Mobile Learning Content Authoring Tools (MLCATs): A Systematic Review

Abstract

Mobile learning is currently receiving a lot of attention within the education arena, particularly within electronic learning. This is attributed to the increasing mobile penetration rates and the subsequent increases in university student enrolments. Mobile Learning environments are supported by a number of crucial services such as content creation which require an authoring tool. The last decade or so has witnessed increased attention to tools for authoring mobile learning content for education. This can be seen from the vast number of conference and journal publications devoted to the topic. Therefore, the goal of this paper is to review works that were published, suggest a new classification framework and explore each of the classification features. This paper is based on a systematic review of mobile learning content authoring tools (MLCATs) from 2000 to 2009. The framework is developed based on a number of dimensions such as system type, development context, Tools and Technologies used, tool availability, ICTD relation, support for standards, learning style support, media supported and tool purpose. This paper provides a means for researchers to extract assertions and several important lessons for the choice and implementation of MLCATs.

1. Introduction

Mobile and ubiquitous learning is emerging as the next generation education environments. This is partly due to the high mobile penetration rates and subsequent increases in university student enrolments [11][45][56]. Therefore, learning demands are increasingly arising from mobile devices thus presenting challenges for content creation [17][28]. In order to deal with these demands, quality content creation is of paramount importance. Authoring tools in general are programs used by academics to create and distribute content in various domains [60]. A tool is considered a MLCAT if the resulting content can be consumed on mobile devices. The use of authoring tools is not a simple task for academics who wish to author electronic content [20][55]. This may be due to steep learning curve(s), some academics being technology shy and resistant to change and inadequate institutional support. The goal of MLCATs is to empower academics (even the non technical ones) to easily author content that is consumable on mobiles so as to provide anywhere, anytime learning. Over time, many researchers have made efforts to design and implement MLCATs thus the diversity of both commercial and non commercial tools that exist [36]. These tools are developed with various goals and purposes in mind hence the varying architectures. Some tools for example are used to author tests [60][45][3][41]), support content re-use [28] and support content authoring for integration with Learning Management Systems (LMS) and present video lectures among others. Numerous articles have published research in journals and conferences relating to MLCATs. This suggests a lot of interest in the design and implementation of innovative MLCATs. Therefore, we feel that this is a good time to review MLCATs. The aim of this paper is to classify and summarize research relevant to M-Learning authoring tools, provide a framework for the integration and classification of articles and to derive suggestions for M-Learning researchers based on the review. The rest of this paper is organized as follows; Section 2 details the procedure we followed when conducting the systematic review, section 3 outlines the characteristics of the primary studies that resulted from the review, section 4 explores our classification framework while sections 5 and 6 detail the discussions and suggestions and conclusions and future work respectively.

2. Procedure

A total of 26 articles were obtained as a result of keyword online database searches from the year 2000 to 2009. The search was narrowed using the terms "mobile learning and content authoring tool*". The sub-sections that follow offer a detailed illustration of the methodology used to extract our primary studies.

2.1 Selection Criteria

The criteria we used for selection and inclusion of articles is outlined as follows:

- We did a literature search based on keywords i.e. *"mobile learning and content authoring tool*"*. Various databases were used to select our primary studies. Mobile learning content authoring tool articles are found in comprehensive subjects such as computer science, human computer interaction and educational technologies among others.

- We surveyed articles from 2000 to 2009 because it is within this period that e-/m-learning have gained wide acceptance. In addition, a number of conferences and journals have been dedicated to m-education environments and ubiquitous computing.

- This review incorporates journal and conference papers and excludes magazines, masters and doctoral dissertations, newspapers and books among others. We are mostly interested in analyzing tools that have been published. It is our belief that conferences and journals represent the highest level of research.

2.2 Data Sources

Our initial studies were selected using eight online databases. A total of 142 articles were generated from our initial search. The number of articles by online database are as follows: ACM Digital Library (96), EBSCOHOST (Electronic Journal Service) (02), Emerald (03), GALE (04), IEEE Xplore (08), Science Direct (05), Springer (02) and Google Scholar (21). A total of 79 articles were excluded based on their titles and abstracts. This was followed by a further inclusion/exclusion of articles based on whether they contained MLCAT literature as their core. 63 articles met the selection criteria and were presented for further review. 37 articles were then excluded because despite having relevant titles, abstracts and full text, they did not offer/present relevant tools for this study. The procedure is illustrated in **figure 1** below.

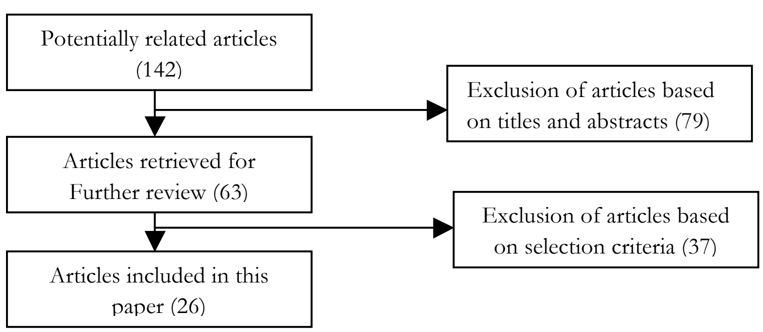

Fig 1: Procedure for selection of articles

2.3 Classification of MLCAT articles by publication year

Figure 2 below shows the number of MLCAT articles by publication year. It can be noted that from 2002 to 2005, there was an increase in articles published with 2005 registering the highest number of articles. From then on, MLCAT publications declined by half in the 2006, 2007 period with a further slight decline in 2008 and 2009. This may be attributed to the fact that many published systems rarely move past the experimental stage and the need for Universities to justify the case for investment in Learning technologies. However, many published tools have been successfully used in various contexts in which they have been developed. Therefore, we believe that the next decade will be characterized by increased interest and development of mobile learning content authoring tools.

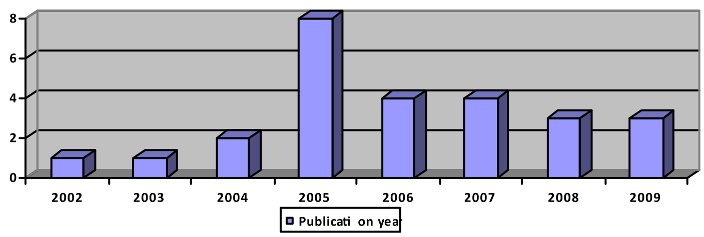

Fig 2: Number of articles by publication year

2.4 Classification of articles by database

Figure 3 below reveals the number of articles by online database. Majority of the articles considered for our study were obtained from the ACM and Google Scholar. This is followed by the IEEE with the least number of articles being obtained from Science Direct, Gale and Springer. The ACM stores articles of various study fields especially human computer interaction, social sciences, ubiquitous computing and education hence the high number of articles.

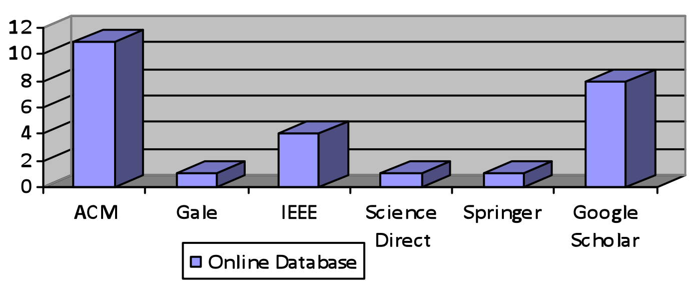

Fig 3: Number of articles by online database

3. Classification Framework

In this section, we present a classification framework which offers an analysis of MLCAT's based on three general dimensions i.e. Technology, Pedagogy and Usability. Technological features are sub divided into system type, development context, tools and technologies used, tool Availability, ICTD relation, content type and supported media. Pedagogical requirements comprise of standards and learning style support whereas usability requirements include existence of an intuitive graphical user interface and accessibility. Figure 4 below summarizes the results.

We distinguish several system types' i.e. artificial intelligence tools (A), traditional authoring tools that use hypertext and multimedia features for content creation (T), video capture systems (V) and natural language speaking and handwriting tools (N). Artificial intelligence tools enable academics create intelligent tutoring system(s) in their domain of expertise through a graphical user interface. The tool then models student usage characteristics so as to provide them with individualized guidance during learning [60]. Video capture tools involve recording, encoding and streaming of the instructor presentations for consumption on various end devices [63] whereas natural language speaking and handwriting tools use recognition software to convert speech and hand written material into editable objects (i.e. text, video, audio or graphics) which are authored for presentation on end devices[34].

The second dimension explores the authoring techniques and development environments used for example some tools use single authoring (S) – a technique used to create a single version of content for adaptation to any given end device, Multiple authoring (M) which involves creation of several content versions for the different consumer devices and Flexible authoring (F) which involves the creation of both single and multiple authored content versions [38]. The development environments include among others Java2 ME, eXtensible Markup Language (XML) which is one of the standards, .NET framework and SMIL among others. In the next dimension, we classify tools against their availability. This implies that a tool is either Web based (w), Client based (c), has a downloadable version available (d) or can be purchased (p).

The fourth dimension classifies tools based on whether they are developed with a developing world (ICTD) context in mind. The developing world is faced with various challenges such as those of infrastructure, poverty, literacy and sparsity. In particular, they are faced with unreliable and intermittent mains electricity, little or no internet bandwidth outside the major cities, little or no user expertise among others. The last two dimensions classify tools based on their purpose and the multimedia supported. The tools explored are used to create learning content, multiple choice quizzes and tests and video lectures among others. In addition, the tools support various media elements such as video (v), text (t), audio (a) and images (i).

Within the pedagogical arena, we explore two features i.e. standards and learning styles. There are various standards available for mobile learning content authoring such as the Sharable Content Object Reference Model (SCORM) [1] and the IMS Global Learning Consortium – Question and Test Interoperability [21]. Moreover, support for learning style and activity of learners such visual, tactile and other learning theories should be taken into account during content authoring for m-learning. Therefore, we classify tools based on their support for standards and learning styles. Within the usability arena, we classify tools based on whether they have an intuitive graphical user interface and/ or support accessibility. Accessibility deals with offering support for people with disabilities. Table 1 below illustrates a classification of the various tools obtained from our review based on the dimensions detailed above.

Dim. / Tool	Technology						Pedagogy		Usability	
	Typ.	Auth.Tech& Techno.	Av.	ICTD	Cont.	MM.	Stds.	LS	Intuitive. GUI	Acc.
[Huang and Kuo 2009] [28]	T, DA, DMD	F, XML, XSLT	w	No	learning content and tests	t, i, a, v	Yes	No	Yes	No
[Romero et al. 2006] [45]	T DA, DMD	S, Java and XML	w	No	adaptive tests	t, i	No	No	No	No
Mobile Author [Alepis and Virvou, 2005] [60]	A, MA, DA, DMD	S, ASP.NET, VB.NET, Windows Server 2000+, IIS, RDBMS	w	No	adaptive content and tests	t, i	No	Yes (Intelligence)	No	No
Tool A [Carro and Martin, 2007] [37]	AI,DA, DMD	?, Java, XML	w	No	Learning content	t, i	No	Yes	Yes	No
Tool B [Simon et al., 2005] [52]	T, DA, DMD	S, XML, XHTML, CSS	c	No	Learning content	t, I, a	No	No	Yes	No
Pen-Based Tool [Luciano and Guiseppe, 2007] [34]	N DA, DMD	??, hand writing, screen capture & video streaming software	??	Yes	Learning content	t, i, v	No	No	No	No
Tool C [Juang et al., 2004] [24]	??, DA,DMD	??, XML	??	No	Learning content	t, i, v	No	Yes(Learning Activity)	??	No
Tool D [Li et al., 2005] [35]	T, MA, DM	F, Visual C++, Pocket PC2003 OS,	??	No	Learning content	t, i, v	No	No	??	No

Table 1: Tool Classification Matrix showing MLCATs Vs Dimensions

Dim. / Tool	Technology						Pedagogy		Usability	
	Typ.	Auth.Tech& Techno.	Av.	ICTD	Cont.	MM.	Stds.	LS	Intuitive. GUI	Acc.
eXeLearning [SourceForge.Net, 2005] [56]	T, D,DA, DMD	??, XHTML, XML	d	No	Learning content	t,i, v	Yes	Yes	??	No
An SMS quiz authoring tool Attewell (2005)[3]	T, DA, DM	??, SMS	c	No	quizzes answered through SMS	t, i	No	No	No	No
A mediaBoard authoring tool Attewell (2005)[3]	T, DA, DM	??, Palmtop, e-mail, MMS	w	No	interactive learning tasks for learner groups	t, i, a	No	Yes	??	No
A Pocket PC authoring tool Attewell (2005) [3]	T, MA, DM	??, PocketPC	c	No	Multiple choice quizzes	t, i	No	No	??	NO
Maxdox [Smith, 2006][50]	T, D, DA, DMD	??, Java, XML, XHTML	w	No	Learning content	t, i, v	No	No	Yes	No
Mobile Point of Interest System) [Broll et al., 2007][7]	T, DA, DMD	??, XML, RFID, GPS	w	No	Learning content	t, i, a	No	No	Yes	No
E-F Editor [Proske et al., 2002] [43]	T, D,DA, DMD	??, XML	w	No	exercises of different types	t, i	No	Yes	No	No
MobiLearn Editor [Gugerbauer, 2004] [17]	T, D, DA, DMD	??, C#, XML	??	No	Learning content	t, i	No	Yes	??	No
ALE Authoring Tool [Kravcik and Specht, 2004] [42]	A, DA, D	??,XML, HTML, CSS	c	No	Learning content and Tests	t, i , a, v, hyperlinks	Yes	No	Yes	No

Table 1: Tool Classification Matrix showing MLCATs Vs Dimensions

Dim. / Tool	Technology						Pedagogy		Usability	
	Typ.	Auth.Tech& Techno.	Av.	ICTD	Cont.	MM.	Stds.	LS	Intuitive. GUI	Acc.
Tele-TASK System [Wolf et al., 2007] [64]	V, DMD,	??, Streaming Server, SMIL, MPEG-4	p	No	Learning content	Video podcasts, t,i,a,v	Yes	No	No	No
GR*i*NS editor [Bulterman and Hardman, 2005][9]	T, DA, DMD,	??, SMIL,	w	No	multimedia content	t, i, a, v	??	No	Yes	No
1001 Stories [Rugbeni et al., 2008] [48]	V, DA, DMD,	??, ??	??	No	Instant multimedia content	t, i, a	??	No	Yes	No
InterMediActor [Valverde-Albacete et al., 2003][62]	??, DA, DD	??, XML, XSLT Style Sheets, XHTML	w	No	multimedia content	t, i, a	??	No	??	No
EduLink [Hsiao et al., 2008] [20]	T,DA, DMD	??, Java	w	No	examples	t, i,v	No	No	Yes	No
Test-IT[Carrico and Sa., 2006] [50]	??, DA, MA, DMD,	??, Java	w	No	Tests, assess-ment, collabora-tive activities	t, i,a	??	No	Yes	No
CThru [Jiang et al., 2009] [24]	V, DMD	??, Java 2D, Java Media Frameworks	c	No	Creating video centered educational spaces	t, i,v	No	No	??	??
e-Portfolio [Santos et al., 2008] [15]	??, HTTP, WAP, Web Services		w	No	multimedia content	t, i, a, v	No	No	??	No
IVA [Roesler et al., 2009] [47]	??, H.264, MPEG-4		??	No	multimedia content	t, i, a, v	No	No	No	No

Table 1: Tool Classification Matrix showing MLCATs Vs Dimensions

5. Results of Classification

A total of 26 tools have been classified as indicated above revealing some interesting observations. From a technology perspective, the biggest number of MLCATs are traditional tools - those that use hypertext and multimedia features for content creation [3][7][9][15][17][20][28][35][43][45][50][52][56], followed by video recording tools [24][47][48][64], artificial intelligence tools [37][42][60] and natural language processing tools [34]. The LMS concept has been successful in many universities. Therefore, as a result majority of the tools are developed with the goal of being integrated into Learning Management Systems. For example [45] is designed for integration into the AHA! System, [56] into Moodle and [37] into the Context-based adaptive Mobile Learning Environment (CoMoLE).

In addition, many of the tools have been developed for desktop authoring, with some also providing for mobile authoring [35][60] and the greatest number supporting distribution of content for access on both mobile devices (smart phones, iPods, cell phones, etc.) and computers.

[19] argue that video content is not mandatory in most learning environments due its limitations such as a constant internet bandwidth availability and visual presentation not getting more than three minutes. Therefore, it is still a challenge to implement video recording within LMS architectures. A number of video recording tools have emerged based on the initial innovations by Apple i.e. [64] which allow for video lectures to be recorded and content delivered to mobile devices i.e. iPods. The resulting content can not be later changed thus implying single authoring. Single authoring refers to creation of a single version of content for adaptation to any given end device. Majority of the tools in our review use this authoring approach with [28][35] offering flexible authoring. A vast number of tools do not mention their authoring techniques hence the use of "??" in our matrix. The natural language processing tools use hand-writing software, screen capture software and video streaming for content delivery and the matrix also reveals that majority of the tools are either web-based or client tools with only [56] having a demo version available and [64] being able to be purchased. This is an indication that many published research tools do not mature into commercial products presenting challenges for m-learning.

In much of the developing world, infrastructure is characterized by little or no internet bandwidth, unreliable and intermittent mains electricity and limited user expertise among others. This implies that the developing world context requires ICTD relevant tools. Majority of the tools explored are developed for user contexts in the developed world and thus do not represent the needs of academics and learners in the developing world. This can be witnessed by the limited success of LMS use i.e. Blackboard, WebCT within the developing world.

In addition, many of the tools in our matrix are developed with the sole purpose of creating learning content [24][28][37][52] whereas others for authoring adaptive tests [45][60], quizzes [3][43] and for authoring instant multimedia (i.e. podcasts, vodcasts) [47][48][64]. Therefore, majority of tools in our matrix generate various multimedia elements i.e. text and images [37][45][60], text, images and video [24][34][35] whereas others support most media types [9][28][42][47].

Within the pedagogical arena we explored support for standards and learning style. This is because these aspects greatly impact on content creation. Our review revealed that some tools offer support for particular standards for example the sharable content reference model (SCORM) or the Question and Test Interoperability (QTI) [28][42][56][64] whereas [3][17][24][42][43][56][60] offer support for learning styles.

Finally, the usability dimension explores the availability of an intuitive graphical user interface (GUI) and support for accessibility – which deals with the provision for people with learning disabilities to utilize the tools. [7][9][17][20][28][37][48][50][52] have GUI's built into the MLCATs whereas none of the tools offer support for accessibility.

6. Discussion/Justification for Choice of Dimensions

MLCATs are still developing with a lot of scope for improvement and increase in sophistication. Many researchers are concerned about content authoring hence the amount of literature on the subject. The attention increased from 2000 to 2005 and then reduced slightly from 2005 to date as shown in figure 2.

This may be due to a lack of strategic business models that make a case for gaining revenue as a result of using MLCATs. In addition, the technologies are merely standardized and our review reveals that the scope of most tools is limited to small groups i.e. a class, laboratory or focus on a particular aspects such as problem based learning and so on. Similarly, the architectures, authoring techniques, system availability and supported user end devices are different for every project. Thus many tools are not fully developed and have remained at prototype level due to inadequate funding, infrastructure and the various design considerations as illustrated from the tool classification matrix.

The availability of the tools we explored is such that they may be client based, Web based, have a download version available or can be purchased. Many client based tools are designed with the aim of being integrated with Learning Management System(s) (LMS) [28][45]. Therefore, although client based tools may have a much more user friendly interface with the ability for authors to create content without the need for an internet connection, integration with external learning material remains weak. On the other hand, Web based content authoring tools are usually implemented as a module within (LMS) or Learning Object Repository (LOR)[36]. The authored content is normally uploaded directly into the LOR but sophisticated functions such as real time recording are not easy to implement and the tools require an always on internet connection. Only a handful of tools in our review have a download version available or can be purchased since majority do not progress past the prototype stage.

According to [6], there is need to adapt content to various contexts either physical or environmental. They argue that context must be understood in order for content to be modeled to adapt to it. The variety of tools explored are developed for use in given contexts such as within the medical domain – problem based learning, museum studies, story telling, school kids, university environments. Over the last decade, e-learning has been exemplified technologically by the rise of virtual learning environments (VLEs), such as WebCT and Blackboard possibly resulting from increasing demand for multi-media interactivity, functionality and bandwidth in networked PC platforms. Pedagogically, we have seen the rise of social constructivist models of learning over previous behaviorists ones. All this is however only mostly true for the so-called developed world. In sub-Saharan Africa m- learning is recognized but as something form of open and distance learning and with different pedagogic traditions - ones that have concentrated on didactic approaches rather than discursive ones. Therefore, m-learning in these parts of the world seems like a reaction to different challenges– usually those of infrastructure, poverty, increased student numbers (ICTD context) and yet almost no tools have been developed this context in mind.

In addition, quality content is not about converting resources into digital form but incorporating the design of elaborate learning activity and usage of learning styles. This is because they represent some of the most influential aspects for mobile learning content creation [6] [24]. Therefore, in order for the content to impact on learners during interaction, it must be matched with the design of appropriate learning activity and learning styles. Although many discussions focus on learning models, learning content development is of paramount importance as it is that which determines the knowledge acquisition process. [3][17][24][43][56][60] offer some support for learning styles and activities whereas the rest of our tools do not. Authoring digital content for online learning is an expensive task which requires effective approaches that allow for re-use/repurposing of content. This can only be accomplished through adherence to standards i.e. [1][21][22]. However, a few tools in our review offer some support for standards [28][42][52][64].

Majority of the tools that adhere to standards are the traditional authoring tools possibly because they are developed for integrated with LMSs which already offer adherence. The other tools do not offer support for standards. Moreover, our review reveals that many e-/m-learning projects have already dealt with content authoring tools but pay little attention to usability. MLCATs require a GUI in order for users to author content for use within a mobile learning environment [67]. A tool's usability may be defined as "*Its efficiency combined with how easy it is to use and learn the system"* [68] or being about learnability, efficiency, memorability, errors and standards [69]. We therefore explore the availability of an intuitive GUI and accessibility. Many MLCATs do not provide an intuitive interface through which authors can see what their content will look like in a browser when published, especially when working offline. The matrix from our review reveals that [7][9][28][37][42][48][50][52] present tools with intuitive GUIs where as non of the tools offers accessibility support for people with learning disabilities.

As noted earlier, many authoring tools are designed for integrated with LMSs thus requiring appropriate management of duplicate resources on the Client and LMS as external material support is sometimes weak. In addition, a number of learning environments utilize a centralized web server model thus requiring internet connectivity for authoring. This is limiting for authors with low bandwidth connectivity or no connectivity at all. [56] was developed as an offline authoring tool without the requirement for connectivity. Since MLCATs is a young research field, many suggestions exist about how to design MLCAT tools but the field seems to be explored in quite an experimental way [35] with majority of the tools developed for only desktop authoring and not mobile device authoring.

7. Conclusions and Future Work

The review was organized with the purpose of providing a comprehensive overview of research on MLCATs. In this paper, we reviewed MLCATs and examined them using the technology, pedagogy and usability dimensions as presented in our cross-tabulation matrix. The paper was based on a literature of MLCATs from 2000 to 2009 using a keyword index and article title search. Overall, we found that the activity related with MLCATs seems to increase dramatically up to 2005 and then decrease slightly from then to 2009. Our review provides literature for researchers on the use of MLCATs and we hope that it will avail some insights to researchers and practitioners for the design and choice of tools. The framework offers some general development considerations for MLCATs and offers a classification of the various tools. We also realize the need for tools to be developed within the contexts of the users in order for successful adoption of these technologies. Many of the MLCATs explored do not use design approaches that involve real system users in context. Therefore, we need to develop MLCATs that represent the needs of users and empower them to author content for use in mobile environments.

Although considerable attention was given to the classification framework design, some limitations still exist. Firstly, some relevant articles might have been overlooked as much of the literature was selected based on a review of the title, keyword or abstract only. Although the titles and abstracts in most cases describe the content quite well, we excluded many articles that did not explore MLCATs as their core. White papers, dissertations, magazines and many articles related to MLCATs were not reviewed as our focus was journal and conference articles which presumably represent the highest level of research. As a result seven online databases were searched for our review. We also used university subscribed online databases which were restricted in some cases. Future work requires the need to adapt learning activities to personalization of course content based on students model and learning styles, ability to track students' progress in mobile environments, provide feedback mechanisms and improve interactivity.
There is also need to study and align the relationship between authoring technology, pedagogy concerns, usability, the ability to create content using mobile devices without the need for additional processing and the need to empower academics who are the domain experts to easily create content without the need for intervention by tool experts.

8. REFRENCES

1. Advanced Distributed Learning Website (2009)[Online at:] http://www.adlnet.org/Pages/Default.aspx {Accessed July 2009}

2. Anacleto, J. C., Carlos, A. J., de Carvalho, A. F., and Dias, A. L. 2008. Bridging the gap among cultures: the challenge faced by teachers on producing content for computer-aided education. In *Proceedings of the 26th Annual ACM international Conference on Design of Communication* (Lisbon, Portugal, September 22 - 24, 2008). SIGDOC '08. ACM, New York, NY, 147-154. DOI= http://doi.acm.org/10.1145/1456536.1456565

3. Attewell .J (2005): From Research and Development to Mobile Learning: Tools for Education and Training Providers and their Learners: Proceedings of mLearn 2005. [Online at:] http://www.mlearn.org.za/CD/papers/Attewell.pdf

4. Brown, E., Cristea, A., Stewart, C., & Brailsford, T. (2005). Patterns in Authoring of Adaptive Educational Hypermedia: A Taxonomy of Learning Styles. *Educational Technology & Society*, 8 (3), 77-90.

5. Berlanga, A. J. and García, F. J. 2005. Authoring tools for adaptive learning designs in computer-based education. In *Proceedings of the 2005 Latin American Conference on Human-Computer interaction* (Cuernavaca, Mexico, October 23 - 26, 2005). CLIHC '05, vol. 124. ACM, New York, NY, 190-201. DOI= http://doi.acm.org/10.1145/1111360.1111380
6. Bhaskar N. U and Govindarajulu P (2009): Essential Aspects of Learning content Development in Context Aware and Adaptive Mobile Learning Applications: Published by the International Journal of Computer Science and Network Security, vol. 9, No. 1. Pg 339-346.

7. Broll, Gregor and Rukzio, Enrico and Wedi, Björn (2007) *Authoring Support for Mobile Interaction with the Real World.* In: Pervasive 2007 Late Breaking Result and Poster, 13 May 2007, Toronto, Ontario, Canada.

8. Bianchi, M. 2004. Automatic video production of lectures using an intelligent and aware environment. In *Proceedings of the 3rd international Conference on Mobile and Ubiquitous Multimedia* (College Park, Maryland, October 27 - 29, 2004). MUM '04, vol. 83. ACM, New York, NY, 117-123. DOI= http://doi.acm.org/10.1145/1052380.1052397
9. Bulterman, D. C. and Hardman, L. 2005. Structured multimedia authoring. *ACM Trans. Multimedia Comput. Commun. Appl.* 1, 1 (Feb. 2005), 89-109. DOI= http://doi.acm.org/10.1145/1047936.1047943

10. Collins T. G(2005): **English Class on the Air: Mobile Language Learning with Cell Phones:** Proceedings of the Fifth IEEE International Conference on Advanced Learning Technologies, pp1-

11. Catherine Ngugi; Nancy Irungu; Benon Muwonge; Patrício Vitorino Langa; Jakob Pederson; Neil Butcher and Sarah Hoosen (of Neil Butcher Associates); Ian Moll, Fatima Adam, Judy Backhouse, Ephraim Mhlanga; Germain Kouame; Ahmed al Seed Tolba; Belinda Mutti and Cathy Eden (2007): Status Report on ICTs and Higher Education in Africa: Published by the Centre of Educational Technology, University of Cape Town, SA

12. Chandra, S. 2007. Lecture video capture for the masses. *SIGCSE Bull.* 39, 3 (Jun. 2007), 276-280. DOI= http://doi.acm.org/10.1145/1269900.1268864

13. Cebeci **(2006):** Using podcasts as audio learning objects: Interdisciplinary Journal of Knowledge and Learning Objects 1552-2210 vol: 2 2006 p:47

14. Chu .W .C, Lin .H, Chen .J, and Lin .X and Lau R.W.H. (2005): **Context-Sensitive Content Representation for Mobile Learning (2005):** ICWL 2005, LNCS 3583, pp. 349 – 354, 2005.

15. de F. Santos, H., Santana, L. H., Martins, D. S., De Souza, W. L., do Prado, A. F., and Biajiz, M. 2008. A ubiquitous computing environment for medical education. In *Proceedings of the 2008 ACM Symposium on Applied Computing* (Fortaleza, Ceara, Brazil, March 16 - 20, 2008). SAC '08. ACM, New York, NY, 1395-1399. DOI= http://doi.acm.org/10.1145/1363686.1364008

16. Friedland, G., Hürst, W., and Knipping, L. 2007. Educational multimedia systems: the past, the present, and a glimpse into the future. In *Proceedings of the international Workshop on Educational Multimedia and Multimedia Education* (Augsburg, Bavaria, Germany, September 28 - 28, 2007). Emme '07. ACM, New York, NY, 1-4. DOI= http://doi.acm.org/10.1145/1290144.1290145

17. Gugerbauer E (2004): Analysis of the Profit of M-Learning and A Framework for Authoring Mobile Learning Content: http:[On line at:]http://www.tk.uni-linz.ac.at/download/gugerbauer.pdf {Accessed} July 2009.

18. Hürst, W., Welte, M., and Jung, S. 2007. An evaluation of the mobile usage of e-lecture podcasts. In *Proceedings of the 4th international Conference on Mobile Technology, Applications, and Systems and the 1st international Symposium on Computer Human interaction in Mobile Technology* (Singapore, September 10 - 12, 2007). Mobility '07. ACM, New York, NY, 16-23. DOI= http://doi.acm.org/10.1145/1378063.1378067

19. Herzog .M .A, Trier .M, and Sieck .J (2006): Production engineering for video based e- and m-learning content: 10th Baltic Region Seminar on Engineering Education ? 2006 UICEE Szczecin, Poland, pp1 – 4.

20. Hsiao, I., Li, Q., and Lin, Y. 2008. Educational social linking in example authoring. In *Proceedings of the Nineteenth ACM Conference on Hypertext and Hypermedia* (Pittsburgh, PA, USA, June 19 - 21, 2008). HT '08. ACM, New York, NY, 229-230. DOI= http://doi.acm.org/10.1145/1379092.1379139.

21. IMS Content Packaging Specification v1.1.3 (July 2003): http://www.imsglobal.org/content/packaging/ {Accessed} June 2009.

22. IMS Global Learning Consortium – Question and Test Interoperability () http://www.imsglobal.org/question/#version2.0 {Accessed}July 2009

23. IEEE Standard for Learning Object Metadata (June 2002): http://ltsc.ieee.org/wg12 {Accessed} June 2009

24. Jiang, H., Viel, A., Bajaj, M., Lue, R. A., and Shen, C. 2009. CThru: exploration in a video-centered information space for educational purposes. In *Proceedings of the 27th international Conference on Human Factors in Computing Systems* (Boston, MA, USA, April 04 - 09, 2009). CHI '09. ACM, New York, NY, 1247-1250. DOI= http://doi.acm.org/10.1145/1518701.1518887

25. Juang . Y, Chen . Y, Chen . Y, Chan .T (2004): Design of Learning Content Development Framework and System for Mobile Technology Enhanced Environment: Proceedings of the IEEE International Conference on Advanced Learning Technologies. Pp 1-3

26. Jokela .T (2003): AUTHORING TOOLS FOR MOBILE MULTIMEDIA CONTENT: ICME, pp 637 – 640.

27. Karampiperis, P. and Sampson, D. 2005. Designing learning systems to provide accessible services. In *Proceedings of the 2005 international Cross-Disciplinary Workshop on Web Accessibility (W4a)* (Chiba, Japan, May 10 - 10, 2005). W4A '05, vol. 88. ACM, New York, NY, 72-80. DOI= http://doi.acm.org/10.1145/1061811.1061825

28. Karampiperis, P. and Sampson, D. 2005. Designing learning services: from content-based to activity-based learning systems. In *Special interest Tracks and Posters of the 14th international Conference on World Wide Web* (Chiba, Japan, May 10 - 14, 2005). WWW '05. ACM, New York, NY, 1110-1111. DOI= http://doi.acm.org/10.1145/1062745.1062893

29. Kuo .Y and Huang .Y (2009) MEAT: An authoring tool for generating adaptable learning resources.(Mobile E-Learning Authoring Tool)(Report). Journal of ***Educational Technology & Society*** 12.2 (April 2009): p.51(18). (8575 words) From *Academic OneFile.*

30. Lichtschlag, L., Karrer, T., and Borchers, J. 2009. Fly: a tool to author planar presentations. In *Proceedings of the 27th international Conference on Human Factors in Computing Systems* (Boston, MA, USA, April 04 - 09, 2009). CHI '09. ACM, New York, NY, 547-556. DOI= http://doi.acm.org/10.1145/1518701.1518786

31. Leitner, M., Wolkerstorfer, P., Sefelin, R., and Tscheligi, M. 2008. Mobile multimedia: identifying user values using the means-end theory. In *Proceedings of the 10th international Conference on Human Computer interaction with Mobile Devices and Services* (Amsterdam, The Netherlands, September 02 - 05, 2008). MobileHCI '08. ACM, New York, NY, 167-175. DOI= http://doi.acm.org/10.1145/1409240.1409259

32. Lara, E. d., Kumar, R., Wallach, D. S., and Zwaenepoel, W. 2003. Collaboration and multimedia authoring on mobile devices. In *Proceedings of the 1st international Conference on Mobile Systems, Applications and Services* (San Francisco, California, May 05 - 08, 2003). MobiSys '03. ACM, New York, NY, 287-301. DOI= http://doi.acm.org/10.1145/1066116.1066126
33. Lanir, J., Booth, K. S., and Tang, A. 2008. MultiPresenter: a presentation system for (very) large display surfaces. In *Proceeding of the 16th ACM international Conference on Multimedia* (Vancouver, British Columbia, Canada, October 26 - 31, 2008). MM '08. ACM, New York, NY, 519-528. DOI= http://doi.acm.org/10.1145/1459359.1459428

34. Low B (2002): Packaging educational content using IMS specifications: Source: **VINE; Volume: 32; Issue: 2; 2002**

35. Luciano .C and Guisseppe .S (2007): Pen-based tools for the creation of handwritten learning content: IEEE First International Workshop on Pen-Based Learning Technologies - Enabling Advanced Graphical, Multimodal and Mobile Learning Interactions. Pp 133 – 136.

36. Li .S, Kim .S and Kim .S (2005): **Collaborative MPEG-4 Contents Authoring, Presentation and Interaction in a Mobile Environment:** Proceedings of the Sixth International Conference on Parallel and Distributed Computing, Applications and Technologies, pp 1-5.
37.
38. Martı´n .E and Carro .R, M (2009): Supporting the Development of Mobile Adaptive Learning Environments: A Case Study. IEEE TRANSACTIONS ON LEARNING TECHNOLOGIES, VOL. 2, NO. 1, pp23-36.

39. MobiLearn IST-2001-37187 Website (): http://www.mobilearn.org/standards/standards.htm#ims {Accesed} July 2009.

40. MOT (2004) Retrieved July 25, 2005, from http://wwwis.win.tue.nl/~acristea/mot.html {Accessed} June 2009.

41. Metso .M, Koivisto .A and Sauvola .J (2001): A Content Model for the Mobile Adaptation of Multimedia Information: The Journal of VLSI Signal Processing, Springer Netherlands, Vol 29.
42. McFarlane, A.; Williams, J.M.; Bonnett, M. Assessment and multimedia ***authoring*** – a tool for externalising understanding. *Journal of Computer Assisted Learning*, Sep2000, Vol. 16 Issue 3, p201-212, 0p; DOI: 10.1046/j.1365-2729.2000.00133.x; (*AN 5518751*)
43. Kravcik . M, Specht .M (2004) - actapress.com: Advanced Technology for Learning, Vol. 1, No. 4, AUTHORING ADAPTIVE COURSES: ALE APPROACH.
44. Näsänen, J., Oulasvirta, A., and Lehmuskallio, A. 2009. Mobile media in the social fabric of a kindergarten. In *Proceedings of the 27th international Conference on Human Factors in Computing Systems* (Boston, MA, USA, April 04 - 09, 2009). CHI '09. ACM, New York, NY, 2167-2176. DOI= http://doi.acm.org/10.1145/1518701.1519031

45. Proske .A, Narciss .S, Korndle .H (2002): The Exercise Format Editor: A Multimedia Tool for the Design of Multiple Learning Tasks [Online at:] http://studierplatz2000.tu-dresden.de/lehrlern/pdf/artikel/ef_editor02.pdf {Accessed} June 2009.

46. Röüling, G., Trompler, C., Mühlhäuser, M., Köbler, S., and Wolf, S. 2004. Enhancing classroom lectures with digital sliding blackboards. In *Proceedings of the 9th Annual SIGCSE Conference on innovation and Technology in Computer Science Education* (Leeds, United Kingdom, June 28 - 30, 2004). ITiCSE '04. ACM, New York, NY, 218-222. DOI= http://doi.acm.org/10.1145/1007996.1008054

47. Romero .C, Ventura .S, Hervas .C, De Bra .P (2006): An Authoring Tool for Building Both Mobile Adaptable Tests and Web Based Adaptive or Classic Tests. Lecture Notes in Computer Science 4018, pp 203 - 212

48. Roesler, V., Husemann, R., and Costa, C. H. 2009. A new multimedia synchronous distance learning system: the IVA study case. In *Proceedings of the 2009 ACM Symposium on Applied Computing* (Honolulu, Hawaii). SAC '09. ACM, New York, NY, 1765-1770. DOI= http://doi.acm.org/10.1145/1529282.1529680
49. Rubegni, E., Sabiescu, A., and Paolini, P. 2008. OneThousandAndOneStories: a format for multichannel multimedia narratives. In *Proceedings of the 15th European Conference on Cognitive Ergonomics: the Ergonomics of Cool interaction* (Funchal, Portugal, September 16 - 19, 2008). J. Abascal, I. Fajardo, and I. Oakley, Eds. ECCE '08, vol. 369. ACM, New York, NY, 1-2. DOI= http://doi.acm.org/10.1145/1473018.1473042

50. Rößling, G., Joy, M., Moreno, A., Radenski, A., Malmi, L., Kerren, A., Naps, T., Ross, R. J., Clancy, M., Korhonen, A., Oechsle, R., and Iturbide, J. Á. 2008. Enhancing learning management systems to better support computer science education. *SIGCSE Bull.* 40, 4 (Nov. 2008), 142-166. DOI= http://doi.acm.org/10.1145/1473195.1473239

51. Sá, M. and Carriço, L. 2006. Handheld devices for cooperative educational activities. In *Proceedings of the 2006 ACM Symposium on Applied Computing* (Dijon, France, April 23 - 27, 2006). SAC '06. ACM, New York, NY, 1145-1149. DOI= http://doi.acm.org/10.1145/1141277.1141549

52. Smith .S (2006):Creating Mobile Learning? : [Online at:] http://www.handheldlearning.co.uk/hl2006/present/stuartsmith.pdf {Accessed} June 2009

53. Simon, R., Wegscheider, F., and Tolar, K. 2005. Tool-supported single authoring for device independence and multimodality. In *Proceedings of the 7th international Conference on Human Computer interaction with Mobile Devices &Amp; Services* (Salzburg, Austria, September 19 - 22, 2005). MobileHCI '05, vol. 111. ACM, New York, NY, 91-98. DOI= http://doi.acm.org/10.1145/1085777.1085793
54. Sharda, N. K. 2007. Authoring educational multimedia content using learning styles and story telling principles. In *Proceedings of the international Workshop on Educational Multimedia and Multimedia Education* (Augsburg, Bavaria, Germany, September 28 - 28, 2007). Emme '07. ACM, New York, NY, 93-102. DOI= http://doi.acm.org/10.1145/1290144.1290160
55. Tortora, G., Sebillo, M., Vitiello, G., and D'Ambrosio, P. 2002. A multilevel learning management system. In *Proceedings of the 14th international Conference on Software Engineering and Knowledge Engineering* (Ischia, Italy, July 15 - 19, 2002). SEKE '02, vol. 27. ACM, New York, NY, 541-547. DOI= http://doi.acm.org/10.1145/568760.568856

56. Tai .Y and Ting .R .Y (2007): **Authoring Tools in e-Learning: A Case Study:** Seventh IEEE International Conference on Advanced Learning Technologies: pp 1-3.
57. The International Telecommunications Union Website (2008): Market Information and Statistics [Online at:] http://www.itu.int/ITU-D/ict/statistics/ict/index.html {Accessed} September, 2008.

58. The SourceForge.Net Website (1999-2008): eXeLearning Tool [Online at:] http://apps.sourceforge.net/trac/exe/wiki {Accessed} July 2009.

59. Teng .C, Chu .H, Wu .C (2004): mProducer: Authoring Multimedia Personal Experiences on Mobile Phones: IEEE International Conference on Multimedia and Expo (ICME), pp 1251 – 1254.

60. Turban, G. and Mühlhäuser, M. 2007. A framework for the development of educational presentation systems and its application. In *Proceedings of the international Workshop on Educational Multimedia and Multimedia Education* (Augsburg, Bavaria, Germany, September 28 - 28, 2007). Emme '07. ACM, New York, NY, 115-118. DOI= http://doi.acm.org/10.1145/1290144.1290163

61. van Dam, A., Becker, S., and Simpson, R. M. 2007. Next-generation educational software: why we need it & a research agenda for getting it. In *ACM SIGGRAPH 2007 Courses* (San Diego, California, August 05 - 09, 2007). SIGGRAPH '07. ACM, New York, NY, 32. DOI= http://doi.acm.org/10.1145/1281500.1281543

62. Virvou M, Alepis E (2005): Mobile Educational Features in Authoring Tools for Personalised Tutoring: *Computers & Education, Volume 44, Issue 1, January 2005, Pages 53-68*

63. Valverde-Albacete, F. J., Pedraza-Jiménez, R., Cid-Sueiro, J., Molina-Bulla, H., Díaz-Pérez, P., and Navia-Vázquez, A. 2003. InterMediActor: an environment for instructional content design based on competences. In *Proceedings of the 2003 ACM Symposium on Applied Computing* (Melbourne, Florida, March 09 - 12, 2003). SAC '03. ACM, New York, NY, 575-579. DOI= http://doi.acm.org/10.1145/952532.952646

64. Weal, M. J., Hornecker, E., Cruickshank, D. G., Michaelides, D. T., Millard, D. E., Halloran, J., De Roure, D. C., and Fitzpatrick, G. 2006. Requirements for in-situ authoring of location based experiences. In *Proceedings of the 8th Conference on Human-Computer interaction with Mobile Devices and Services* (Helsinki, Finland, September 12 - 15, 2006). MobileHCI '06, vol. 159. ACM, New York, NY, 121-128. DOI= http://doi.acm.org/10.1145/1152215.1152241

65. Wolf, K., Linckels, S., and Meinel, C. 2007. Teleteaching anywhere solution kit (Tele-TASK) goes mobile. In *Proceedings of the 35th Annual ACM SIGUCCS Conference on User Services* (Orlando, Florida, USA, October 07 - 10, 2007). SIGUCCS '07. ACM, New York, NY, 366-371. DOI= http://doi.acm.org/10.1145/1294046.1294132

66. Zhang, C., Rui, Y., Crawford, J., and He, L. 2008. An automated end-to-end lecture capture and broadcasting system. *ACM Trans. Multimedia Comput. Commun. Appl.* 4, 1 (Jan. 2008), 1-23. DOI= http://doi.acm.org/10.1145/1324287.1324293

67. Ihamäki H and Vilpola I (2004); *Electronic Journal on e-Learning Volume 2 Issue 1*; [Online] http://www.ejel.org/volume-2/vol2-issue1/issue1-art18-ihamaki-vilpoloa.pdf {Accessed} November 2004.

68. Adell J Castellet J M, Gumbau J P (May 2004**);** *Selection of an open source virtual learning environment for Universitat JaumeI* [Online] http://cent.uji.es/doc/eveauji_en.pdf {accessed} November 2004.

69. Nielsen J (1992): *Finding usability problems through heuristic evaluation;* Published by ACM Press New York, NY, USA; Pages: 373 – 380.