Journal of Quality and Technology Management
Volume X, Issue II, December 2014, Page 67 – 80

QUALITY ASSESSMENT OF COFALE: AN AUTHORING TOOL FOR ADAPTIVE EDUCATIONAL HYPERMEDIA SYSTEMS

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ABSTRACT

E-learning has become more learners centred because of adaptation. It is very difficult process to develop adaptive educational hypermedia systems because of complex nature of adaptation mechanism. There are several authoring tools through which it becomes very easy for everybody to develop such kind of systems. COFALE is also used for this purpose. It is an open source adaptive learning content management system. In this paper, we have assessed its quality through evaluating its object oriented design in terms of complexity, cohesion and coupling along with its usability in terms of adaptation features.

Keywords: *E-learning, adaptive hypermedia, complexity, cohesion, coupling, and usability.*

1) INTRODUCTION

E-learning has changed all the parameters of distance education. Learning in this mode was a dull and dry activity but now e-learning is fast, convenient, self paced and interactive (Hall, 2001). Martindale, Cates and Qian (2003) have classified educational websites in different categories including 1) instructional, 2) learning activities, 3) content collection, 4) links, 5) reference, 6) teacher resources, 7) vicarious participation, 8) interpersonal interaction, 9) virtual exhibits, 10) nonprofit organizations, 11) curriculum or research projects and 12) commercial. A lot of such kinds of online educational systems are running but still something is lacking that is personalisation or customization which means systems should adapt learners' characteristics and guide them according to their preferences and educational background. In this regard, adaptive hypermedia can solve these problems through user modelling (De Bra, 1999). Adaptive educational hypermedia systems (AEHSs) are more dynamic and learners centred. These systems not only reduce the

cognitive over load but enhance the learning performance and overall quality of education as well. Along with educational material in adaptive mode, AHESs may also provide facilities of adaptive peer searching and adaptive assessment.

Adaptation process is implemented in the forms of adaptive presentation and adaptive navigation. Adaptive presentation (Brusilovsky, 2001; Bunt et al., 2007) is also called content level adaptation because online educational material of AEHS is appeared according to the learner's needs, preferences and educational background. Brusilovsky (1996) have described some methods and techniques for adaptive presentation. Methods include *additional explanations, prerequisite explanations, comparative explanations, explanation variants* and *sorting.* Techniques to implement these methods include *conditional text, stretchtext, fragment and page variants* and *frame based technique*.

Adaptive navigation (Brusilovsky 2003, 2007) is implemented at links level. It helps learners to navigate within hyperspace of AEHS by adding or removing hyperlinks according to the information stored in the learner (or user) model. Brusilovsky (1996) have explained some methods and techniques for adaptive navigation. Methods include *global guidance, local guidance, global orientation support, local orientation support* and *managing personalised views*. Techniques to implement these methods include *direct guidance, link sorting, link hiding, link annotation* and *link generation*.

There are several examples of AEHS like ELM-ART (Weber, 2008), PT (Kay and Kummerfeld, 1997), JointZone (Ng et al., 2002), ActiveMath (Melis and Siekmann, 2004) and MATHEMA (Papadimitriou et al., 2010). Development of AEHS is a difficult process because of their complex structure so different reference models are used to define the adaptation process at conceptual level including AHAM (Wu, 2002), XAHM (Cannataro and Pugliese, 2001) and Munich Reference Model (Koch and Wirsing, 2002).

There are few frameworks or authoring tools available to develop AEHS like KBS-Hyperbook (Nejdl and Wolpers, 1998), AHA! (De Bra and Calvi, 1998), InterBook (Brusilovsky et al., 1998), Multibook (Fischer and Steinmetz, 2000), NetCoach (Weber et al., 2001), MOT (Cristea and De Mooij, 2003) and GRAPLE Authoring Tool (Glahn et al., 2011). These tools have made the development process very easy. Anybody can generate

online courses without writing any programming code but these tools focus on adaptation features only. Architecture of e-learning applications (Bučko et al., 2005) requires some extra elements like *educational resources, evaluation, supplement environment* and *collaboration environment*. Usually learning content management systems cater such kinds of learning environments but unfortunately most of them don't focus on adaptation. That is why, we have focused on COFALE (Chieu, 2007) which not only provides e-learning elements but caters adaptation as well.

COFALE (Cognitive Flexibility in Adaptive Learning Environment) is a learning content management system which is used to develop adaptive online courses providing cognitive flexibility. It is available for free under the GNU General Public License. Evaluation of this system on technical grounds becomes very significant because of its open source environment so that we can do further research to extend its functionalities. The objective of this research is to assess the quality of design and usability of this system.

2) FRAMEWORK OF COFALE

COFALE is based on an open source learning content management system, ATutor (Inclusive Design Research Centre, 2013). It has been designed using PHP 4.2.0. All data related to one particular domain, adaptation process and learners is stored in MySQL database. It runs on an open source Apache 1.3.x server. Twenty percent source code of ATutor 1.4.3 was contributed by COFALE including five thousand lines of PHP code and fifteen hundred person-hours of programming work (Chieu, 2005). It has adopted the basic architecture of ATutor as shown in Figure 1.

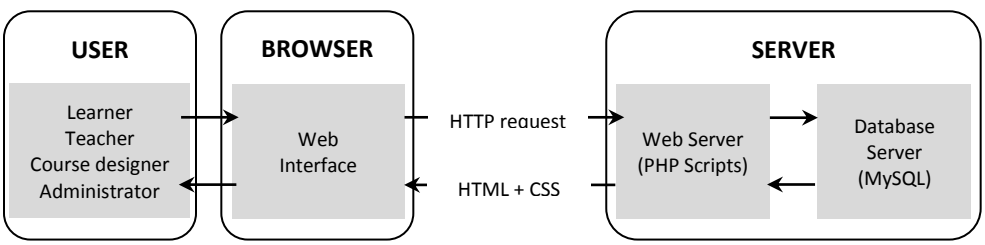

Figure 1: General Architecture of ATutor (Chieu, 2005, p. 142).

When a user logs into the system and sends a request using a web browser then browser forwards that request to the server where PHP is already installed. Depending on the request, server updates MySQL database in which data related to the users and course content are stored and indexed. Then server generates HTML code and sends back to the browser. Using that code, browser generates a web page for the user.

Authoring environment of COFALE is comprised of some easy to use instructor tools for development of adaptive online courses. Authors can use *Add Content* option for development of web pages for which system provides two options. First option is plain text editor for those who are not familiar with HTML tags and second is HTML editor. Option to import already available web pages along with images is also available as shown in Figure 2.

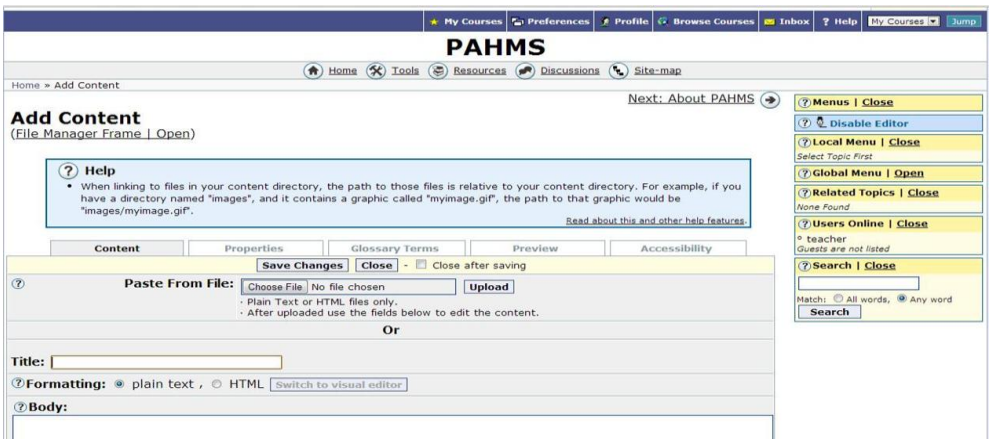

Figure 2: Adding a new web page through Add Content option.

Through *Learner Model Manager*, stereotyped learner (or user) models can be defined according to the different groups of learners like novices or experts. Different communication tools are also available like discussion forums, chat room, inbox for sending & receiving messages and immediate messaging facility to online learners. *Test Manager* tool to assess the learners' knowledge through online tests is also available.

3) METHODOLOGY

To assess the quality of the system on technical grounds, it is necessary to analyse its design and usability. We have evaluated design of COFALE version 1.0 in terms of three Cs: complexity, cohesion and coupling. For this purpose, we have done reverse engineering with the help of commercially available tools including "Enterprise Architect" version 8.0.860 (Sparks, 2010) and "Understand" version 3.0.631 (Scientific Toolworks, Inc., 2012). Then we have used different metrics to compute three Cs.

Survey method was used to assess the usability of COFALE. Brusilovsky (1996) discussed the taxonomy of adaptive hypermedia in detail. As adaptation enhances usability (Benyon, 1993) so we have adopted that taxonomy as criteria to design our questionnaire (see Appendix A) comprised of ten statements. It was designed on five point Likert scale ranges from 1 to 5 indicating strongly disagree, disagree, undecided, agree and strongly agree respectively. Survey was conducted from thirty students of BS (Computer Science) studying at University of Management and Technology (UMT), Lahore, Pakistan. These students had interacted with the system PAHMS which was developed using COFALE and then gave opinion through questionnaire.

4) QUALITY ASSESSMENT OF COFALE

The design of COFALE is object oriented but not modular so we have computed complexity of code along with cohesion and coupling at class level to assess the quality of system's design. Usability of the system has also been assessed in terms of its adaptive features related to adaptive presentation and adaptive navigation.

4.1) Complexity of the COFALE

Complexity is a qualitative measure to predict the reliability and maintainability of a system. Before calculating complexity of the system, we have gathered some basic information about source code using commercially available tool "Understand" version 3.0.631 (Scientific Toolworks, Inc., 2012). Few statistics related to classes, functions and lines within source code of COFALE are given in the Table 1.

Table 1: Source Code Statistics of COFALE.

No. of Classes:	83
No. of Files:	509
Program Units (Functions):	1317
No. of Lines:	105770
Blank Lines:	11416
Lines of Code:	59524
Comment Lines of Code:	26136
Lines Inactive:	0
Executable Statements:	36442
Declarative Statements:	3405

Cyclomatic complexity measures the complexity of the system by providing the number of possible distinct paths through source code. Cyclomatic complexity metric (McCabe and Watson, 1994) for all files and functions to ascertain the complexity of programme control flow within COFALE has also been computed using the tool "Understand" as shown in Figure 3.

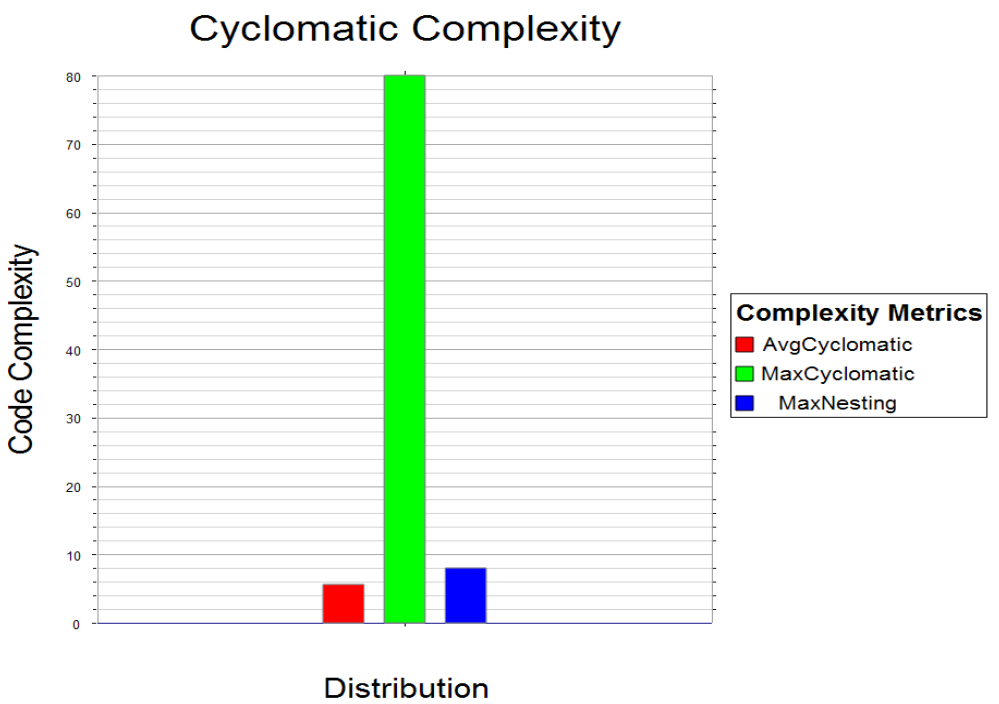

Figure 3: Cyclomatic Complexity of COFALE.

Cyclomatic complexity of any piece of code should be less than 10 otherwise it is not viewed as being good. Maximum cyclomatic complexity of one of the functions within the source code of COFALE is found 80. Higher nesting level or depth of nested control structures (i.e. if, while, for, and switch) also demonstrates extreme complexity of source code. Nesting depth below than 4 is considered good but the depth higher than 8 shows extreme complexity of functions. Maximum nesting level in one of the functions within the code of COFALE is found 8. There are 1317 functions in the code of the system but cyclomatic complexity of majority of these functions is found less than 10. Average cyclomatic complexity of the system is 5.58. This shows better quality of the source code of COFALE.

4.2) Cohesion of Classes within COFALE

High cohesion promotes information-hiding which means that any module or class encapsulates its functions and attributes that are related to each other and that particular module or class as well. We have used commercially available tool "Enterprise Architect" version 8.0.860 (Sparks, 2010) to generate complete design of COFALE through reverse engineering. The design of COFALE is object oriented rather than modular so we have used lack of cohesion in methods (LCOM2) metric (Henderson-Sellers et al., 1996; Borkar and Khonde, 2012) to determine the overall cohesion of methods in classes of the system. Sum of values of computed LCOM2 metrics of 83 classes within COFALE is 30.59 so the average value of LCOM2 metrics for all classes is 0.368. It means there is 36.8 percent lack of cohesion in methods of classes. As value of 0.368 is less than maximum limit that is 1.0 so it shows that methods within classes of COFALE are highly cohesive and shows better quality of design.

4.3) Coupling between Classes within COFALE

Coupling between components or classes is directly related to reusability. If coupling increases, not only reusability of components or classes decreases but it is also become complicated to modify, test and maintain the system afterwards. Because of object oriented design of COFALE, coupling between object classes (CBO) metric (Chidamber and Kemerer, 1994) has been computed for each class of the system. Sum of values of CBO metrics of 83 classes of the system is 160 so the average value of CBO

metrics for all classes of COFALE is 1.927 which is less than maximum limit that is 4.0. It shows that classes within the system are loosely coupled which is good.

4.4) Usability of COFALE

Usability is a qualitative measure that how easily and efficiently a user interacts with a system. Usability of COFALE in terms of adaptation has been assessed through survey. After getting data from university students, we have employed one-sample *t*-test to judge the opinion of these users that whether they are strongly disagreed, disagreed, undecided, agreed or strongly agreed with the statements of the questionnaire (see Annexure A). Mean response value for each statement was calculated with the help of *t*-test. This value may range from 1 to 5 and the test value is 3. Thus if mean response value for any statement is higher than 3 then it means that majority of the users agree with the statement otherwise they disagree with it.

First of all, mean score for all statements of questionnaire has been calculated using SPSS version 16.0 to judge the overall opinion of the users about adaptive features provided by COFALE as shown in Tables 2 and 3.

Table 2: One-sample statistics for adaptive features provided by COFALE

	N	Mean	Std. Deviation	Std. Error Mean
Overall Opinion of the users	30	3.6767	0.28246	0.05157

Table 3: One-sample t-test for adaptive features provided by COFALE

	Test Value = 3					
	t	df	Sig. (2-tailed)	Mean Difference	95% Confidence Interval of the Difference	
					Lower	Upper
Overall Opinion of the users	13.122	29	0.000	0.67667	0.5712	0.7821

Descriptive statistics are given in Table 2 including number of respondents (N=30), mean score of overall opinion of the users, standard deviation and standard error of the mean which are used to compute *t* statistics. Table 3 reports the results of the one sample *t*-test including *t*-

value, degrees of freedom (df=N-1), significance (2-tailed) or *p*-value and mean difference. Probability level or the level of significance (symbolised as α) is set to 0.05 as most of the educational researchers use this value as a standard (Gay, Mills & Airasian, 2012). On the basis of probability level, the level of confidence is 95%. Lower and upper bounds of confidence interval are 0.5712 and 0.7821 respectively. For adaptive features provided by COFALE, the value of t(29)=13.122, *p*=0.000 is significant at α=0.05. The mean value of 3.676 is higher than the test value of 3 which shows that the opinion of the users is in the favour of overall adaptive environment provided by COFALE.

One-sample *t*-test is also applied to calculate mean response values for all statements of questionnaire separately regarding COFALE as shown in Table 4.

Table 4: Mean response values for all statements regarding COFALE.

Statements	N	Mean
Statement 1	30	4.4667
Statement 2	30	4.4333
Statement 3	30	4.3333
Statement 4	30	3.8000
Statement 5	30	4.1000
Statement 6	30	1.5000
Statement 7	30	2.4333
Statement 8	30	3.7333
Statement 9	30	4.0000
Statement 10	30	3.9667

Table 4 shows that the users are agreed with most of the statements of questionnaire regarding COFALE. Mean response values for statements 1 to 5 show that the system supports all features related to adaptive navigation including *global guidance, local guidance, global orientation support, local orientation support* and *managing personalised views*. Users are not agreed with the statements 6 and 7 as mean values for these statements are less than test value 3.0. This shows that the system does not provide content in different formats. Moreover, it does not support some features related to adaptive presentation including *comparative explanations, explanation variants* and *sorting* but the satisfactory results for statements 8 and 9 demonstrate that system supports adaptive

presentation in shape of *additional explanations* and *prerequisite explanations*. Mean response value for statement 10 shows that system also provides facility of adaptive peer searching for collaborative learning.

5) CONCLUSION

To ascertain the quality of object oriented design of COFALE, we have measured three Cs: complexity, cohesion and coupling. Average cyclomatic complexity is not high which shows quality of code structure and minimum logical complexity of internal design flow of the system. Classes of the system are also highly cohesive which demonstrates that system is easily extensible, testable and maintainable. Similarly, coupling between classes of the system is not high that reinforce its extensibility. As for as usability of COFALE in terms of adaptation is concerned, the survey results exhibit that environment provided by the system supports adaptive navigation and adaptive peer searching in very good manner. It partially supports adaptive presentation as well.

There are some limitations of COFALE as well. Its design is not modular but further functionalities can be added in modular form for simplicity in future. There is a need to enhance its features related to adaptive presentation including *comparative explanations, explanation variants* and *sorting*. Although facility to assess the learners through online tests is also available in it but there is a need to make this functionality adaptive. As a whole, COFALE seems better authoring tool for the development of adaptive online courses.

REFERENCES

Benyon, D. (1993), "Adaptive systems: A solution to usability problems", *User Modeling and User-Adapted Interaction,* Vol. 3, No. 1, pp. 65-87.

Borkar, Y. and Khonde, Y. (2012), "Software efficiency measurement system using conceptual cohesion and coupling of classes", in *Proceedings of 2nd Computer Science On-line Conference* (CSOC 2012), OpenPublish, Vsetin, Czech Republic, pp. 138-148.

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. (2003), "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. (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.

Bučko, M., Sivý, I., Gáti, J., Kártyás, G. and Madarász, L. (2005), "Communication tools in e-learning systems", in *Proceedings of the 6th International Symposium of Hungarian Researchers on Computational Intelligence* in Budapest, 2005, available at: http://conf.uni-obuda.hu/mtn2005/Bucko.pdf (accessed 12 October, 2013).

Bunt, A., Carenini, G. and Conati, C. (2007), "Adaptive content presentation for the web", in Brusilovsky, P., Kobsa, A. and Nejdl, W. (Eds.), *The Adaptive Web: Methods and Strategies of Web Personalization*. Springer-Verlag, Berlin, Germany, pp. 409-432. [doi:10.1007/978-3-540-72079-9_13]

Cannataro, M. and Pugliese, A. (2001), "**XAHM: An XML-based adaptive hypermedia model and its implementation", in *Proceedings of the** International Workshops OHS-7, SC-3, and AH-3 on Hypermedia: Openness, Structural Awareness, and Adaptivity* in Århus, Denmark, 2001, Springer, Berlin, Germany, pp. 252-263. [doi:10.1007/3-540-45844-1_24]

Chidamber, S. R. and Kemerer, C. F. (1994), "A metrics suite for object-oriented design", *IEEE Transactions on Software Engineering*, Vol. 20, No. 6, pp. 476-493.

Chieu, V. M. (2005), "Constructivist learning: An operational approach for designing adaptive learning environments supporting cognitive flexibility" (Unpublished doctoral dissertation), Catholic University of Louvain, Belgium.

Chieu, V. M. (2007), "COFALE: An authoring system for creating web-based adaptive learning environments supporting cognitive flexibility", *Journal of Computers (JCP),* 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.

De Bra, P. (1999), "Design issues in adaptive hypermedia application development", in *Proceedings of the 2nd Workshop on Adaptive Systems and User Modeling on the WWW, 8th International World Wide Web Conference* in Toronto, Canada, 1999, Eindhoven University of Technology, Eindhoven, pp. 29-39.

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.

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.

Gay, L. R., Mills, G. E. and Airasian, P. W. (2012). *Educational Research: Competencies for Analysis and Applications*, Pearson, Upper Saddle River, NJ.

Glahn, C., Steiner, C., De Bra, P., Docq, F., O'Donnell, E., Verpoorten, D., Hillemann, E., Nussbaumer, A., Ssebunnya, M., Eweis, A., De Troyer, O. and Stash, N. (2011), "GRAPPLE: Second empirical evaluation in academic settings", Deliverable No. D9.5 Version: 1.1, Eindhoven University of Technology, The Netherlands.

Hall, B. (2001), "E-learning guidebook: Six steps to implementing e-learning", available at: http://www.findlearning.com/learn/ls.nsf/rlookup/sixsteps?open (accessed 02 October 2013)

Henderson-Sellers, B., Constantine, L. and Graham, I. (1996), "Coupling and cohesion (towards a valid metrics suite for object-oriented analysis and design)", *Object Oriented Systems*, Vol. 3, No. 3, pp. 143-158.

Inclusive Design Research Centre. (2013), *"ATutor"*, available at: http://idrc.ocad.ca/index.php/research-and-development/ongoing-projects (accessed 25 September 2013).

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, pp. 47-69.

Koch, N. and Wirsing, M. (2002), "The Munich Reference Model for adaptive hypermedia applications", in *Proceedings of 2nd International Conference on Adaptive Hypermedia and Adaptive Web-Based Systems* in Malaga, Spain, 2002, Springer-Verlag, London, UK, pp. 213-222. [doi:10.1007/3-540-47952-X_23]

Martindale, T., Cates, W. M. and Qian, Y. (2003), "Educational web sites: A classification system for educators and learners", *Educational Technology,* Vol. 43, No. 6, pp. 47-50.

McCabe, T. J. and Watson, A. H. (1994), "Software complexity", *Crosstalk*, Vol. 7, No. 12, pp. 5-9.

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.

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.

Papadimitriou, A., Gyftodimos, G. and Grigoriadou, M. (2010), "The learning facilities and adaptation techniques of the MATHEMA", *The International Journal of Learning*, Vol. 17, No. 1, pp. 155-172.

Scientific Toolworks, Inc. (2012), "Understand – source code analysis & metrics" (Version 3.0.631) [Software], available at: http://www.scitools.com/download/ (accessed 15 October 2012).

Sparks, G. (2010), "Enterprise Architect" (Version 8.0.860) [Software], available at: http://www.sparxsystems.com.au/ (accessed 14 October 2012).

Weber, G. (2008), "Model-based learning environments: From sophisticated intelligent tutoring systems to Simple Adaptive Learning Environments", in Ifenthaler, D., Pirnay-Dummer, P., Spector, J. M. (Eds.), *Understanding Models for Learning and Instruction*, Springer, New York, USA, pp. 225-245. [doi:10.1007/978-0-387-76898-4_12]

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.

Wu, H. (2002), "A reference architecture for adaptive hypermedia applications" (Unpublished doctoral dissertation), Eindhoven University of Technology, Eindhoven, The Netherlands.

ANNEXURE A

Quality Assessment of COFALE: An Authoring Tool for Adaptive Educational Hypermedia Systems

Questionnaire

Directions: Some statements related to adaptive features provided by COFALE are listed below. There is a five point scale against each statement: Strongly Agree (5), Agree (4), Undecided (3), Disagree (2) and Strongly Disagree (1). Please select the appropriate number which represents your opinion.

1)	Global guidance is available to suggest all possible web links to follow.	5	4	3	2	1
2)	Local guidance is available to suggest next most suitable web link.	5	4	3	2	1
3)	Global orientation support through complete site map is provided.	5	4	3	2	1
4)	Local orientation support by recommending most relevant links to the current web page is provided.	5	4	3	2	1
5)	Learner can easily change the layout of the system.	5	4	3	2	1
6)	Web links are sorted according to the learner's educational level with comparative explanation.	5	4	3	2	1
7)	Educational material is presented in different mediums like text, audio or video.	5	4	3	2	1
8)	Content is presented according to the learner's preferences and educational background.	5	4	3	2	1
9)	Prerequisites to one particular concept are shown to the learner.	5	4	3	2	1
10)	Facility of adaptive peer searching is available.	5	4	3	2	1