A Cloud-based Framework for Personalized Mobile Learning Provisioning using Learning Objects Metadata Adaptation

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Abstract: With the proliferation of Internet-capable mobile handheld devices and the availability of wireless broadband networks, mobile learning is increasingly adopted to deliver learning content anywhere and anytime to mobile users. Offering compelling mobile learning solutions faces several challenges. These challenges are mainly the adaptation of the learning material to the profile and preferences of the mobile user and the support of multiple devices. Other concerns include the storage, retrieval, and processing of learning content outside of mobile devices. Furthermore, building rich learning management systems requires the integration of learning content from third party providers. This paper describes our proposed cloud-based framework for delivering adaptive mobile learning services. The paper explains the benefits and requirements of cloud-based solutions for educational organizations, and describes the components of the proposed framework together with the process of integrating learning objects imported from third-party providers with in-house learning objects of the educational organization.

1 INTRODUCTION

E-learning continues to grow phenomenally in both academia and industry, but most e-learning developments involve wired infrastructures. In parallel with that trend, we are witnessing a growing interest in mobile learning (or m-learning) solutions, which are fuelled by the proliferation of modern handheld devices (such as smartphones and tablets) having advanced and sophisticated technological capabilities and the availability of wireless broadband connections.

Mobile learning is relatively immature with respect to technologies and principles and methods of instruction, but it is evolving rapidly. A review of the literature reveals several initiatives on the adoption of mobile learning. Mobile handheld devices are supporting training of corporate mobile workers (Pimmer et al., 2008) and are enriching medical training (Davies et al., 2012), and music composition (Jung et al., 2006).

Traditional research-based learning systems fall into two categories: Intelligent Tutoring Systems (ITS) and Adaptive Hypermedia Systems (AHS) (Brusilovsky, 2003). AHS solutions focus mainly on the adaptation of the instructional process (course content adaptation, course navigation adaptation, problem-solving support, etc.) to the learner model. Commercial Learning Management Systems (LMS), like Blackboard and WebCT, focus mainly on the management of the learning process (registration and tracking of students, learning material creation and delivery capability, skill assessment, communication teacher-learner and learner-learner, etc.). The educational and corporate training market continue to adopt mainly these systems, which LMS companies developed in the context of classical learning using wired infrastructure.

This work aims to take advantage of the proliferation of mobile devices and the promises of cloud computing to propose a mobile learning solution. We present in this paper a cloud-based mobile learning framework whose main objective is to fill the gap between the current approach to Web-based education (based on mobile devices, wireless networks, and learning object repositories), and robust but underused ITS and AHS technologies. This framework attempts to address both the adaptation of the learning material to the mobile learner model, the user mobility, the heterogeneity of mobile devices, and the integration of external learning material from various providers and learning object repositories (Lehman, 2007). The motivation behind considering a cloud-based solution for mobile learning is that mobile devices are still lacking the necessary resources regarding

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storage and computing power, compared with a conventional information-processing device such as a workstation or a laptop.

The remainder of the paper is organized as follows: Section 2 presents background information on mobile learning. Section 3 presents pertinent literature and related works on adaptive mobile learning. Section 4 describes the benefits of cloud computing for mobile learning. Section 5 presents the architecture of our proposed framework. Section 6 details the process of integrating learning objects from third party providers. Finally, section 7 concludes the paper and highlights future work.

2 MOBILE LEARNING

As a result of the improved capabilities of mobile devices and the increasing availability of wireless networks, there are great opportunities for using mobile learning as a new channel to convey knowledge and complement the already established Web-based e-learning model.

Numerous studies have defined mobile learning differently, which suggests that mobile learning is still in an evolving stage. Traxler J. (Traxler, 2005) defined mobile learning as: *"Any educational provision where the sole or dominant technologies are handhelds or palmtop devices."* Crompton et al. (Crompton, 2013) defined mobile learning as: *"learning across multiple contexts, through social and content interactions, using personal electronic devices"*. Gipple et al. (Gipple, 2016) made a blurred distinction between mobile learning and e-Learning: *"mLearning facilitates learning 'on the move', and so it is not static or tied to a place; it is learning within context. This may include learning while traveling, driving, sitting, or walking; it may be hands-free learning or eyes-free learning. These interpretations impact on the implementation and hence the definition of mobile learning. By focusing on the context how mLearning is being used, designers and developers can identify the advantages that mobile learning can provide for learners rather than on the limitations of the technology. It allows educators to capitalize on learner engagement inherent in mobile technology to provide learners with the best and most convenient learning tools possible."*

Two main characteristics of mobile learning are *ubiquity* and *mobility*. Ubiquity represents the state or capacity of accessing computing technologies and learning material whenever and wherever the mobile learner needs them. Mobility represents the quality of being able to learn while on the go using various mobile handheld devices. Mobile learners can access learning services from anywhere, and anytime. Other characteristics of mobile learning include:

- *Interactivity*: mobile learners manage the learning process they are involved in as opposed to the traditional learning in which learners sit passively while the instructor feeds them with information.
- *Ability to Access a Variety of Learning Material Anytime from Anywhere*, which can help in understanding the learning concepts under study.
- *Flexibility*: mobile learning is spontaneous and not planned in advance.
- *Collaboration*: mobile technologies in addition to social networking technologies provide opportunities for collaboration between learners themselves and collaboration with instructors.

Some case studies and projects investigated and experimented with mobile learning as a new channel to convey knowledge. Cavus et al. (Cavus, 2009) investigated the potential of using wireless technologies in learning new technical English words. Results of the study, in which forty-five students participated, showed that the students learned in an effective way new technical vocabulary using their cell phones. 9ine Consulting (Heinrich, 2012) investigated the use of iPads at Longfield Academy in Kent in which over 800 students had iPad across all levels of the school. The study revealed the value of the iPad as an educational tool, the involvement of the teachers, the motivation of the students in using the iPad, and the rising progress in the quality of students' work.

3 RELATED WORK

3.1 Adaptive Learning

Several research efforts widely investigated adaptive learning and personalization of learning material according to the learner's model in web-based learning systems. Personalization of the learning material has been studied and evaluated in the areas of psychology of learning and teaching methods (Tennyson, 1988), (Litchfield, 1990). The empirical evaluation of these methods showed that personalized course material increases the learning speed and help learners understand better the teaching material (Brusilovsky, 2003).

Well-known projects include AHA (De Bra, 2001) (De Bra, 2002), DCG (Vassileva, 1998), and ELM-ART (Weber, 2001). AHA is a generic system for adaptive hypermedia whose aim is to bring adaptivity to web-based applications. It supports adaptive content presentation and adaptive navigation. DCG is an authoring tool for adaptive courses. It supports adaptive sequencing and offers different levels of re-planning the course. ELM-ART is an on-site intelligent learning environment that supports example-based programming, intelligent analysis of problem solutions, and advanced testing and debugging facilities.

Within the context of mobile learning, only few research works have investigated the issue of adaptation and personalization of learning content based on the learner's model. Economides et al. (Economides, 2006) described a general framework for adaptive mobile learning. The input to the adaptation engine is the learner's state, the infrastructure's state, the current educational activity's state, and the environment's state. Each one of these states consists of some dimensions. Probabilistic adaptation decisions are made when context information is inaccurate. Jung et al. (Jung, 2006) proposed a mobile learning system that adapts content provided to the learner based on her attributes. The adaptation engine relies on a user model, a domain model, and an adaptation model as in AHA (De Bra, 2001) (De Bra, 2002). The user model is shaped as a collection of pairs of attributes/values. The domain model is a hierarchical structure of learning content. The adaptation model consists of a set of rules on how to update the user model based on the progress in learning. Fang et al. (Fang, 2009) proposed an architecture for adaptive mobile learning, which relies on a learning object model. Learning Objects represent digital resources that are reusable. The authors of this work provided a taxonomy of the learner model, of the learner's environment model, and the learning object model. However, they did not provide a detailed representation and description of each model. They described the adaptation process only at the conceptual level. Other works typically implemented the adaptation process as a set of adaptation rules. Huang (Huang et al., 2012) proposed an approach to transform HTML-based content into formats appropriate for mobile devices. The approach relies on the concept of coherence and an algorithm that detects coherence sets. The drawback of this approach is its limitation to HTML content. Learning systems often use multimedia content that requires various technologies for its presentation.

3.2 Cloud-based Mobile Learning

Cloud-based mobile learning is becoming the subject of several research efforts. Velev (Velev, 2014) described some of the challenges and opportunities in the development and use of cloud-based mobile learning. He described how social media, big data, and cloud computing could make possible the development of mobile learning solutions through mobile devices, allowing learners to access learning content while on the move. Masud (Masud, 2013) proposed a high-level conceptual cloud-based architecture to support mobile learning. The proposed solution advocates a private cloud that could be used by higher education institutions. However, the authors did not describe the interactions between the components of the architecture from the learning perspective. They just described the technical details of their solution, which includes servers, virtualization, storage, and network access.

The main cloud providers and technology companies such as Google, Microsoft, and CISCO are promoting their solutions for cloud-based education. For example, Google Apps for Education offers email, calendar, website creation and office applications, communications, to every student and staff member in the educational institution.

When building mobile learning solutions, the following technical issues need to be considered:

a) How to implement and manage the adaptation of the learning material to the learner's preferences and profile?
b) How to provide support for multiple mobile devices?
c) How to extend the solution with the learning material from third party providers?

In this work, we propose a mobile learning solution based on cloud-based services and a two-fold student modeling mechanism. Cloud-based services address the problem of managing the learning infrastructure and multi-device support and adaptation. The two-fold student modeling allows handling the personalization process in a very flexible manner.

4 CLOUD-BASED MOBILE LEARNING PROVISIONING

Cloud computing enables a service provisioning model for computing services that relies on the Internet. This model typically involves the provisioning of dynamically scalable and virtualized services. The advent of cloud computing has an impact on developers, end-users, and organizations.

For developers, cloud computing provides greater amounts of storage than ever before and better processing power for running the applications they develop. For end-users, a user using the cloud through a native application or a web-based application can access his documents and files whenever he wants and wherever he is, rather than having to remain at his desk. Also, cloud computing opens the door to group collaboration as users from different locations might share documents and files at lower costs and in an efficient way. Small and medium-sized businesses might also benefit immediately from the huge infrastructure of the cloud without being concerned with its administration. They might store massive amounts of data than on their premises' systems. Therefore, their computing staff no longer needs to worry about upgrading software. Instead, they will be free to focus further on innovation.

Cloud services are applications or services offered using cloud computing. Cloud services delivery models include:

- Software-as-a-Service (SaaS): the cloud service application runs on the servers of the cloud provider. Users access the service via a Web interface or by using an API.
- Platform-as-a-Service (PaaS): businesses develop and deploy their business applications in a cloud environment by using software tools offered by the cloud provider, who is responsible for maintaining and managing the cloud infrastructure.
- Infrastructure-as-a-Service (IaaS): businesses rent compute, storage, and network resources and access them across the Internet or via a private network.

Training organizations and academic institutions can take advantage of cloud computing to deploy e-Learning and mobile learning platforms that are rich in multimedia content and with high storage requirement without being concerned with the issues of infrastructure management, software and hardware upgrade. Cloud computing can boost readiness of learning solutions by allowing teachers and students to access the learning platform from anywhere using internet-enabled devices. By lowering operation costs through cloud computing, a training organization can develop more in-house learning content, access open learning content, or purchase content from third parties learning material providers.

The SaaS delivery model, as demonstrated by the offerings of the main cloud providers and players, is the most appropriate cloud-based solution for implementing both e-Learning and m-Learning platforms that include Learning Management Systems (LMS), learning material repositories, authoring tools, and collaboration solutions like video conferencing and screen sharing. Indeed, educational institutions can easily and quickly implement SaaS-based solutions without incurring the maintenance costs, normally inherent to in-house solutions, while benefiting from the latest software updates and new features offered by the cloud provider.

For mobile learning solutions to be successful, it is important to create compelling, engaging and connected mobile learner experiences. Therefore, backend components or services need to feed the mobile learner application with relevant learning material and allow interactions between learner and instructor, between learners, and more. With cloud computing solution, it is becoming possible to develop backend solutions that scale to meet the growing demand. By leveraging the cloud infrastructure, solutions can be implemented without having to worry about things such as managing machines or load balancing.

Typical requirements for a compelling mobile learning solution include: (1) support for multiple devices, (2) storage, retrieval, and processing learning content outside of mobile devices, (3) integration of new learning content from third party providers, (4) user authentication, and (5) high scalability.

5 FRAMEWORK OVERVIEW

5.1 Context

We are considering a learning environment where learners take courses asynchronously. In this context, learners have personal desires to enhance their knowledge and careers. They often have long-term learning plans and do prefer flexible and personalized learning environments that take into consideration their preferences. Most of these learners are always mobile and require having access to their learning material from everywhere, anytime, and using diverse mobile devices. So, the context of this work takes into consideration the following requirements: asynchronous learning, mobile learners, heterogeneous mobile devices, tailored courses, and personalized interfaces with a similar look and feel.

5.2 System Architecture

In this context, we are proposing a cloud-based framework for implementing an adaptive mobile learning system that supports mobile learners connecting to the learning platform using various mobile devices. The cloud service of the training organization has the following components: the *Profile Manager (PM)*, the *Course Delivery Manager (CDM)*, the *Device Profile Manager (DPM)*, and The *Learning Objects Manager (LOM)*. The learner's device has the following components: The *Learner Profile Manager (LPM),* the *Learner Course Delivery Manager (LCDM),* and the *Learner Tutoring Interface Manager (LTIM)*.

PM manages the knowledge concerning the learners. Its main tasks are:

- Performing user authentication
- Acting as a central register for registering each new learner.
- Managing and assuring the consistency of the databases containing learners' profiles.
- Receiving service requests from terminals and giving access to user profiles data.
- Initiating the LPM on the remote device.
- Checking the version of LPM and LTIM that resides on remote devices and automatically download any necessary updates.

DPM manages the knowledge concerning the various devices. Its main tasks are:

- Acting as a central register, where each new learner device must be registered.
- Managing and assuring the consistency of the databases containing devices profiles.

CDM manages knowledge about courses and teaching strategies. Its main tasks are:

- Providing an interface for defining learning objects and courses knowledge (study guide and study plan).
- Receiving service requests from devices and giving access to courses material.
- Generating the course study guide and study plan based on the user profile and the teaching strategy.
- Packaging the course teaching material according to the user profile and device profile.
- Initiating the LCDM and the LTIM on the learner's device.

LOM is in charge of managing in-house learning objects and access to third parties learning objects.

LPM carries and manages a local copy of the learner profile (preferences and learner's model) on the learner's device. Its main tasks are:

- Providing the other components of the learner's device (LCDM and LTIM) with the learner information (profile, identification).
- Managing and synchronizing the learner profile information with the training organization cloud service.
- Providing the local personalization of the learning material. In collaboration with the LCDM and LTIM, LPM ensures the display of the learning material according to the learner's preferences and her device capabilities.

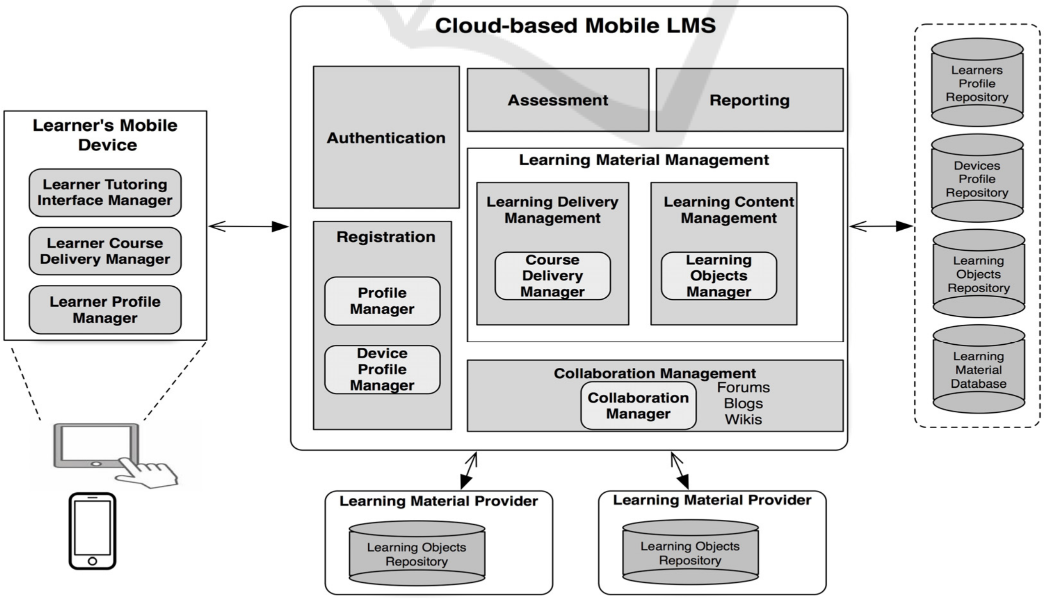

Figure 1: Architecture overview.

LCDM manages the course delivery to the roaming user. The main tasks of the course provider are:

- Carrying and managing the learning material and study plan.
- Providing a personalized learning service to the learner based on her model and learning style.
- Synchronizing the learning content with the educational institution cloud service.
- Ensuring the adaptation and packaging of external learning content. Since the system is open to third-party providers, external learning material may need to be converted to the required format and adapted to the learner and device profiles.

LTIM is in charge of maintaining the profile of the learner's device and ensures that the display of services is done according to the user preferences and device capabilities.

The back-end databases of the framework include:

- *Learners' Profile Repository*: for each learner the system maintains a profile that has two components, the learner's model and the learner preferences regarding the learning style, interfaces and content display.
- *Devices' Profiles Repository*: contains for each device a description of its features and capabilities that are useful for the learning service provision (screen size, bandwidth limit, colors, resolution, etc.). Some features that can be automatically detected by the system (Operating System, Browser, Plug-ins) are not stored in the repository but integrated to the profile when initializing the Learner Tutoring Interface Manager.
- *Learning Objects Repository*: contains the learning material defined as learning objects.
- *Learning Material Database*: for each unit of the learning material the system maintains its study guide and its study plan structures.

5.3 Knowledge Structures for Adaptive Delivery of Learning Material

Study Guide: the learning material content is organized around a set of concepts. Each concept has a teaching material associated with it that comes either from an external provider or an in-house learning object. The study guide defines the relationships between these concepts. The relationships consist of prerequisite, similarity and substitute relationships.

Study Plan: The learning material structure is organized into units and sections, and for each section a set of concepts is learned using different tasks: readings, labs, and tests. The study plan defines the sequencing of the learning material content and the time constraints and deadlines for different tasks of the learning process.

Learner's Model: a fuzzy overlay model based on the learning material concepts. The model represents static beliefs about the learner and simulates the learner's reasoning in some cases. With each concept in the model is associated a fuzzy value that represents the assessment of the learner's knowledge regarding this concept. Two different versions of the learner's model are used by the system: a global model and a local model. The global learner's model is stored in the Learner Profile Repository and represents concepts reported to the system about the learner or learned from different learning materials. This model represents in addition to the concepts and associated fuzzy values, the relationships between concepts (prerequisite, similarity, and substitute). The local learner's model is managed by the user agent within the learner's device and is related to a specific learning material. This model represents only the course concepts and associated values. It is refined based on the learner's interaction with the system when reading the learning material and doing the assessment exercises. The local model is also used to update the global learner's model. The local model is initialized from the global model.

Teaching Strategy: A set of rules that implement the adaptation controls for the learning material. It consists of rules for sequencing the learning components, rules for adding or dropping learning components and rules for selecting between similar or equivalent learning components.

6 ADAPTATION OF THIRD PARTY PROVIDERS CONTENT

In traditional learning systems, learning content is organized into several chunks called courses. Each one may last up to one or several hours. In modern learning systems, however, content is built from smaller units of learning, lasting for few minutes, called learning objects (LOs). LOs allow customizing courses for each learner or even for a whole organization. A single learning object may be used in diverse contexts for multiple purposes. In LO repositories, each LO has descriptive metadata allowing it to be easily found in a search and integrated with other LOs to build much larger units of learning. LOs metadata can be written in XML or any other proprietary format. The IEEE 1484.12.1 Standard for Learning Object Metadata is an internationally recognized open standard for describing LOs (IEEE, 2002). Pertinent attributes of LOs include the type of object, author, owner, format, and pedagogical attributes such as interaction style.

The proposed framework is open to third party providers that can provide their learning material as learning objects. Their content can be plugged into the framework. With the availability of open learning objects repositories, it is now possible to search for appropriate learning content that can be integrated with local content based on the mobile learner's profile and the study plan. Examples of such repositories are MERLOT (MERLOT, 2016) and WISC-ONLINE (WISC-ONLINE, 2016).

Heterogeneity in LOs metadata requires a process for adapting the learning content, built from various in-house and imported LOs, to the learner's profile and device profile. The framework uses a common metadata model to describe LOs. This process, depicted in figure 2, involves two steps:

***Step 1*:** metadata adapters are used to translate imported LOs metadata models used by third parties LO repositories to that common metadata model.

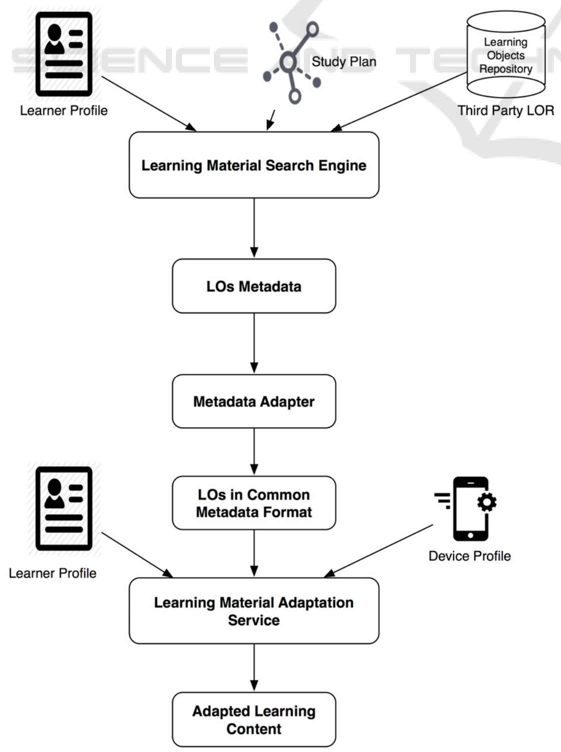

Figure 2: LOs metadata adaptation process.

***Step 2*:** The metadata of imported LOs, described using the common model of the framework, and the learner's profile and the device profile are the input of the adaptation (transformation) service, which generates content adapted to the learner's device. Open source software tools for developing mobile applications such as PhoneGap and Apache Cordova allow generating native apps for different kind of platforms (Android, iOS, etc.) and various kinds of devices. The adaptation service may use this kind of tools for generating adapted content to the learner's device.

7 CONCLUSIONS

Training organizations, which offer mobile-learning, face the following challenges: support and adaptation of learning content to multiple devices, adaptation of the learning material to the mobile learner profile and preferences, and the ability to integrate learning content from external training providers and open repositories with in-house learning content.

In this paper, we have described our proposed cloud-based framework for adaptive mobile learning. We described the components of the framework at the cloud service of the educational institution and the components to deploy on the device of the mobile learner. The proposed solution takes advantage of the benefits procured by the cloud regarding elasticity of resources and scalability by supporting a large number of mobile learners. It permits to adapt both the course content and the mobile learner interface dynamically. We have also described the process of importing learning objects from third party learning providers and their integration with in-house learning objects, which allows building and adapting the study plan and the learning material to the mobile learner profile.

As a future work, we intend to build a prototype of the proposed framework and to experiment with few LO repositories to create dynamic content.

REFERENCES

Brusilovsky, P. (2003). Adaptive navigation support in educational hypermedia: The role of learner knowledge level and the case for meta-adaptation, *British Journal of Educational Technology*, 34(4), pages 487–497.

Cavus, N. and Ibrahim D. (2009). M-Learning: an experiment in using SMS to support learning new English language words, *British Journal of Educational Technology,* 40(1), pages 78-91.

Chung, T. S., Rust, R. T., and Wedel, M. (2008). My Mobile Music: An Adaptive Personalization System for Digital Audio Players, *Marketing science*, 28(1), pages 52–68.

Crompton, H. (2013). A historical overview of mobile learning: Toward learner-centered education, In Z.L. Berge & L. Y. Muilenburg (Eds.), *Handbook of mobile learning*, pages 3–14, Florence, KY: Routledge.

Davies, B. S., Rafique, J., Vincent, T. R., Fairclough, J., Packer, M. H., Vincent, R., and Haq, I. (2012). Mobile Medical Education (MoMEd) - how mobile information resources contribute to learning for undergraduate clinical students - a mixed methods study, *BMC Med Educ*, 12(1), pages 1.

De Bra, P. and Ruiter, J. P. (2001). AHA! Adaptive Hypermedia for All, *In Proc. of WebNet—World Conference on the WWW and Internet*, Association for the Advancement of Computing in Education, pages 262–268.

Economides, A. (2006). Adaptive Mobile Learning, *Fourth IEEE International Workshop on Wireless, Mobile and Ubiquitous Technology in Education*, WMUTE '06, pages 26–28.

Fang, H., Liu, J., Huang, R., and Li, Y. (2009). Research on adaptive mobile learning resources platform based on learning object model, *the Int. Conference on Application of Information and Communication Technologies*, AICT 2009, pages 1–6.

Gipple, J. and Lord, E. (2016). Understanding Mobile Learning and Best Practices, ICS Learning Group. http://www.icslearninggroup.com/whitepapers/understanding-mobile-learning-and-best-practices/.

Heinrich, P. (2012). THE IPAD AS A TOOL FOR EDUCATION, A study of the introduction of iPads at Longfield Academy, Kent. http://www.emergingedtech.com/2012/07/study-finds-benefits-in-use-of-ipad-as-educational-tool/

Huang, J.J.S., Yang, S.J.H., Chen, Z.S.C., Wu, F.C.C. (2012). Web content adaptation for mobile device: A fuzzy-based approach, *Knowledge Management & E-Learning: An International Journal*, 4(1), pages 102–122.

IEEE. (2002). IEEE Standard for Learning Object Metadata, *IEEE Std 1484.12.1-2002*, pages i-32, doi: 10.1109/IEEESTD.2002.94128.

Jung, H., Park, S., and Chung, K. S. (2006). An Architecture for Adaptive Mobile Learning, *In Proc. of the 20th Int. Conf. on Advanced Information Networking and Applications*, AINA 2006, 2, pages 219–223.

Lehman, R. (2007). Learning object repositories, *New directions for adult and continuing education*, 2007(113), pages 57–66.

Litchfield, B. C., Driscoll, M. P., and Dempsey. J. V. (1990). Presentation sequence and example difficulty: Their effect on concept and rule learning in computer-based instruction, *Journal of computer-based instruction*, 17, pages 35-40.

Masud, M. A. H. and Huang, X. (2013). M-learning Architecture for Cloud-based Higher Education System of Bangladesh, *Mobile Computing*, 2(4), pages 84–94.

MERLOT. (2016). Multimedia Educational Resource for Learning and Online Teaching. http://www.merlot.org.

Oh, J., Herrera, J., Bryan, N. J., Dahl, L., and Wang, G. (2010). Evolving the mobile phone orchestra, *In Proc. of the Int. Conf. on New Interfaces for Musical Expression*, pages 82–87.

Pimmer, C. and Gröhbiel, U. (2008). Mobile Learning in corporate settings. Results from an Expert Survey, *mLearn2008*, The Bridge from Text to Context.

Tennyson, R. D. and Christenson, D. L. (1988). MAIS: an intelligent learning system, *In D. H. Jonassen (Eds.), Instructional Designs for microcomputer courseware*. Hillsdale: N. J.: Erlbaum.

Traxler, J. (2005). Defining mobile learning, *IADIS International Conference on Mobile Learning*.

Vassileva, J., and Deters, R., 1998. Dynamic Courseware Generation on the WWW, *British Journal of Educational Technologies*, 29(1), pages 5-14.

Velev, D.M. (2014). Challenges and opportunities of Cloud-based Mobile Learning, *Int. J. of Information and Education Technology*, 4(1), pages 49-53.

Weber, G. & Brusilovsky, P. (2001). ELM-ART: An adaptive versatile system for Web-based instruction, *Int. J. of Artificial Intelligence in Education*, Special Issue on Adaptive and Intelligent Web-based Educational Systems, 12 (4), pages 351-384.

WISC-ONLINE. (2016). Wisc-Online By teachers, for students, get unstuck. https://www.wisc-online.com/