Journal of Quality and Technology Management
Volume VII, Issue II, December, 2011, Page 63 - 82

COMPARATIVE STUDY OF FRAMEWORKS FOR THE DEVELOPMENT OF BETTER QUALITY ADAPTIVE HYPERMEDIA BASED EDUCATIONAL SYSTEMS

F. Baig
Division of Science and Technology,
University of Education, Lahore – Pakistan

ABSTRACT

Majority of the online educational systems provide same content to all the learners without considering their personal needs, goals and educational background. This makes the learning process more difficult and boring. Adaptive hypermedia can enhance the quality of these systems through personalisation or customisation. Adaptive hypermedia based educational system (AHES) builds learners' profile as a learner model and then presents the content to them according to their preferences and previous educational record. Development of AHES is a lengthy and difficult process because it involves implementation of adaptation along with development of communication tools and digital library etc. To make this process easy, different authoring tools or frameworks are available like AHA!, InterBook, NetCoach and COFALE. In this paper, their analysis and comparison are described through which selection of a framework to develop better quality AHES becomes easy.

Keywords: *E-learning, Adaptive Hypermedia, Adaptive Presentation, Adaptive Navigation.*

INTRODUCTION

We are passing through information age. Now it is very important that right information at right time through economical way and in efficient manner should reach us. That is why, most of the institutions are trying to adopt the way of e-learning nowadays to improve the quality of education. In this regard, tools of information technology (IT) can play a vital role in the shape of information resources on web, communication technologies like audio, video conferencing, virtual reality, simulations and database management systems (Hung et al., 2003). E-learning has changed the whole educational scenario by utilising all of these tools of IT (Hamilton and Zimmerman, 2002). E-learning is a broader concept and it

is existed in different modes. Online education is one of them in which web is used as a major tool of communication (Hegngi, 1997). This mode of education is also called hypermedia based education. According to Hodges and Saba (2002), advantages of hypermedia based education are not only for the learner but for the instructor and institute as well.

For the learner, hypermedia based education is quite fast because he or she can learn at home or office and no need to travel towards college or university, so it not only saves time but travelling cost as well. It can be adaptive so that learner can skip the study material which is already known to him or her (Hum and Ladouceur, 2001). This mode of education also provides collaborative environment which is quite good in social point of view, because learner gets opportunity to interact with learners belong to different communities and cultures (De Verneil and Berge, 2000).

Instructor can also save his or her time in online education. Study material for online education is prepared once and then it is used by so many learners at any time. Even that material can be shared easily with other instructors all over the world or within a specific community of instructors. Interaction level of instructor with learners also becomes wider because instructor can communicate with huge number of learners at a time. He or she can develop personal relationships with the learners as well.

Hypermedia based education is also beneficial at the institution level in terms of cost of delivering education. First of all, there is no need of huge buildings and classrooms. In this way, administrative kinds of activities are also reduced. Time to deliver education is reduced as well and institution can earn more by educating thousands of learners at once (Hum and Ladouceur, 2001).

According to Giguere and Minotti (2003) high quality hypermedia based educational system should have following characteristics:

- The content of the websites should be learner centred.
- Appropriate tools for learning activities like discussion forums and announcement board should be part of this.
- Learning objectives should be clearly defined.
- Educational material should be easily accessible.

- Educational material should be available in different formats.
- Learners should have facility to share their views and material easily.
- Training process should not be much lengthy.
- Any expert should monitor and facilitate the learning process.
- Online technical help should be provided.
- Online assessment through tests, assignments and discussions should be done.

These guidelines have much importance but still online education or training is difficult and there are always some possibilities of non-completion of online educational programmes which are not providing what the learners expect and what they are really interested in. So the workload of learners is increased and it becomes very difficult for them to manage online learning (Kearsley and Blomeyer, 2004). This issue can be resolved with the help of personalisation or customisation.

ADAPTIVE HYPERMEDIA BASED EDUCATIONAL SYSTEMS

Adaptive hypermedia can make online educational systems more dynamic through personalisation or customization which means that systems should adapt learners' characteristics and guide them according to their needs and previous academic record. In this way, quality of online educational systems can be enhanced. When adaptive features are added to web based educational system then such system becomes adaptive hypermedia based educational system (AHES) which is more learners centred.

Adaptive hypermedia based educational system (AHES) is a type of intelligent tutoring system (ITS) (Murray, 1999). Most of the online educational systems present same content to all learners without considering their educational background and preferences. In this way mechanism of "one-size-fits-all" makes the learning process more difficult and boring because every learner has to spend more time to dig out the relevant material (Brusilovsky and Maybury, 2002). On the other hand, the aim of adaptive hypermedia based educational systems (AHESs) is to reduce cognitive overload. AHESs also provide adaptive collaborative environment and adaptive testing. AHESs build learners profile as a learner model and use this knowledge to simplify the browsing experience and guide the learners within information space to find more

relevant information. All kinds of information or concepts are contained in domain model. Moreover, adaptation is achieved through adaptive presentation and adaptive navigation. Both of them are parts of adaptation model of the system.

Adaptive presentation (Brusilovsky, 2001) is content level adaptation because the content of AHES is altered according to the learner's goals, needs and educational background. For example, if someone has no prior knowledge about one particular subject or domain area then only basic concepts about that subject or domain area will be shown to that learner. On the other hand, advanced concepts will be shown to the experts. According to Brusilovsky (1996), five methods are used for adaptive presentation: *Additional explanations, prerequisite explanations, comparative explanations, explanation variants* and *sorting*. To implement these methods, four techniques are used: *Conditional text, stretchtext, fragment and page variants* and *frame based technique*.

Adaptive navigation (Brusilovsky 2003a, 2007) helps learners to navigate within hyperspace of AHES by adaptation at hyperlinks level based on information stored in learner model. Brusilovsky (1996) described five methods for adaptive navigation: *Global guidance, local guidance, global orientation support, local orientation support* and *managing personalised views*. There are five techniques to implement methods for adaptive navigation including *direct guidance, link sorting, link hiding, link annotation* and *link generation*.

ELM-ART (Brusilovsky et al., 1996) and PT (Kay and Kummerfeld, 1997) are pioneers in this field. After them, we have so many other examples of AHES like JointZone (Ng et al., 2002), AES-CS (Triantafillou et al., 2002) and ActiveMath (Melis and Siekmann, 2004).

FRAMEWORKS FOR THE DEVELOPMENT OF AHESs

Development of AHES is not an easy task because it involves so many processes including development of e-learning tools like discussion forums, chatting, emailing and digital library etc. Moreover, educationists who need to develop such kind of systems are not familiar with computer programming languages. It is a very difficult task for computer specialists as well to take care of all adaptation processes, user or learner modelling and e-learning tools. Hence, some frameworks or authoring tools are

available which provide shell for the development of AHES. These tools are very helpful for teachers to develop and maintain the quality of online adaptive courses. If some one has background of web related programming languages then he or she can develop web pages manually in these tools. There are several frameworks for the development of adaptive systems but only few of them are specially designed for educational systems like KBS-Hyperbook (Nejdl and Wolpers, 1998), Multibook (Fischer and Steinmetz, 2000), WEAR (Moundridou and Virvou, 2001), MOT (Cristea and De Mooij, 2003) and ACCT (Dagger et al., 2005). We have analysed the authoring environments of AHA! (De Bra and Calvi, 1998), InterBook (Brusilovsky et al., 1998), NetCoach (Weber et al., 2001) and COFALE (Chieu, 2007) only because they are providing comparatively better adaptation features. Then we compared these frameworks to facilitate their selection in order to develop better quality AHESs.

The Adaptive Hypermedia Architecture (AHA!)

The development of AHA! (De Bra and Calvi, 1998) was started in 1996 at Eidenhoven University of Technology and its first version 1.0 was released in 2000 (De Bra et al., 2000) and now AHA! 3.0 (De Bra et al., 2003) is being used. It is an open source framework which consists of Java servlets. Figure 1 shows the architecture of AHA!

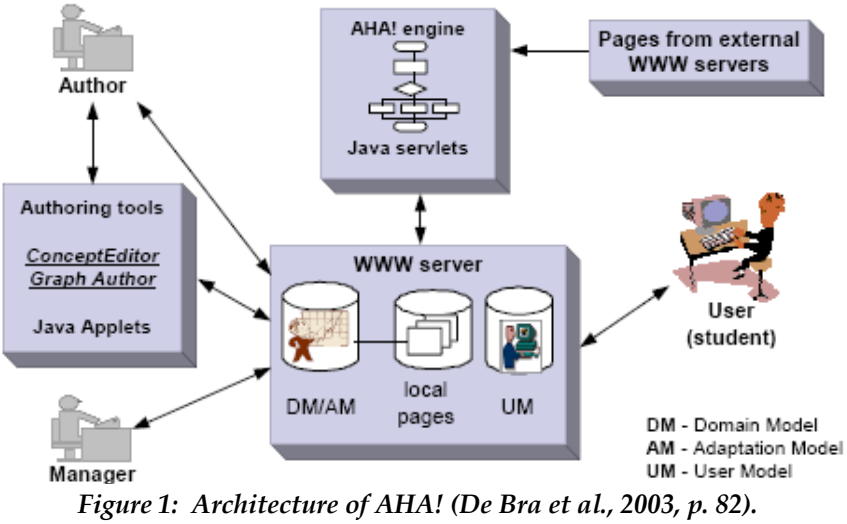

Figure 1: Architecture of AHA! (De Bra et al., 2003, p. 82).

Java servlets are activated when web pages are requested by the user. AHA! engine presents pages to the user from local or external servers.

These pages are generated from combined domain and adaptation model. These are adapted as well. Along with this, user or learner model is updated with the help of *event-condition-action* rules. All data related to domain, adaptation and learner models is stored as XML files or in a single MySQL database. AHA! runs on Tomcat server which is also open source.

AHA! supports overlay learner model. For each concept in domain model there is a concept attribute and Boolean attribute value in learner model. Whenever learner visits a concept then attribute value of that concept is changed, for example, whether a learner knows that concept or not. At the start of a course designed by AHA!, values of all attributes are "false". There is another concept "Personal" in learner model which has also some attributes through which learners' preferences and characteristics are described (De Bra et al., 2004a).

Course Authoring: AHA! provides some authoring tools for course development which are not difficult in use (De Bra et al., 2006, 2007). It provides *Graphical Author tool* for creating concepts and relationship between them as shown in Figure 2.

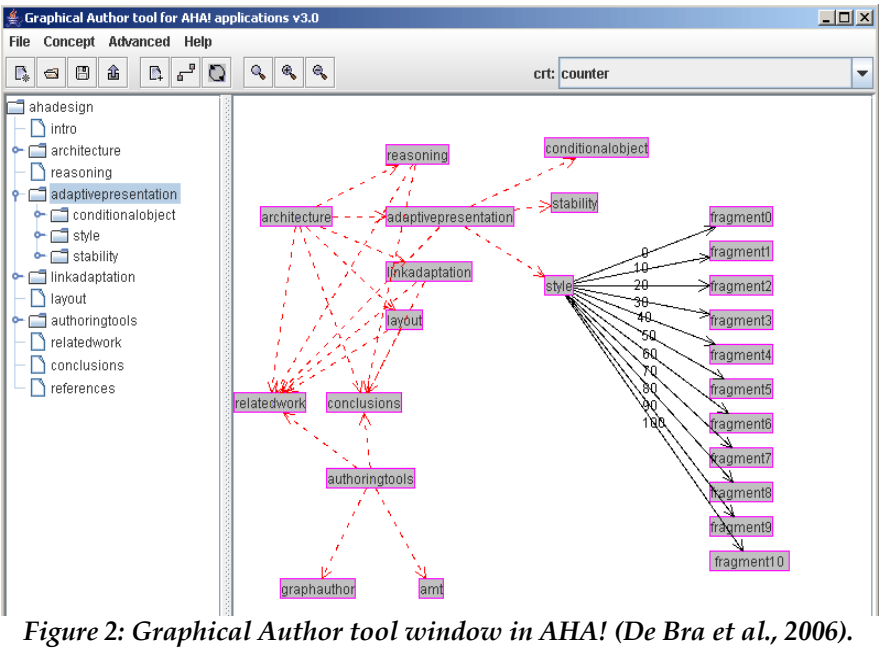

Figure 2: Graphical Author tool window in AHA! (De Bra et al., 2006).

Conceptual structure of the application or course is saved as XML file. This structure can be made in any other tool as well which can generate

XML files. The *Graphical Author tool* uses this conceptual structure for generating adaptation rules. Information content of the course can be made using any other authoring tool which can generate files of HTML, XHTML or XML. AHA! does not offer tool for creating information content. It only uses handlers for processing files of different formats. Along with this AHA! also supports images and media files of different formats. Usually, authors only use *Graphical Author tool* but if anyone wants to implement adaptation rules by him or herself at low level then *Concept Editor* is also available.

For transferring pages of information content and other media files from author's personal computer to AHA! server, the *Application Management tool* is used as shown in Figure 3.

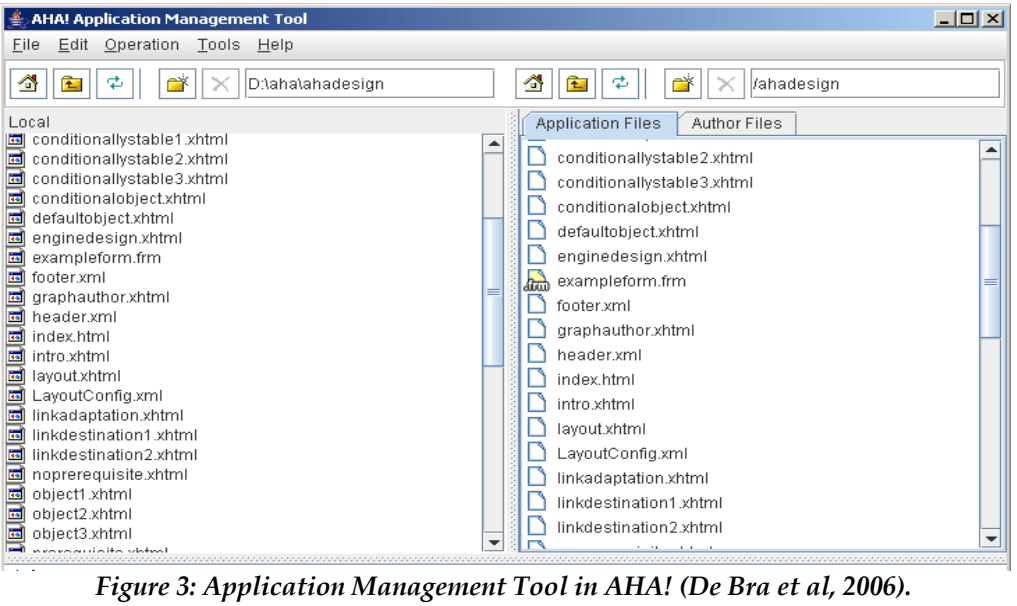

Figure 3: Application Management Tool in AHA! (De Bra et al, 2006).

It can also be used to activate *Graphical Author tool* and *Concept Editor*. For learner's evaluation AHA! offers *Test Editor* for developing randomised or sequential adaptive multiple choice tests. AHA! also supports different layouts and skins. Multiple-framed course can be developed through it in which every concept can be presented with different layouts.

Adaptation Support: Adaptation process in AHA! is based on conceptual structure saved in combined domain & adaptation model and information stored in learner model. AHA! supports both adaptive presentation and adaptive navigation (De Bra et al., 2004b; De Bra et al.,

2006). AHA! supports adaptive presentation techniques including *conditional text* and *fragment variants*. In advance, adaptivity of inclusion of external objects can also be implemented in the course. Another presentation style of fragments called *dimming fragments* can be implemented as well through which either fragments get emphasised or dimmed according to the learner model. In AHA!, adaptive navigation techniques can also implemented including *link sorting, link hiding, link annotation* and *direct guidance*.

InterBook

InterBook is used to develop adaptive online educational courses in the shape of textbooks. Its architecture is based on textbook ELM-ART, one of the pioneer adaptive systems. It was developed using CL-HTTP, Common LISP HTTP server. CL-HTTP is used to develop online intelligent systems (Brusilovsky et al., 1998). InterBook is only available for Apple Macintosh systems.

Domain model of an electronic text book developed by InterBook consists of all the educational concepts described by the author. These concepts can be shown by two main windows provided by InterBook: G*lossary Window* and *Textbook Window* (Brusilovsky et al., 1996). *Glossary window* is divided into two parts. Upper portion shows the glossary of concepts. Lower portion shows the pages in which required concept can be found along with the list of those concepts for which required concept is prerequisite as shown in Figure 4.

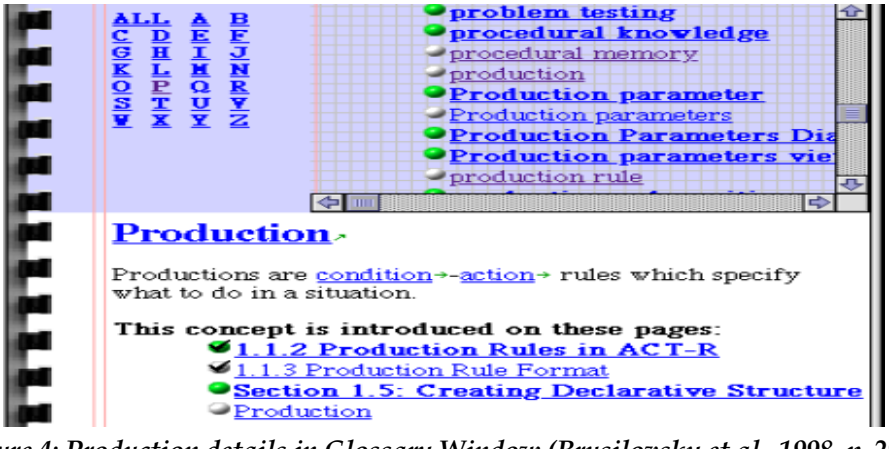

Figure 4: Production details in Glossary Window (Brusilovsky et al., 1998, p. 296).

Textbook Window is designed to show the detail of required concept. It also shows the list of relevant concepts. Upper portion of this window shows the current position of the concept in the whole textbook. It is also used to open *Search Window*, *Help Window*, *Glossary Window* and *Content Window* as shown in Figure 5.

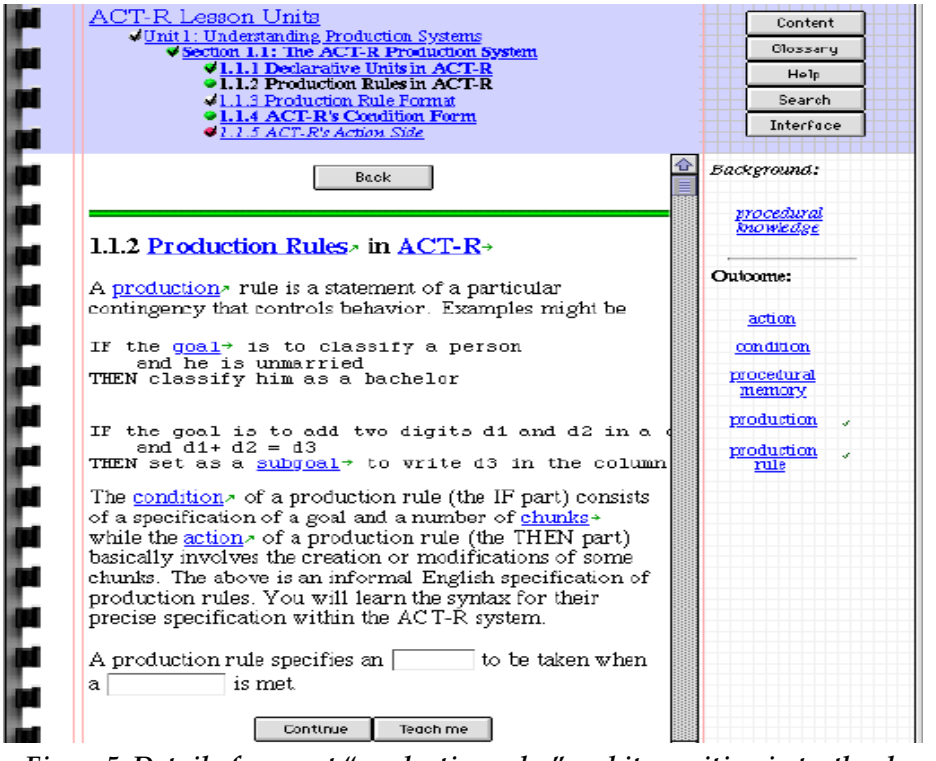

Figure 5: Detail of concept "production rules" and its position in textbook (Brusilovsky et al., 1998, p. 297).

InterBook supports overlay learner model for adaptive navigation support. When a learner gets registered in electronic textbook then he or she is asked to select experience level with online systems then the interface layout is changed according to this selection.

Course Authoring: There are few steps to develop electronic textbook through InterBook (Eklund et al., 1997). First of all, an electronic textbook is written in Microsoft Word file then it is converted into InterBook format. Textbook should be written in such a way that it can be recognised by InterBook. For this purpose, titles or subtitles in textbook should have text style like "Header 1", or "Header 2" etc. In this way, InterBook can easily develop adaptive annotation in the file. Then file is saved as RTF format which is converted to HTML file using any

conversion tool. After this, extension of HTML file is changed to "*.inter". Now file is recognisable by InterBook. The textbook material presented to the learners is based on learner model, learners' level of knowledge about online educational systems and fragments extracted from original HTML files.

Adaptation Support: InterBook provides facilities to implement both adaptive presentation and adaptive navigation (Eklund et al., 1997). For implementing adaptive navigation in the shape of local and global guidance, it provides direct guidance facility. It also supports adaptive annotation as shown in Figure 6.

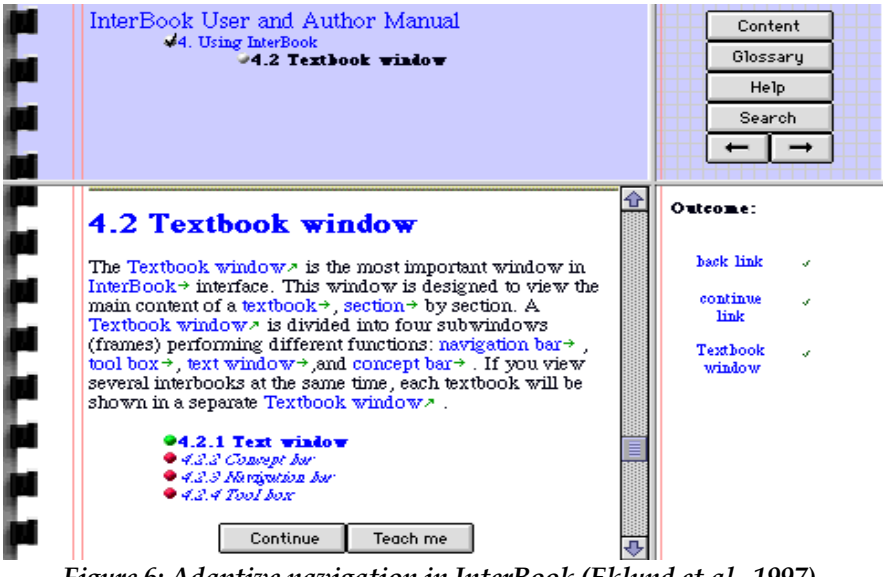

Figure 6: Adaptive navigation in InterBook (Eklund et al., 1997).

As for as adaptive presentation is concerned, InterBook helps to implement prerequisite explanations in the shape of *prerequisite-based help*. If a learner has some problem to understand one particular domain concept then he or she must has problem in its prerequisite concepts so *help* provides links of all those prerequisite concepts to learner (Brusilovsky et al., 1998).

NetCoach

NetCoach (Weber et al., 2001) is based on Common LISP HTTP server. It is available for Microsoft Windows, Apple Macintosh and Linux. It is also used to develop online adaptive courses without knowing programming concepts (Brusilovsky, 2003b). In NetCoach, domain model consists of all

the concepts related to a course. There are two types of these concepts: *prerequisites* and *inferences.*

Prerequisites are those concepts which are necessary to be learnt before reading one particular concept. On the other hand, *inferences* are those concepts which can be skipped to reach that specific concept (Henze, 2003).

NetCoach supports multi layered overlay model (Weber, 1999). In this model, first layer stores information that whether a learner has visited one particular concept. Status of different tests or exercises related to that concept is described by second layer that whether these tests has been passed successfully or not. Information about that concept as prerequisite or inference of any other concept is stored in third layer. Last layer stores information that whether learner is already familiar with the concept or not.

Course Authoring: NetCoach provides some editors to develop adaptive course (Weber et al., 2001). In *Concept Editor*, author can describe all the concepts of a course and their relationship with each other as *prerequisites* or *inferences* in the shape of chapters as shown in Figure 7.

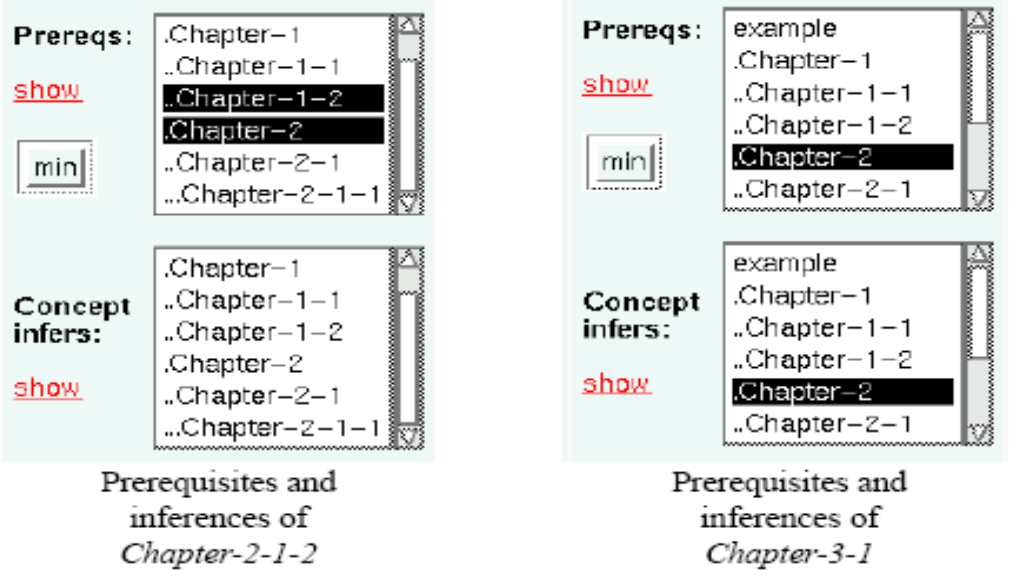

Figure 7: Describing relationship between concepts in Concept Editor (Weber et al., 2001, p. 232).

These concepts can be written in simple text form and then can be converted in HTML form in NetCoach. Already developed HTML files, images or flash animations can be uploaded to NetCoach. *Test Editor* helps author to design tests consist of closed or open ended questioners. System evaluates the result automatically.

In NetCoach, an author of a course has facility to register some tutors for facilitating learners regarding course. These tutors monitor performance of learners through *online-interface*. Tutors can add or remove learners and provide access privileges to them. They also manage different learners' groups through which learners exchange their ideas and educational material.

Adaptation Support: NetCoach supports both adaptive presentation and adaptive navigation (Weber et al., 2001) as shown in Figure 8.

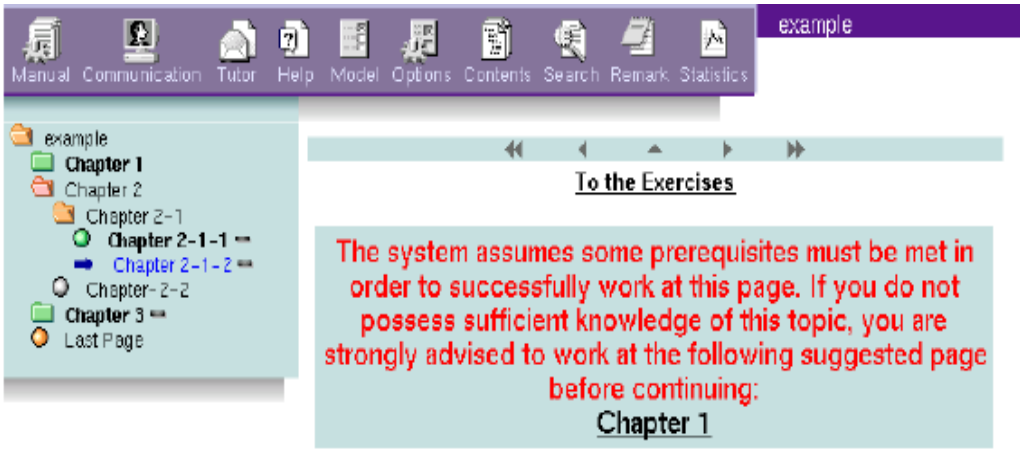

Figure 8: Curriculum sequencing and link annotation in the adaptive environment developed by NetCoach (Weber et al., 2001, p. 230).

Adaptive presentation can be achieved by setting learning goals. If a learner wants to read only introductory portion of a course then only introductory concepts will be presented to him or her.

Communication Support: Courses designed through NetCoach provide both synchronous and asynchronous communication facilities like email and chatting. Learners can not only interact with other learners but with tutors as well. Tutors can provide help through *help window*. For open debate on something especial, tutors place discussion topics in discussion list. Then learners give their opinion about that topic which can be read

by everybody. Tutors can also send important messages to all learners. Learners receive it during studying the course or when ever they get login the system (Weber et al., 2001).

Cognitive Flexibility in Adaptive Learning Environment (COFALE)

COFALE (Chieu, 2007) is an open source adaptive learning content management system (LCMS) which is based on ATutor (Inclusive Design Research Centre, 2010). COFALE is used to develop adaptive educational systems providing cognitive flexibility. It has been designed using PHP!. All data related to domain, adaptation and learners is stored in MySQL database. It runs on open source Apache server.

Course Authoring: COFALE provides some authoring tools for adaptive online course development. First of all, it provides *hypermedia editor* for development of HTML web pages through which domain content is shown to the learners. Using hypermedia editor, author can develop web pages in either plain text or HTML editor mode. Already developed web pages can also be uploaded. Different kinds of images can also be imported to COFALE. It supports stereotyped learner model because different modes are defined according to different groups of learners like novices or experts then they are assigned to each learner. Figure 9 shows *Learner Model Manager* through which models can be defined.

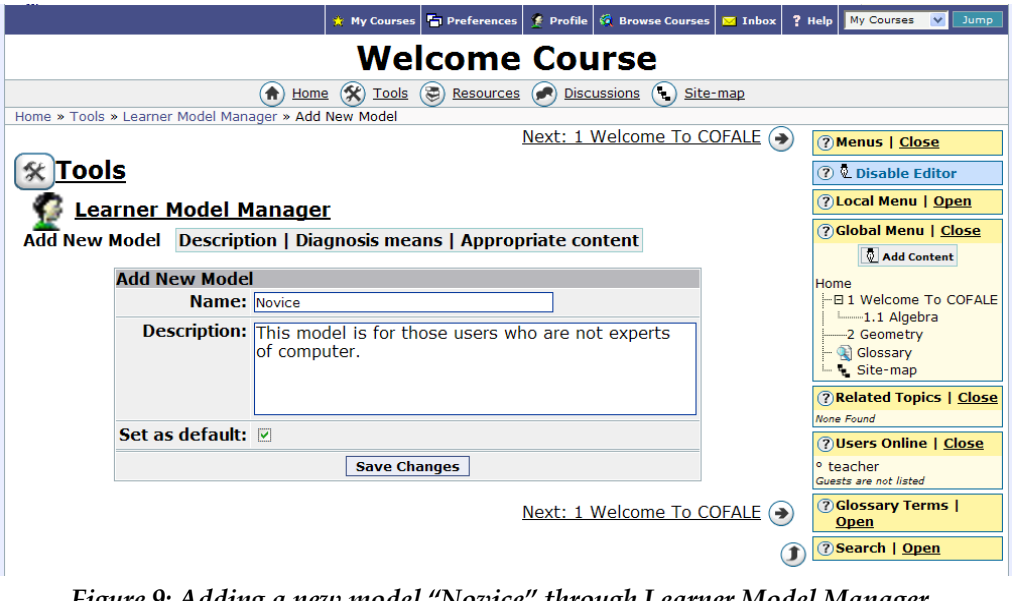

Figure 9: Adding a new model "Novice" through Learner Model Manager.

COFALE also provides *Enrolment manager* tool which is used to cancel the enrolment of learners. Model of any learner can also be changed with it. For learners' assessment, COFALE also provide *Test manager* tool for designing open and closed ended tests. Course author can also develop glossary consisting of terms related to domain. He or she can add relevant external resources like reference books or websites as well with the help of *Resource manager.*

Adaptation Support: COFALE supports both adaptive navigation and adaptive presentation. It provides direct guidance along with local or global view of content as shown in Figure 10. Learner can also change the layout of the system by changing the options given for personal preferences.

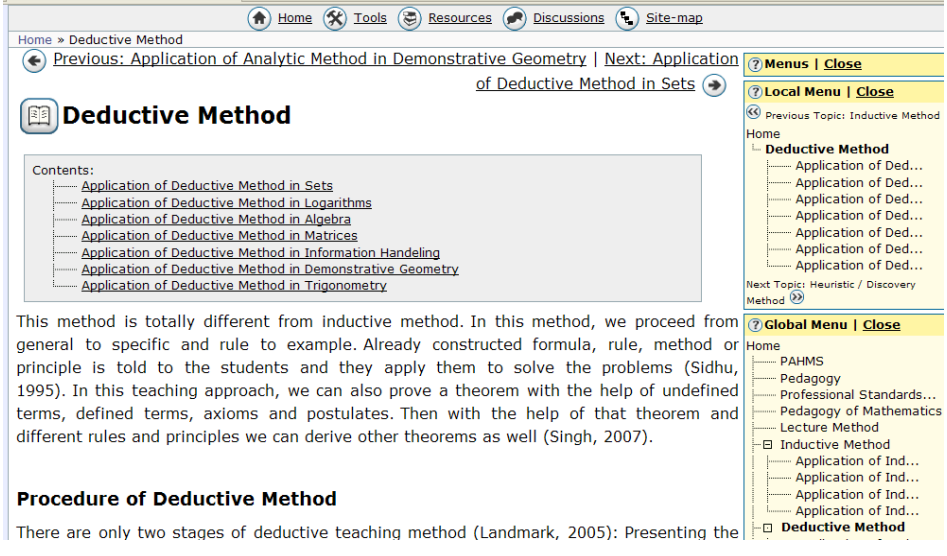

Figure 10: Global guidance with the help of Global Menu and Contents option at the top of the lesson.

With the help of *My Tracker*, learners can check their progress that how many pages he or she has visited and for how much time. *My Test* tool provides information that which tests have been cleared with how much marks.

Communication Support: COFALE also provides adaptive communication support through which learner is given facility to find out peers according to his or her model for interaction. Different communication tools are part of COFALE like discussion forums, chat, email and instant messaging facility to online learners as shown in Fig. 11.

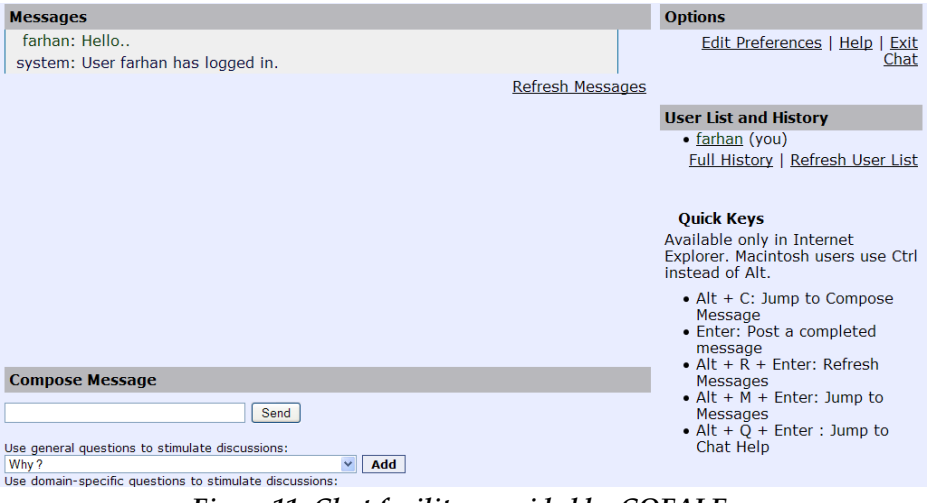

Figure 11: Chat facility provided by COFALE.

Author can also create different forums for learners to share their views with the help of *Add Forum* tool.

COMPARISON OF FRAMEWORKS

After reviewing the adaptation features provided by AHA!, InterBook, NetCoach and COFALE we have compared them with each other as shown in Table 1.

Table 1: Comparison of frameworks for the development of AHES.

Features of Framework		AHA!	InterBook	NetCoach	COFALE
Platform Independence		X		X	X
Adaptive Presentation	Additional explanations	X		X	X
	Prerequisite explanations				X
	Comparative explanations	X			
	Explanation variants	X			
	Sorting				
Adaptive Navigation	Global guidance	X	X	X	X
	Local guidance	X	X	X	X
	Global orientation support	X	X		X
	Local orientation support	X	X	X	X
	Managing personalised view	X	X	X	X
Communication Support				X	X

Table 1 shows that InterBook does not support adaptive presentation as compared to AHA!, NetCoach and COFALE. Even it does not give any communication facility. It is platform dependent as well. AHA! and NetCoach are platform independent and these tools also support both adaptive presentation and adaptive navigation. On the other hand, AHA! does not provide communication facilities and NetCoach supports only one feature of adaptive presentation. So COFALE seems quite better because it supports maximum features. It is open source as well. After this comparison, we can easily say that COFALE is better option for the development of AHES. AHA! can be another good option because it provides more adaptive features comparatively. It is also open source. If someone wants to focus on curriculum sequencing and better communication support rather than adaptation features then NetCoach can also be a good choice.

CONCLUSION AND FUTURE WORK

In developing countries where e-learning is totally a neglected area, such kind of frameworks or authoring tools can play a vital role because teachers can develop high quality adaptive online courses easily at low cost according to the social, economical and cultural background of students living in both rural and urban areas. Teachers can select any tool according to their requirements. Governments and non governmental organisations should play their role in this regard by organising capacity building workshops to train teachers so that they can utilise such kind of tools in a better way.

A lot of teachers can also be trained in adaptive and flexible mode if teachers training institutes utilise such kind of tools. In this way, not only the resources of these institutes will be saved but time of the teachers also. In corporate sector, different adaptive training programmes can also be designed for huge number of employees.

Selection of suitable framework or authoring tool for the development of AHES is very important to maintain the quality of the system. An appropriate framework provides not only better adaptation features but e-learning tools also. Open source framework can be a good option because this kind of authoring tool is free and can be modified or improved according to the requirements. Existing frameworks lack in adaptive testing to evaluate the academic performance of the learners.

Moreover, facility of proper adaptive collaborative learning is not provided by these frameworks. Incorporating new techniques of adaptive presentation and adaptive navigation can further enhance the performance of these tools. There is a great need to work in these areas.

REFERENCES

Brusilovsky, P. (1996), "Methods and techniques of adaptive hypermedia", *User Modeling and User-Adapted Interaction*, Vol. 6, No. 2-3, pp. 87-129.

Brusilovsky, P. (2001), "Adaptive Hypermedia", *User Modeling and User-Adapted Interaction,* Vol. 11, No. 1-2, pp. 87-110.

Brusilovsky, P. (2003a), "Adaptive navigation support in educational hypermedia: The role of student knowledge level and the case for meta-adaptation", *British Journal of Educational Technology,* Vol. 34, No. 4, pp. 487-497.

Brusilovsky, P. (2003b), "Developing adaptive educational hypermedia systems: From design models to authoring tools", in Murray, T., Blessing, S. and Ainsworth, S. (Eds.), *Authoring Tools for Advanced Technology Learning Environment*, Kluwer Academic Publishers, Dordrecht, Netherlands, pp. 377-409.

Brusilovsky, P. (2007), "Adaptive navigation support", in Brusilovsky, P., Kobsa, A. and Neidl, W. (Eds.), *The Adaptive Web: Methods and Strategies of Web Personalization*, Lecture Notes in Computer Science, Vol. 4321, Springer-Verlag, New York, pp. 263-290.

Brusilovsky, P., Eklund, J. and Schwarz, E. (1998), "Web-based education for all: a tool for development adaptive courseware", *Computer Networks and ISDN Systems,* Vol. 30, No. 1-7, pp. 291-300.

Brusilovsky, P. and Maybury, M.T. (2002), "From adaptive hypermedia to the adaptive web", *Communication of the ACM*, Vol. 45, No. 5, pp. 30-33.

Brusilovsky, P., Schwarz, E. and Weber, G. (1996), "A tool for developing adaptive electronic textbooks on WWW", in *Proceedings of World Conference of the Web Society (WebNet'96)* in San Francisco, CA, 1996, AACE, Chesapeake, Virginia, pp. 64-69.

Chieu, V.M. (2007), "COFALE: An authoring system for creating web-based adaptive learning environments supporting cognitive flexibility", *Journal of Computers*, Vol. 2, No. 5, pp. 27-37.

Cristea, A.I. and De Mooij, A. (2003), "Adaptive Course Authoring: My Online Teacher", in *Proceedings of the Tenth International Conference*

on Telecommunications (ICT-2003) in Tahiti Island, Papetee, French Polynesia, 2003, IEEE Computer Society Press, Washington, DC, pp. 1762- 1769.

Dagger, D., Wade, V. and Conlan, O. (2005), "Personalisation for all: Making adaptive course composition easy", *Educational Technology & Society*, Vol. 8, No. 3, pp. 9-25.

De Bra, P., Aerts, A., Berden, B., De Lange, B., Rousseau, B., Santic, T., Smits, D. and Stash, N. (2003), "AHA! The adaptive hypermedia architecture", in *Proceedings of the Fourteenth ACM Conference on hypertext (HYPERTEXT'03)* in Nottingham, UK, 2003, ACM, New York, pp. 81-84.

De Bra, P., Aerts, A., Houben, G.J. and Wu, H. (2000), "Making general-purpose adaptive hypermedia work", in *Proceedings of the World Conference on the WWW and Internet (WebNet 2000)* in San Antonio, Texas, 2000, AACE, Chesapeake, VA, pp. 117-123.

De Bra, P. and Calvi, L. (1998), "AHA! An open adaptive hypermedia architecture", *The New Review of Hypermedia and Multimedia,* Vol. 4, No. 1, pp. 115-139.

De Bra, P., Stash, N. and Smits, D. (2004a), "Creating adaptive applications with AHA! Tutorial for AHA! Version 3.0", in Aroyo, L. and Tasso, C. (Eds.), *AH 2004 Tutorials,* Eindhoven University of Technology, Eindhoven, pp. 1-29.

De Bra, P., Stash, N. and Smits, D. (2004b), "Creating adaptive textbooks with AHA! (An Interactive Round Table)", in *Proceedings of the World Conference on E-Learning in Corporate, Government, Healthcare, and Higher Education (E-Learn 2004)* in Washington, DC, USA, 2004, AACE, Chesapeake, VA, pp. 2588-2593.

De Bra, P., Smits, D. and Stash, N. (2006), "The Design of AHA!", in *Proceedings of the Seventeenth Conference on Hypertext and Hypermedia* in Odense, Denmark, 2006, ACM, New York, pp. 171-195.

De Bra, P., Stash, N., Smits, D., Romero, C. and Ventura, S. (2007), "Authoring and management tools for adaptive educational hypermedia systems: The AHA! Case study", in Jain, L.C., Tedman, R.A. and Tedman, D.K. (Eds.), *Evolution of Teaching and Learning Paradigms in Intelligent Environment*, Springer Verlag, Berlin, pp. 285-308.

De Verneil, M. and Berge, Z. (2000), "Going online: Guidelines for faculty in higher education", *International Journal of Educational Telecommunications,* Vol. 6, No. 3, pp. 227-242.

Eklund, J., Brusilovsky, P. and Schwarz, E. (1997), "Adaptive Textbooks on the WWW", in Ashman, H., Thistewaite, P., Debreceny, R. and Ellis, A. (Eds.), in *Proceedings of the Third Australian Conference on the World Wide Web (AUSWEB97)* in Queensland, Australia, 1997, Southern Cross University Press, Lismore, Australia, pp. 186-192

Fischer, S. and Steinmetz, R. (2000), "Automatic creation of exercises in adaptive hypermedia learning systems", in *Proceedings of the Eleventh ACM on Hypertext and Hypermedia* in San Antonio, Texas, 2000, ACM, New York, pp.49-55.

Giguere, P. and Minotti, J. (2003), "Developing high-quality web-based training for adult learners", *Educational Technology,* Vol. 43, No. 4, pp. 57-58.

Hamilton, S. and Zimmerman, J. (2002), "Breaking through zero-sum academics: Two students' perspectives on computer mediated learning environment", in Rudestam, K.E. and Schoenholtz-Read, J. (Eds.), *Handbook of Online Learning: Innovations in High Education and Corporate Training,* Sage Publications, Inc., Thousand Oaks, California, pp. 257-276.

Hegngi, Y.N. (1997), "*On-line teaching and learning: A description of the development of the media technology and diversity online course and its electronic discourse analysis"* (Unpublished doctoral dissertation), Virginia Polytechnic Institute & State University, USA.

Henze, N. (2003), "From web based educational systems to education on the web: on the road to the adaptive web", in *Proceedings of the Seventh International Conference on Knowledge-Based Intelligent Information and Engineering Systems (KES 2003)* in Oxford, UK, 2003, Springer, Berlin, pp. 297-303.

Hodges, P. and Saba, L. (2002), "Teaching statistics online", in Rudestam, K.E. and Schoenholtz-Read, J. (Eds.), *Handbook of Online Learning: Innovations in High Education and Corporate Training,* Sage Publications, Inc., Thousand Oaks, California, pp. 389-404.

Hum, D. and Ladouceur, A. (2001), "*E -Learning the new frontier*", available at: http://www.cata.ca/files/PDF/Resource_Centres/hightech/ reports/ studies/elearning.pdf (accessed 11 February 2009)

Hung, D., Tan, S.C. and Chen, D.-T. (2003), "IT integration and online leaning in the Singapore school", *Educational Technology,* Vol. 43, No. 3, pp. 37-45.

Inclusive Design Research Centre. (2010), "*ATutor",* available at: http://idrc.ocad.ca/index.php/research-and-development/ongoing-projects (accessed 10 May 2010).

Kay, J. and Kummerfeld, B. (1997), "User models for customized hypertext", in Nicholas, C. and Mayfield, J. (Eds.), *Intelligent Hypertext: Advanced Techniques for the World Wide Web* (Vol. 1326), Springer-Verlag, Berlin.

Kearsley, G. and Blomeyer, R. (2004), "Preparing K-12 teachers to teach online", *Educational Technology*, Vol. 44, No. 1, pp. 49-52.

Melis, E. and Siekmann, J. (2004), "ActiveMath: An intelligent tutoring system for mathematics", in *Proceedings of the Seventh International Conference on Artificial Intelligence and Soft Computing (ICAISC 2004)* in Zakopane, Poland, 2004, Springer-Verlag, Berlin, pp. 91-101.

Moundridou, M. and Virvou, M. (2001), "Authoring and delivering adaptive web-based textbooks using WEAR", in *Proceedings of the IEEE International Conference on Advanced Learning Technologies (ICALT'01)* in Madison, Wisconsin, USA, 2001, IEEE Computer Society, Washington, DC, pp. 185-188.

Murray, T. (1999), "Authoring intelligent tutoring systems: An analysis of the state of the art", *International Journal of Artificial Intelligence in Education,* Vol. 10, pp. 98-129.

Nejdl, W. and Wolpers, M. (1998), "*KBS Hyperbook - A Data-Driven Information System on the Web"* (Technical report), University of Hannover, Germany.

Ng, M.H., Hall, W., Maier, P. and Armstrong, R. (2002), "The application and evaluation of adaptive hypermedia techniques in web-based medical education", *Association for Learning Technology Journal,* Vol. 10, No. 3, pp. 19-40.

Triantafillou, E., Pomportsis, A. and Georgiadou, E. (2002), "AES-CS: Adaptive educational system based on cognitive styles", in Brusilovsky, P., Henze, N. and Millán, E. (Eds.), in *Proceedings of Second International Conference on Adaptive Hypermedia and Adaptive Web-Based Systems (AH'2002)* in Málaga, Spain, 2002, University of Málaga, Spain, pp. 10-20.

Weber, G. (1999), "Adaptive learning systems in the World Wide Web", in Kay, J. (Ed.), in *Proceedings of the Seventh International Conference on User Modeling (UM99)* in Banff, Canada, 1999, Springer, Vienna, pp. 371-378.

Weber, G., Kuhl, H.-C. and Weibelzahl, S. (2001), "Developing adaptive internet based courses with the authoring system NetCoach", in

Reich, S., Tzagarakis, M. and De Bra, P. (Eds.), *Hypermedia: Openness, Structural Awareness, and Adaptivity*, Lecture Notes in Computer Science, Vol. 2266, Springer-Verlag, Berlin, pp. 226-238.