boost adaptive hypermedia research, providing both a challenge and an attractive platform. Almost all the papers published before 1996 describe classic pre-Web hypertext and hypermedia. In contrast, the majority of papers published since 1996 are devoted to Web-based adaptive hypermedia systems.

In the field of educational adaptive hypermedia, the major driving factor behind the second-generation adaptive educational hypermedia was Web-based education. The need to address the heterogeneous audience of Web-based courses individually was clear to many researchers and practitioners. A few early adaptive hypermedia systems developed for Web-based education context by 1996 such as ELM-ART (Brusilovsky, Schwarz & Weber, 1996a), InterBook (Brusilovsky, Schwarz & Weber, 1996b), PT (Kay & Kummerfeld, 1997), and 2L670 (De Bra, 1996) provided a "proof of existence" and influenced a number of more recent systems. The majority of adaptive educational hypermedia systems developed since 1996 are Web-based systems and were developed for Web-based education context. Some earlier examples are: Medtech (Eliot, Neiman & Lamar, 1997), AST (Specht et al., 1997), ADI (Schöch, Specht & Weber, 1998), Hy-SOM: (Kayama & Okamoto, 1999), AHM (Pilar da Silva et al., 1998), MetaLinks (Murray, Condit & Haugsjaa, 1998), CHEOPS (Negro, Scarano & Simari, 1998), RATH (Hockemeyer, Held & Albert, 1998), ACE (Specht & Oppermann, 1998), TANGOW (Carro, Pulido & Rodrígues, 1999), Arthur (Gilbert & Han, 1999), CAMELEON (Laroussi & Benahmed, 1998), KBS-Hyperbook (Henze & Nejdl, 1999), AHA! (De Bra & Calvi, 1998), SKILL (Neumann & Zirvas, 1998), and Multibook (Steinacker et al., 1999).

The choice of the Web as a development platform turned out to be a wise choice for educational hypermedia systems. It granted long life to a number of pioneer systems. In particular, the first Web-based adaptive educational hypermedia systems developed before 1996 such as ELM-ART, InterBook, and 2L670 are still in use and have been significantly updated and extended with a number of new techniques (Brusilovsky et al., 1998; De Bra & Calvi, 1998; De Bra & Ruiter, 2001; Weber & Brusilovsky, 2001). Over the years, these systems were used for several experimental studies (Brusilovsky & Eklund, 1998; Brusilovsky et al., 1998; De Bra & Calvi, 1998; Eklund, 1999; Weber, 1999) that further guided development of the field.

The work on second-generation adaptive educational hypermedia was performed mainly between 1996 and 2002. It can be roughly split into three different streams with no clear-cut borders. The largest stream of work (produced mainly by researchers coming from the Web-based education side) focused on creating adaptive Web-based educational systems with elements of adaptive hypermedia. The main motivation was to produce systems that could be used in the process of teaching, not in developing new technologies. As a result, the works of this stream broadly re-used already existing technologies and explored various subject areas and approaches. A smaller stream of work (produced mainly by researchers who were very familiar with ITS or the adaptive hypermedia area) focused on producing new techniques for adaptive hypermedia. For example early AHA! project (De Bra & Calvi, 1998) explored several approaches to link removal, MetaLinks (Murray, 2001; Murray et al., 1998) explored advance approaches to hyperspace structuring, INSPIRE explored the use of learning styles (Papanikolaou et al., 2003), and MANIC (Stern & Woolf, 2000) explored innovative approaches for user modeling and adaptive presentation. Finally, the originally small but rapidly expanded stream of work focused on developing frameworks and authoring tools for producing adaptive hypermedia systems. The majority of work in this direction achieved the level of *frameworks* for adaptive Web-based education KBS-Hyperbook (Henze & Nejdl, 2000), SKILL (Neumann & Zirvas, 1998), Multibook (Steinacker et al., 1999), ACE (Specht & Oppermann, 1998), CAMELEON (Laroussi &

Benahmed, 1998), MediBook (Steinacker et al., 2001), and ECSAIWeb (Sanrach & Grandbastien, 2000). While not reaching the level of end-used authoring tools, a framework typically introduces a generic re-usable architecture and approach that could be used to produce a range of adaptive systems with low overhead. A few of the most experienced teams that were working on adaptive hypermedia projects for several years introduced practical authoring systems that could be applied by end-used to develop adaptive hypermedia systems and courses (Brusilovsky, 2003). Examples are InterBook (Brusilovsky et al., 1998), ART-Web/NetCoach (Weber, Kuhl & Weibelzahl, 2001), AHA! (De Bra & Ruiter, 2001), ACE (Specht & Oppermann, 1998), and MetaLinks (Murray, 2003).

I started exploring Web-based adaptive hypermedia at Moscow State University in 1994 (Brusilovsky, 1995a; Brusilovsky, 1995b) and continued this work at the University of Trier as an Alexander von Humboldt fellow. I was privileged to work with Gerhard Weber, the head of one of the most prominent German ITS research group and a developer of ELM-PE system (Weber & Möllenberg, 1995). Together with Prof. Weber, we developed an innovative and practical Web-based ITS ELM-ART (Brusilovsky et al., 1996a; Weber & Brusilovsky, 2001) – the first one to integrate a large adaptive hypermedia component. This system later won the prestigious European Academic Software award and, according to researchindex.com remains one of the most highly cited ITS/AH systems.

While ELM-PE was a domain-oriented ITS, the work on the system allowed us to generalize the domain-independent aspects of ELM-ART and eventually develop several authoring systems. The list of authoring systems that have roots in ELM-ART include InterBook (Brusilovsky et al., 1996b), ART-Web/NetCoach (Weber et al., 2001), and ACE (Specht & Oppermann, 1998). InterBook, the first system in this group, was developed at Carnegie Mellon's Human-Computer Interaction Institute where I moved to work with John Anderson, one of the greatest scholars in the field of ITS and Cognitive Science. InterBook was an attempt to refine the concepts and technologies of adaptive navigation support explored in domain-dependent systems ISIS-Tutor and ELM-ART (Brusilovsky et al., 1998). InterBook has been used to run several large-scale empirical studies of educational adaptive hypermedia (Brusilovsky & Eklund, 1998; Brusilovsky & Pesin, 1998) that have demonstrated the value of adaptive hypermedia in proving personalized access to learning material. It was also used to develop several adaptive Web-based courses including an ACT-R course developed with Prof. Anderson (Brusilovsky & Anderson, 1998).

ADAPTIVE EDUCATIONAL HYPERMEDIA: THE THIRD GENERATION

Altogether, the systems of the second-generation adaptive educational hypermedia demonstrated a variety of ways to integrate adaptation technologies in the context of Web-based education and the value of these technologies. Yet, they failed to influence practical Web-based education. Almost 10 years after the appearance of the first adaptive Web-based educational systems just a handful of these systems were used for teaching real courses, typically in a class lead by one of the authors of the adaptive system. Instead, the absolute majority of Web-enhanced courses rely on so-called learning management systems (LMS) such as Blackboard (Blackboard Inc., 2002) or WebCT (WebCT, 2002). LMS are powerful integrated systems that support a number of needs of teachers and students. Teachers can use a LMS to develop Web-based course notes and quizzes, to communicate with students and to monitor their progress. Students can use it for communication and collaboration. The complete dominance of LMS over adaptive systems may look surprising. Actually, for every function that a typical LMS perform we can find an AWBES that can do it much better than the LMS. Adaptive textbooks created with such systems as AHA! (De Bra & Ruiter, 2001), InterBook (Brusilovsky et al., 1998) or NetCoach (Weber et al., 2001) can help students learn faster and better. Adaptive quizzes delivered by such systems as SIETTE (Conejo, Guzman & Millán, 2004) and QuizGuide (Sosnovsky, Brusilovsky & Shcherbinina, 2004) evaluate student knowledge more precisely with less questions. Adaptive class monitoring systems (Oda, Satoh & Watanabe, 1998) give the teachers much better chances to notice students that are lagging behind. Adaptive collaboration support systems (Constantino Gonzalez, Suthers & Escamilla de los Santos, 2003) can enforce the power of collaborative learning. It seems obvious that the problem of modern adaptive systems is not their performance, but their inability to answer the needs of practical Web-enhances education. The challenge of integrating adaptive hypermedia technologies into the regular educational process has defined the current third generation of adaptive educational hypermedia research.

Different research groups stress different reasons for the domination of LMS and pursue different research directions. One of the research streams focused on LMS's versatility attempting to provide in one system as many teacher and learner support features (from content authoring to quizzes to discussion forums) as provided by a modern LMS - plus an ability to adapt to the user (Specht et al., 2002a; Weber et al., 2001). A different stream addressed another superior feature of an LMS - an ability to integrate open corpus Web content. The systems of this stream explored several approaches to integrating open corpus content in an adaptive hypermedia system while providing adaptive guidance to this content (Brusilovsky, Chavan & Farzan, 2004; Carmona et al., 2002; Henze & Nejdl, 2001). Most recent projects, however, choose not to compete with present-day LMS, but instead to focus on adaptive features of the coming generation of Web-based educational systems. This new generation that is coming to replace modern LMS will be based on system interoperability and reusability of content to be supported by a number of emerging standards including the most often cited SCORM (ADLI, 2003; ADLI, 2004). A number of research teams are trying now to integrate existing adaptive hypermedia technologies with the ideas of standard-based reusability (Bollin, Mittermeir & Wohlfahrt, 2002; Conlan, Dagger & Wade, 2002a; Conlan et al., 2002b; Delestre, PÈcuchet & Barry-GrÈboval, 1999; Dolog et al., 2003; Fischer, 2001; Karagiannidis, Sampson & Cardinali, 2002; Specht et al., 2002a) though other teams argue that the current generation of standards is not able to support the ideas of adaptive learning (Brusilovsky, 2004; Mödritscher et al., 2004). Other teams focus on related issues that are not covered by standards yet, such as resource discovery architectures (Manouselis & Sampson, 2002; Nejdl et al., 2002; Simon et al., 2003; Specht et al., 2002b). Yet another direction of work attempts to explore the ideas of the Semantic Web for content representation and resource discovery and capitalise on the standards such as RDF and Topic Maps (Dichev, Dicheva & Aroyo, 2004; Dolog et al., 2003; Jacquiot, Bourda & Popineau, 2004; Nejdl et al., 2002).

Our work on 3rd generation adaptive hypermedia has focused on three topics. We started our quest for practical AH systems in 1998 with the exploration of advanced indexing techniques. We expected that advanced content indexing approaches that include content typing and introducing multiple concept roles will help in dealing with large volumes of educational content while providing better guidance precision. We have successfully implemented advanced indexing ideas in two projects - ADAPTS and CoCoA. ADAPTS, a performance support system for avionics technicians (Brusilovsky & Cooper, 1999; Brusilovsky & Cooper, 2002) has integrated an AI-based intelligent aircraft diagnosis with an adaptive hypermedia personalized information access. ADAPTS has demonstrated that an elaborated approach to content indexing can be used for advanced adaptive presentation and adaptive navigation support in a huge volume of hypermedia content. CoCoA (Brusilovsky, 2000) was developed during my work for Carnegie Technology Education, a non-profit company founded by Carnegie Mellon University. A part of my mandate and my major motivation was to develop an innovative platform for practical personalized Web-based education. However, due to the need to deliver content through non-adaptive LMS, we have focused on a different practical use of advanced content indexing - content checking (Brusilovsky

& Vassileva, 2003). The reality of practical Web-based education has demonstrated that classic closed corpus adaptive hypermedia based on manual content indexing has a limited applicability in the context of modern Web-enhanced education that has to deal with large volumes of diverse and poorly indexed educational material. While in some application areas (such as aircraft maintenance explored in ADAPTS) it is feasible to have a team of experts to encode the content knowledge about thousands and thousands of available resources, the economics of practical education cannot afford it. Even in the best educational Digital Libraries, content metadata are insufficient for the needs of adaptive guidance and are most often incomplete and incoherent.

After joining the School of Information Sciences at the University of Pittsburgh in 2000, I focused my adaptive hypermedia research on two goals: developing technologies for "open corpus adaptive hypermedia" and developing a component-based architecture for assembling adaptive Web-based educational systems. Working on the first goal, we have developed the Knowledge Sea (Brusilovsky & Rizzo, 2002a; Brusilovsky & Rizzo, 2002b) and Knowledge Sea II (Brusilovsky et al., 2004) systems for browsing-based access to external resources using Kohonen self-organized maps. Knowledge Sea has explored several techniques that are able to organize open corpus educational content and to provide some form of adaptive navigation support without manual context indexing. Working on the second goal, we have developed an open architecture KnowledgeTree (Brusilovsky, 2004) that allows us to assemble a versatile adaptive educational system from re-usable components developed by different teams.

Overall, I hope that the work on the 3rd generation adaptive educational hypermedia will eventually lead to deeper and deeper integration of adaptive technologies into the process of everyday Web-enhancing learning thus maximizing the ability of every student to achieve his of her learning goals.

BIBLIOGRAPHY

ADLI (2003) Sharable Content Object Reference Model (SCORM) Version 1.3, Advanced Distributed Learning Initiative. http://www.adlnet.org/

ADLI (2004) Overview of SCORM 2004, Advanced Distributed Learning Initiative. http://www.adlnet.org/screens/shares/dsp_displayfile.cfm?fileid=992 (Accessed January, 2004)

Beaumont, I. (1994) User modeling in the interactive anatomy tutoring system ANATOM-TUTOR. *User Modeling and User-Adapted Interaction* 4 (1), 21-45.

Blackboard Inc. (2002) Blackboard Course Management System 5.1, Blackboard Inc. http://www.blackboard.com/ (Accessed 21 January, 2002)

Böcker, H. D., Hohl, H., and Schwab, T. (1990) °πAdaptερ - Individualizing Hypertext. In: D. Diaper (ed.) *INTERACT'90*. (Proceedings of IFIP TC13 Third International Conference on Human-Computer Interaction, Cambridge, 27-31 August, 1990) Amsterdam: North-Holland, pp. 931-936.

Bollin, A., Mittermeir, R. T., and Wohlfahrt, R. (2002) Component-based Content Development for E-Learning Systems. In: M. Driscoll and T. C. Reeves (eds.) Proceedings of World Conference on E-Learning, E-Learn 2002, Montreal, Canada, October 15-19, 2002, AACE, pp. 1206-1209.

Boyle, C. and Encarnacion, A. O. (1994) MetaDoc: an adaptive hypertext reading system. *User Modeling and User-Adapted Interaction* 4 (1), 1-19.

Boyle, C. and Teh, S. H. (1993) Multimedia intelligent documentation: Metadoc V. In: Proceedings of 11th annual international conference on Systems documentation, Kitchener Canada, October 5 - 8, 1993, pp. 21 - 27.

Brusilovsky, P. (1992a) A framework for intelligent knowledge sequencing and task sequencing. In: C. Frasson, G. Gauthier and G. McCalla (eds.) *Intelligent Tutoring Systems*. (Proceedings of Second International Conference on Intelligent Tutoring Systems, ITS'92, Montreal, June 10-12, 1992) Berlin: Springer-Verlag, pp. 499-506.

Brusilovsky, P. (1992b) Intelligent Tutor, Environment and Manual for Introductory Programming. *Educational and Training Technology International* 29 (1), 26-34.

Brusilovsky, P. (1995a) Adaptive learning with WWW: The Moscow State University Project. In: P. Held and W. F. Kugemann (eds.) *Telematics for Education and Training*. (Proceedings of Telematics for Education and Training Conference, Düsseldorf/Neuss, 24-26 November 1994) Amsterdam: IOS, pp. 252-255.

Brusilovsky, P. (1995b) Intelligent tutoring systems for World-Wide Web. In: R. Holzapfel (ed.) Proceedings of Third International WWW Conference (Posters), Darmstadt, April 10-14, 1995, Fraunhofer Institute for Computer Graphics, pp. 42-45, also available at http://www.igd.fhg.de/archive/1995_www95/proceedings/posters/48/index.html.

Brusilovsky, P. (1996) Methods and techniques of adaptive hypermedia. In P. Brusilovsky and J. Vassileva (eds.), *User Modeling and User-Adapted Interaction* 6 (2-3), Special Issue on Adaptive Hypertext and Hypermedia, 87-129.

Brusilovsky, P. (1997) Integrating hypermedia and intelligent tutoring technologies: from systems to authoring tools. In: P. Kommers, A. Dovgiallo, V. Petrushin and P. Brusilovsky (eds.): *New media and telematic technologies for education in Eastern European countries*. Enschede: Twente University Press, pp. 129-140.

Brusilovsky, P. (2000) Course sequencing for static courses? Applying ITS techniques in large scale Web-based education. In: G. Gauthier, C. Frasson and K. VanLehn (eds.) *Intelligent Tutoring Systems*. Lecture Notes in Computer Science, Vol. 1839, (Proceedings of 5th International Conference on Intelligent Tutoring Systems (ITS 2000), Montréal, Canada, June 19-23, 2000) Berlin: Springer Verlag, pp. 625-634.

Brusilovsky, P. (2003) Developing Adaptive Educational Hypermedia Systems: From Design Models to Authoring Tools. In: T. Murray, S. Blessing and S. Ainsworth (eds.): *Authoring Tools for Advanced Technology Learning Environments: Toward cost-effective adaptive, interactive, and intelligent educational software*. Norwood: Ablex, pp. 377-409, also available at http://www2.sis.pitt.edu/~peterb/papers/KluwerAuthBook.pdf.

Brusilovsky, P. (2004) KnowledgeTree: A distributed architecture for adaptive e-learning. In: Proceedings of The Thirteenth International World Wide Web Conference, WWW 2004 (Alternate track papers and posters), New York, NY, 17-22 May, 2004, ACM Press, pp. 104-113.

Brusilovsky, P. and Anderson, J. (1998) ACT-R electronic bookshelf: An adaptive system for learning cognitive psychology on the Web. In: H. Maurer and R. G. Olson (eds.) Proceedings of WebNet'98, World Conference of the WWW, Internet, and Intranet, Orlando, FL, November 7-12, 1998, AACE, pp. 92-97.

Brusilovsky, P., Chavan, G., and Farzan, R. (2004) Social adaptive navigation support for open corpus electronic textbooks. In: P. De Bra (ed.) Proceedings of Third International Conference on Adaptive Hypermedia and Adaptive Web-Based Systems (AH'2004), Eindhoven, the Netherlands, , pp. in press.

Brusilovsky, P. and Cooper, D. W. (1999) ADAPTS: Adaptive hypermedia for a Web-based performance support system. In: P. Brusilovsky and P. De Bra (eds.) Proceedings of Second Workshop on Adaptive Systems and User Modeling on WWW at 8th International Word Wide Web Conference and 7-th International Conference on User Modeling, Toronto and Banff, Canada, May 11 and June 23-24, 1999 Published as Computer Science Report, No. 99-07, Eindhoven University of Technology, Eindhoven. pp. 41-47, also available at http://wwwis.win.tue.nl/asum99/brusilovsky/brusilovsky.html.

Brusilovsky, P. and Cooper, D. W. (2002) Domain, Task, and User Models for an Adaptive Hypermedia Performance Support System. In: Y. Gil and D. B. Leake (eds.) Proceedings of 2002 International Conference on Intelligent User Interfaces, San Francisco, CA, January 13-16, 2002, ACM Press, pp. 23-30, also available at http://www2.sis.pitt.edu/~peterb/papers/IUI02.pdf.

Brusilovsky, P. and Eklund, J. (1998) A study of user-model based link annotation in educational hypermedia. In P. Carlson (ed.) *Journal of Universal Computer Science* 4 (4), Special Issue on Assessment Issues for Educational Software, 429-448, also available at http://www.iicm.edu/jucs_4_4/a_study_of_user.

Brusilovsky, P., Eklund, J., and Schwarz, E. (1998) Web-based education for all: A tool for developing adaptive courseware. *Computer Networks and ISDN Systems* (Proceedings of Seventh International World Wide Web Conference, 14-18 April 1998) 30 (1-7), 291-300.

Brusilovsky, P. and Pesin, L. (1994) An intelligent learning environment for CDS/ISIS users. In: J. J. Levonen and M. T. Tukianinen (eds.) Proceedings of The interdisciplinary workshop on complex learning in computer environments (CLCE94), Joensuu, Finland, May 16-19, 1994, EIC, pp. 29-33, also available at http://cs.joensuu.fi/~mtuki/www_clce.270296/Brusilov.html.

Brusilovsky, P. and Pesin, L. (1998) Adaptive navigation support in educational hypermedia: An evaluation of the ISIS-Tutor. *Journal of Computing and Information Technology* 6 (1), 27-38.

Brusilovsky, P., Pesin, L., and Zyryanov, M. (1993) Towards an adaptive hypermedia component for an intelligent learning environment. In: L. J. Bass, J. Gornostaev and C. Unger (eds.) *Human-Computer Interaction*. Lecture Notes in Computer Science, Vol. 753, (Proceedings of 3rd International Conference on Human-Computer Interaction, EWHCI'93, Moscow, Russia, August 3-7, 1993) Berlin: Springer-Verlag, pp. 348-358.

Brusilovsky, P. and Rizzo, R. (2002a) Map-based horizontal navigation in educational hypertext. *Journal of Digital Information* 3 (1), also available at http://jodi.ecs.soton.ac.uk/Articles/v03/i01/Brusilovsky/.

Brusilovsky, P. and Rizzo, R. (2002b) Using maps and landmarks for navigation between closed and open corpus hyperspace in Web-based education. *The New Review of Hypermedia and Multimedia* 9, 59-82.

Brusilovsky, P., Schwarz, E., and Weber, G. (1996a) ELM-ART: An intelligent tutoring system on World Wide Web. In: C. Frasson, G. Gauthier and A. Lesgold (eds.) *Intelligent Tutoring Systems*. Lecture Notes in Computer Science, Vol. 1086, (Proceedings of Third International Conference on Intelligent Tutoring Systems, ITS-96, Montreal, June 12-14, 1996) Berlin: Springer Verlag, pp. 261-269, also available at http://www.contrib.andrew.cmu.edu/~plb/ITS96.html.

Brusilovsky, P., Schwarz, E., and Weber, G. (1996b) A tool for developing adaptive electronic textbooks on WWW. In: H. Maurer (ed.) Proceedings of WebNet'96, World Conference of the Web Society, San Francisco, CA, October 15-19, 1996, AACE, pp. 64-69, also available at http://www.contrib.andrew.cmu.edu/~plb/WebNet96.html.

Brusilovsky, P. and Vassileva, J. (2003) Course sequencing techniques for large-scale web-based education. *International Journal of Continuing Engineering Education and Lifelong Learning* 13 (1/2), 75-94.

Brusilovsky, P. L. and Gorskaya-Belova, T. B. (1992) An environment for physical geography teaching. *Computers and Education* 18 (1 3), Special Issue on Computers Educ., 85-88.

Carmona, C., Bueno, D., Guzman, E., and Conejo, R. (2002) SIGUE: Making Web Courses Adaptive. In: P. De Bra, P. Brusilovsky and R. Conejo (eds.) Proceedings of Second International Conference on Adaptive Hypermedia and Adaptive Web-Based Systems (AH'2002) Proceedings, Málaga, Spain, May 29-31, 2002, pp. 376-379.

Carro, R. M., Pulido, E., and Rodrígues, P. (1999) TANGOW: Task-based Adaptive learNer Guidance on the WWW. In: P. Brusilovsky and P. D. Bra (eds.) Proceedings of Second

Workshop on Adaptive Systems and User Modeling on the World Wide Web, Toronto and Banff, Canada, May 11 and June 23-24, 1999 Published as Computer Science Report, No. 99-07, Eindhoven University of Technology, Eindhoven. pp. 49-57.

Conejo, R., Guzman, E., and Millán, E. (2004) SIETTE: A Web-based tool for adaptive teaching. *International Journal of Artificial Intelligence in Education* 14 (1), 29-61.

Conlan, O., Dagger, D., and Wade, V. (2002a) Towards a standards-based approach to e-Learning personalization using reusable learning objects. In: M. Driscoll and T. C. Reeves (eds.) Proceedings of World Conference on E-Learning, E-Learn 2002, Montreal, Canada, October 15-19, 2002, AACE, pp. 210-217.

Conlan, O., Wade, V., Gargan, M., Hockemeyer, C., and Albert, D. (2002b) An architecture for integrating adaptive hypermedia services with open learning environments. In: P. Barker and S. Rebelsky (eds.) Proceedings of ED-MEDIA'2002 - World Conference on Educational Multimedia, Hypermedia and Telecommunications, Denver, CO, June 24-29, 2002, AACE, pp. 344-350.

Constantino Gonzalez, M. A., Suthers, D., and Escamilla de los Santos, J. G. (2003) Coaching web-based collaborative learning based on problem solution differences and participation. In P. Brusilovsky and C. Peylo (eds.), *International Journal of Artificial Intelligence in Education* 13 (2-4), Special Issue on Special Issue on Adaptive and Intelligent Web-based Educational Systems, 263-299.

De Bra, P. and Calvi, L. (1998) AHA! An open Adaptive Hypermedia Architecture. In P. Brusilovsky and M. Milosavljevic (eds.), *The New Review of Hypermedia and Multimedia* 4, Special Issue on Adaptivity and user modeling in hypermedia systems, 115-139.

De Bra, P. and Ruiter, J.-P. (2001) AHA! Adaptive hypermedia for all. In: W. Fowler and J. Hasebrook (eds.) Proceedings of WebNet'2001, World Conference of the WWW and Internet, Orlando, FL, October 23-27, 2001, AACE, pp. 262-268.

De Bra, P. M. E. (1996) Teaching Hypertext and Hypermedia through the Web. *Journal of Universal Computer Science* 2 (12), 797-804, also available at http://www.iicm.edu/jucs_2_12/teaching_hypertext_and_hypermedia.

de La Passardiere, B. and Dufresne, A. (1992) Adaptive navigational tools for educational hypermedia. In: I. Tomek (ed.) *Computer Assisted Learning*. (Proceedings of ICCAL'92, 4-th International Conference on Computers and Learning, Wolfville, Canada, June 17-20, 1992) Berlin: Springer-Verlag, pp. 555-567.

Delestre, N., PÈcuchet, J.-P., and Barry-GrÈboval, C. (1999) Why to use a dynamic adaptive hypermedia for teaching, and how to design it? In: P. D. Bra and J. Leggett (eds.) Proceedings of WebNet'99, World Conference of the WWW and Internet, Honolulu, HI, Oct. 24-30, 1999, AACE, pp. 277-282.

Dichev, C., Dicheva, D., and Aroyo, L. (2004) Using Topic Maps for Web-based Education. *Advanced Technology for Learning* 1 (1), 1-7.

Dolog, P., Gavriloaie, R., Nejdl, W., and Brase, J. (2003) Integrating Adaptive Hypermedia Techniques and Open RDF-Based Environments. In: Proceedings of The Twelfth International World Wide Web Conference, WWW 2003, Budapest, Hungary, 20-24 May, 2003, pp. 88-98.

Eklund, J. (1999). *A study of adaptive link annotation in educational hypermedia* (Ph.D. Thesis). University of Syndey.

Eklund, J. and Brusilovsky, P. (1998) The value of adaptivity in hypermedia learning environments: A short review of empirical evidence. In: P. Brusilovsky and P. De Bra (eds.) Proceedings of Second Adaptive Hypertext and Hypermedia Workshop at the Ninth ACM International Hypertext Conference Hypertext'98, Pittsburgh, PA, June 20, 1998 Published as Computing Science Reports, No. 98/12, Eindhoven University of Technology, Eindhoven. pp. 13-19.

Eliot, C., Neiman, D., and Lamar, M. (1997) Medtec: A Web-based intelligent tutor for basic anatomy. In: S. Lobodzinski and I. Tomek (eds.) Proceedings of WebNet'97, World Conference of the WWW, Internet and Intranet, Toronto, Canada, November 1-5, 1997, AACE, pp. 161-165.

Fischer, S. (2001) Course and exercise sequencing using metadata in adaptive hypermedia learning systems. *Journal of Educational Resources in Computing* 1 (1), also available at http://delivery.acm.org/10.1145/380000/376700/a5-fischer.pdf?CFID=187844&CFTOKEN=23728107.

Gilbert, J. E. and Han, C. Y. (1999) Arthur: Adapting Instruction to Accommodate Learning Style. In: P. D. Bra and J. Leggett (eds.) Proceedings of WebNet'99, World Conference of the WWW and Internet, Honolulu, HI, Oct. 24-30, 1999, AACE, pp. 433-438.

Gonschorek, M. and Herzog, C. (1995) Using hypertext for an adaptive helpsystem in an intelligent tutoring system. In: J. Greer (ed.) Proceedings of AI-ED'95, 7th World Conference on Artificial Intelligence in Education, Washington, DC, 16-19 August 1995, AACE, pp. 274-281.

Hammond, N. (1989) Hypermedia and learning: Who guides whom? In: H. Maurer (ed.) *Computer Assisted Learning*. Lecture Notes in Computer Science, Vol. 360, (Proceedings of 2-nd International Conference on Computer Assisted Learning, ICCAL'89, Dallas, TX, May 9-11, 1989) Berlin: Springer-Verlag, pp. 167-181.

Henze, N. and Nejdl, W. (1999) Adaptivity in the KBS Hyperbook System. In: P. Brusilovsky, P. D. Bra and A. Kobsa (eds.) Proceedings of Second Workshop on Adaptive Systems and User Modeling on the World Wide Web, Toronto and Banff, Canada, May 11 and June 23-24, 1999 Published as Computer Science Report, No. 99-07, Eindhoven University of Technology, Eindhoven. pp. 67-74.

Henze, N. and Nejdl, W. (2000) Extendible adaptive hypermedia courseware: Integrating different courses and Web material. In: P. Brusilovsky, O. Stock and C. Strapparava (eds.) *Adaptive Hypermedia and Adaptive Web-Based Systems*. Lecture Notes in Computer Science, (Proceedings of Adaptive Hypermedia and Adaptive Web-based Systems, AH2000, Trento, Italy, August 28-30, 2000) Berlin: Springer-Verlag, pp. 109-120.

Henze, N. and Nejdl, W. (2001) Adaptation in open corpus hypermedia. In P. Brusilovsky and C. Peylo (eds.), *International Journal of Artificial Intelligence in Education* 12 (4), Special Issue on Special Issue on Adaptive and Intelligent Web-based Educational Systems, 325-350, also available at http://cbl.leeds.ac.uk/ijaied/abstracts/Vol_12/henze.html.

Hockemeyer, C., Held, T., and Albert, D. (1998) RATH - A relational adaptive tutoring hypertext WWW-environment based on knowledge space theory. In: C. Alvegård (ed.) Proceedings of CALISCE'98, 4th International conference on Computer Aided Learning and Instruction in Science and Engineering, Göteborg, Sweden, June 15-17, 1998, pp. 417-423.

Hohl, H., Böcker, H.-D., and Gunzenhäuser, R. (1996) Hypadapter: An adaptive hypertext system for exploratory learning and programming. In P. Brusilovsky and J. Vassileva (eds.), *User Modeling and User-Adapted Interaction* 6 (2-3), Special Issue on Adaptive Hypertext and Hypermedia, 131-156.

Jacquiot, C., Bourda, Y., and Popineau, F. (2004) GEAHS: A Generic Educational Adaptive Hypermedia System. In: L. Cantoni and C. McLoughlin (eds.) Proceedings of ED-MEDIA'2004 - World Conference on Educational Multimedia, Hypermedia and Telecommunications, Lugano, Switzerland, June 21-26, 2004, AACE, pp. 571-578.

Kaplan, C., Fenwick, J., and Chen, J. (1993) Adaptive hypertext navigation based on user goals and context. *User Modeling and User-Adapted Interaction* 3 (3), Special Issue on User models & user-adapt. interact., 193-220.

Karagiannidis, C., Sampson, D. G., and Cardinali, F. (2002) An architecture for Web-based e-Learning promoting re-usable adaptive educational e-content. *Educational Technology & Society* 5 (4).

Kay, J. and Kummerfeld, B. (1997) User models for customized hypertext. In: C. Nicholas and J. Mayfield (eds.): *Intelligent hypertext: Advanced techniques for the World Wide Web*. Lecture Notes in Computer Science, Vol. 1326, Berlin: Springer-Verlag.

Kay, J. and Kummerfeld, R. J. (1994) An individualised course for the C programming language. In: Proceedings of Second International WWW Conference, Chicago, IL, 17-20 October, 1994, also available at http://www.ncsa.uiuc.edu/SDG/IT94/Proceedings/Educ/kummerfeld/kummerfeld.html.

Kayama, M. and Okamoto, T. (1999) Hy-SOM: The semantic map framework applied on an example case of navigation. In: G. Cumming, T. Okamoto and L. Gomez (eds.) *Advanced Research in Computers and Communications in Education*. Frontiers ub Artificial Intelligence and Applications, Vol. 2, (Proceedings of ICCE'99, 7th International Conference on Computers in Education, Chiba, Japan, 4-7 November, 1999) Amsterdam: IOS Press, pp. 252-259.

Laroussi, M. and Benahmed, M. (1998) Providing an adaptive learning through the Web case of CAMELEON: Computer Aided MEdium for LEarning on Networks. In: C. Alvegård (ed.) Proceedings of CALISCE'98, 4th International conference on Computer Aided Learning and Instruction in Science and Engineering, Göteborg, Sweden, June 15-17, 1998, pp. 411-416.

Manouselis, N. and Sampson, D. (2002) Dynamic Educational e-Content Selection Using Multiple Criteria in Web-based Personalized Learning Environments. In: P. Barker and S. Rebelsky (eds.) Proceedings of ED-MEDIA'2002 - World Conference on Educational Multimedia, Hypermedia and Telecommunications, Denver, CO, June 24-29, 2002, AACE, pp. 1213-1218.

Milosavljevic, M. (1997) Augmenting the user's knowledge via comparison. In: A. Jameson, C. Paris and C. Tasso (eds.) *User Modeling*. (Proceedings of 6th International Conference on User Modeling, UM97, Chia Laguna, Sardinia, Italy, June 2-5, 1997) Wien: SpringerWienNewYork, pp. 119-130.

Mödritscher, F., Gütl, C., García Barrios, V. M., and Maurer, H. (2004) Why do Standards in the Field of E-Learning not fully support Learner-centred Aspects of Adaptivity? In: L. Cantoni and C. McLoughlin (eds.) Proceedings of ED-MEDIA'2004 - World Conference on Educational Multimedia, Hypermedia and Telecommunications, Lugano, Switzerland, June 21-26, 2004, AACE, pp. 2034-2039.

Murray, T. (2001) Characteristics and Affordances of Adaptive Hyperbooks. In: W. Fowler and J. Hasebrook (eds.) Proceedings of WebNet'2001, World Conference of the WWW and Internet, Orlando, FL, October 23-27, 2001, AACE, pp. 899-904.

Murray, T. (2003) MetaLinks: Authoring and affordances for conceptual and narrative flow in adaptive hyperbooks. In P. Brusilovsky and C. Peylo (eds.), *International Journal of Artificial Intelligence in Education* 13 (2-4), Special Issue on Special Issue on Adaptive and Intelligent Web-based Educational Systems, 199-233.

Murray, T., Condit, C., and Haugsjaa, E. (1998) MetaLinks: A preliminary framework for concept-based adaptive hypermedia. In: Proceedings of Workshop "WWW-Based Tutoring" at 4th International Conference on Intelligent Tutoring Systems (ITS'98), San Antonio, TX, August 16-19, 1998, also available at http://www-aml.cs.umass.edu/~stern/webits/itsworkshop/murray.html.

Negro, A., Scarano, V., and Simari, R. (1998) User adaptivity on WWW through CHEOPS. In: P. Brusilovsky and P. De Bra (eds.) Proceedings of Second Adaptive Hypertext and Hypermedia Workshop at the Ninth ACM International Hypertext Conference Hypertext'98, Pittsburgh, PA, June 20, 1998 Published as Computing Science Reports, No. 98/12, Eindhoven University of Technology, Eindhoven. pp. 57-62.

Nejdl, W., Wolf, B., Qu, C., Decker, S., Sintek, M., Naeve, A., Nilsson, M., Palmér, M., and Risch, T. (2002) EDUTELLA: A P2P Networking Infrastructure Based on RDF. In: Proceedings of 11th International World Wide Web Conference, Honolulu, Hawaii, USA, 7-11 May 2002, also available at http://www2002.org/CDROM/refereed/597/index.html.

Neumann, G. and Zirvas, J. (1998) SKILL - A scallable internet-based teaching and learning system. In: H. Maurer and R. G. Olson (eds.) Proceedings of WebNet'98, World Conference of the WWW, Internet, and Intranet, Orlando, FL, November 7-12, 1998, AACE, pp. 688-693, also available at http://nestroy.wi-inf.uni-essen.de/Forschung/Publikationen/skill-webnet98.ps.

Oberlander, J., O'Donell, M., Mellish, C., and Knott, A. (1998) Conversation in the museum: experiments in dynamic hypermedia with the intelligent labeling explorer. In P. Brusilovsky and M. Milosavljevic (eds.), *The New Review of Multimedia and Hypermedia* 4, Special Issue on Adaptivity and user modeling in hypermedia systems, 11-32.

Oda, T., Satoh, H., and Watanabe, S. (1998) Searching deadlocked Web learners by measuring similarity of learning activities. In: Proceedings of Workshop "WWW-Based Tutoring" at 4th International Conference on Intelligent Tutoring Systems (ITS'98), San Antonio, TX, August 16-19, 1998, also available at http://www.sw.cas.uec.ac.jp/~watanabe/conference/its98workshop1.ps.

Papanikolaou, K. A., Grigoriadou, M., Kornilakis, H., and Magoulas, G. D. (2003) Personalising the interaction in a Web-based Educational Hypermedia System: the case of INSPIRE. *User Modeling and User Adapted Interaction* 13 (3), 213-267 .

Pérez, T., Gutiérrez, J., and Lopistéguy, P. (1995) An adaptive hypermedia system. In: J. Greer (ed.) Proceedings of AI-ED'95, 7th World Conference on Artificial Intelligence in Education, Washington, DC, 16-19 August 1995, AACE, pp. 351-358.

Pilar da Silva, D., Durm, R. V., Duval, E., and Olivié, H. (1998) Concepts and documents for adaptive educational hypermedia: a model and a prototype. In: P. Brusilovsky and P. De Bra (eds.) Proceedings of Second Adaptive Hypertext and Hypermedia Workshop at the Ninth ACM International Hypertext Conference Hypertext'98, Pittsburgh, PA, June 20, 1998 Published as Computing Science Reports, No. 98/12, Eindhoven University of Technology, Eindhoven. pp. 35-43.

Sanrach, C. and Grandbastien, M. (2000) ECSAIWeb: A Web-based authoring system to create adaptive learning systems. In: P. Brusilovsky, O. Stock and C. Strapparava (eds.) *Adaptive Hypermedia and Adaptive Web-Based Systems*. Lecture Notes in Computer Science, (Proceedings of Adaptive Hypermedia and Adaptive Web-based Systems, AH2000, Trento, Italy, August 28-30, 2000) Berlin: Springer-Verlag, pp. 214-226.

Schöch, V., Specht, M., and Weber, G. (1998) "ADI" - an empirical evaluation of a tutorial agent. In: T. Ottmann and I. Tomek (eds.) Proceedings of ED-MEDIA/ED-TELECOM'98 - 10th World Conference on Educational Multimedia and Hypermedia and World Conference on Educational Telecommunications, Freiburg, Germany, June, 20-25, 1998, AACE, pp. 1242-1247.

Simon, B., Miklós, Z., Nejdl, W., Sintek, M., and Salvachua, J. (2003) Smart space for learning: A mediation infrastructure for learning services. In: Proceedings of The Twelfth International World Wide Web Conference, WWW 2003, Budapest, Hungary, 20-24 May, 2003, pp. 97-101.

Sosnovsky, S., Brusilovsky, P., and Shcherbinina, O. (2004) QuizGuide: Increasing the Educational Value of Individualized Self-Assessment Quizzes with Adaptive Navigation Support. In: Proceedings of World Conference on E-Learning, E-Learn 2004, Washington, DC, USA, November, 2004, AACE, pp. in press.

Specht, M., Kravcik, M., Klemke, R., Pesin, L., and Hüttenhain, R. (2002a) Adaptive Learning Environment (ALE) for Teaching and Learning in WINDS. In: Lecture Notes in Computer Science, Vol. 2347, (Proceedings of Second International Conference on Adaptive Hypermedia and Adaptive Web-Based Systems (AH'2002), Málaga, Spain, May 29-31, 2002) Berlin: Springer-Verlag, pp. 572-581.

Specht, M., Kravcik, M., Pesin, L., and Klemke, R. (2002b) Learner's Lounge: Information Brokering for the Adaptive Learning Environment. In: M. Driscoll and T. C. Reeves (eds.) Proceedings of World Conference on E-Learning, E-Learn 2002, Montreal, Canada, October 15-19, 2002, AACE, pp. 2510-2512.

Specht, M. and Oppermann, R. (1998) ACE - Adaptive Courseware Environment. In P. Brusilovsky and M. Milosavljevic (eds.), *The New Review of Hypermedia and Multimedia* 4, Special Issue on Adaptivity and user modeling in hypermedia systems, 141-161.

Specht, M., Weber, G., Heitmeyer, S., and Schöch, V. (1997) AST: Adaptive WWW-Courseware for Statistics. In: P. Brusilovsky, J. Fink and J. Kay (eds.) Proceedings of Workshop "Adaptive Systems and User Modeling on the World Wide Web" at 6th International Conference on User Modeling, UM97, Chia Laguna, Sardinia, Italy, June 2, 1997, Carnegie Mellon Online, pp. 91-95, also available at http://www.contrib.andrew.cmu.edu/~plb/UM97_workshop/Specht.html.

Steinacker, A., Faatz, A., Seeberg, C., Rimac, I., Hörmann, S., Saddik, A. E., and Steinmetz, R. (2001) MediBook: Combining semantic networks with metadata for learning resources to build a Web based learning system. In: Proceedings of ED-MEDIA'2001 - World Conference on Educational Multimedia, Hypermedia and Telecommunications, Tampere, Finland, June 25-30, 2001, AACE, pp. 1790-1795.

Steinacker, A., Seeberg, C., Rechenberger, K., Fischer, S., and Steinmetz, R. (1999) Dynamically generated tables of contents as guided tours in adaptive hypermedia systems. In: Proceedings of ED-MEDIA/ED-TELECOM'99 - 11th World Conference on Educational Multimedia and Hypermedia and World Conference on Educational Telecommunications, Seattle, WA, , AACE.

Stern, M. K. and Woolf, B. P. (2000) Adaptive content in an online lecture system. In: P. Brusilovsky, O. Stock and C. Strapparava (eds.) *Adaptive Hypermedia and Adaptive Web-based systems*. Lecture Notes in Computer Science, (Proceedings of Adaptive Hypermedia and Adaptive Web-based systens, Trento, Italy, August 28-30, 2000) Berlin: Springer-Verlag, pp. 225-238.

WebCT (2002) WebCT Course Management System 3.8, WebCT, Inc., Lynnfield, MA. http://www.webct.com (Accessed 2 July, 2002)

Weber, G. (1999) Adaptive learning systems in the World Wide Web. In: J. Kay (ed.) (Proceedings of 7th International Conference on User Modeling, UM99, Banff, Canada, June 20-24, 1999) Wien: SpringerWienNewYork, pp. 371-378.

Weber, G. and Brusilovsky, P. (2001) ELM-ART: An adaptive versatile system for Web-based instruction. In P. Brusilovsky and C. Peylo (eds.), *International Journal of Artificial Intelligence in Education* 12 (4), Special Issue on Adaptive and Intelligent Web-based Educational Systems, 351-384, also available at http://cbl.leeds.ac.uk/ijaied/abstracts/Vol_12/weber.html.

Weber, G., Kuhl, H.-C., and Weibelzahl, S. (2001) Developing adaptive internet based courses with the authoring system NetCoach. In: P. D. Bra, P. Brusilovsky and A. Kobsa (eds.) Proceedings of Third workshop on Adaptive Hypertext and Hypermedia, Sonthofen, Germany, July 14, 2001, Technical University Eindhoven, pp. 35-48, also available at http://wwwis.win.tue.nl/ah2001/papers/GWeber-UM01.pdf.

Weber, G. and Möllenberg, A. (1995) ELM-Programming-Environment: A Tutoring System for LISP Beginners. In: K. F. Wender, F. Schmalhofer and H.-D. Böcker (eds.): *Cognition and Computer Programming*. Norwood, NJ: Ablex, pp. 373-408.

Weber, G. and Specht, M. (1997) User modeling and adaptive navigation support in WWW-based tutoring systems. In: A. Jameson, C. Paris and C. Tasso (eds.) *User Modeling*. (Proceedings of 6th International Conference on User Modeling, Chia Laguna, Sardinia, Italy, June 2-5, 1997)

Wien: SpringerWienNewYork, pp. 289-300, also available at http://www.psychologie.uni-trier.de:8000/projects/ELM/Papers/UM97-WEBER.html.