Chapter 1
Roadmap for Adaptive and Personalized Learning in Ubiquitous Environments

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Abstract There is greater awareness in educational system regarding benefits authentic learning experiences bring to the learning process. As a result, ubiquitous educational environments have started to gain acceptance in mainstream education. These environments break the boundaries of the classroom and enable learning to take place in the contexts where learners are able to relate with the learning scenarios in their own living and work environments, leading to better learning experience. This chapter focuses on various contexts that arise in such environments where seamless immersion of formal and informal activities and interactions has potential to contribute to the learning process. With particular focus on adaptivity for individual learners, the chapter explores the diminishing boundaries of formal and informal learning, and the potential of location-aware context-sensitive approaches that are emerging as successor of Web 2.0 paradigm.

1.1 Introduction

The exponential growth of wireless technology in recent years, increasing availability of high bandwidth network infrastructures, advances in mobile technologies, and the popularity of handheld devices have opened up new accessibility opportunities for education. Mobile learning environments overcome the restrictions of classroom or workplace-restricted learning and extend e-learning by bringing the concepts of anytime and anywhere to reality, aiming at providing people with better educational experience in their daily living environments. Use of devices such as mobile phones and personal digital assistants allows new opportunities for learners by being intensely connected. Therefore, educational content can be accessed and interaction can take place whenever learners need it, in different areas of life, regardless of space and time.

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While "mobile learning" is a growing research area, aspects of adaptivity and personalization become more and more important. Incorporating adaptivity and personalization issues in mobile learning systems allows these systems to provide learners with an environment that is not only accessible anytime and anywhere, but also accommodating to the individual preferences and needs of learners. Being aware of and considering the current context of the learners as well as, for example, their different knowledge, interests, learning styles, and so on, leads to a more effective, convenient, and successful learning experience in a mobile learning environment.

This chapter first takes a look at current state of e-learning, the issues learners encounter in existing e-learning solutions, and considers a roadmap for moving toward mobile learning, and subsequently to ubiquitous learning. Particular focus is given on how to provide adaptive and personalized learning in ubiquitous environments. Online Learning has been around for quite some time. Every academic institution has embraced some form or shape of online learning. Taking it further to cater for people who are travelling, who are trying to learn from wherever they can, brings us to mobile learning or m-learning. The question then remains, how we can bring authentic context in learning process, where the ubiquitous learning starts to make sense. This chapter investigates that question.

1.2 Research Issues in Current e-Learning Approaches

Learners in online education have somewhat different requirements compared to traditional brick and mortar institutions. Online learners are not present on campus. Teachers do not see them face to face, and most of the time, face-to-face interaction takes place only when these students actually come to their degree-awarding institution for graduation at the end of their studies, if they come at all. So, trying to teach learners who are at a distance, and facilitating for them the kind of learning experience that will be called good learning experience or even better learning experience than what traditional universities could perhaps provide in the situation where large classrooms are becoming reality, various research issues need to be investigated in order to provide learners the kind of learning experience they deserve. Several research issues are identified where learners demand or expect certain functionality in online learning environments.

1.2.1 Social Interaction

First research issue is that the learners in current online learning environments feel very isolated. When they are engaging in learning process, they are perhaps at their home or their work, and they do not see the same kind of peer exposure as campus-based students see. A lot of research is going on under the umbrella of social

networking area looking at how to facilitate learning communities to enhance the social presence or social learning aspect. A major research area under social networking is to provide social learning community. While there are multitudes of social platforms available, research is ongoing to find solutions that can comply with the privacy issues formal educational institutions experience. An example implementation of such research is Athabasca University's Landing platform (Rahman and Dron 2012) that tries to combine different functionality that is available in various publicly available social platforms, and tries to provide that within the confines of the educational environment, within the secure platform that is required for providing learning experience, and not something that is accessible by anyone who is not part of that particular educational community.

1.2.2 Immersive Environments

Research is also ongoing to provide learning platforms using immersive environments for learning. Many of such immersive environments are now becoming available as open-source platforms, providing opportunities for teachers to configure them to their particular requirements. These platforms enable students to collaborate while gaining hands-on experience for the kind of activities that are typically not possible in traditional online environments, for example, laboratories. It is important to note that these environments are not to replace what used to be done in a physical hands-on environment, but to provide initial practice or initial experience, and also to provide the kind of experience that otherwise would be very costly or prohibitive in certain situations where that affects either public safety or affects production lines, or something similar. So, how can that kind of experience be provided to the learners is another research area that has attracted attention of researchers focusing on ubiquitous learning.

1.2.3 Mobile Learning

Third, online learners are typically not fresh students coming out of high school. They are generally people who are already working. They have their jobs, their families, and other similar reasons why education is not their first priority. They have many other priorities that they have to take care of, and therefore, they learn whenever they can, whichever way they can, and they expect that they will be able to access the content, access the learning activities, and have social interaction through various means. This has garnered a lot of attention of researchers, and the whole area of mobile learning has emerged to support these needs of the students. In particular, research is on-going toward using wide variety of wireless devices and applications, with focus on widening access to education to remote and isolated communities. The idea is to provide content and interaction accessible through

different devices, wherever learners are and wherever they would like to access these on devices of different sizes and functionality. One of the major aims of the research on mobile learning is to remove communication and educational barriers and make learning convenient and available anytime and anywhere. Communities such as immigrants and their families, disabled people, people working and living in remote areas, and others in situations that prevent them from attending education at a prescribed time and location can particularly benefit from mobile learning research.

1.2.4 Adaptivity and Personalization

Since online learners come from different backgrounds, they have different work, life, and learning experiences, they are working at different places, coming from different places, and they also need personalized support that is typically nonexistent in existing online learning environments. The question then is, how we can support them by understanding them, by understanding what their needs are, at that particular moment when they are trying to learn, and provide the learning experience accordingly. This has resulted in the research area which has evolved under the umbrella of adaptivity and personalization. Efforts are underway to identify how we can design different paradigms and architectures for personalized learning, and then implement learning systems that take into account different characteristics of learners, the kind of technologies that are available, in the physical environment these learners are trying to learn, and then consider the context in which the learning is taking place. Researchers are also focusing on combining all that with the authentic experience learners can get within the physical environment they are learning, so as to take advantage of real-life objects that are available in such environment and combining them with virtual or electronic information to provide suitable learning experience.

The basic idea behind these research approaches is to empower learners, knowing that these are the learners who are learning within their own environment, within their own restrictions or confinements of their own life style. How can we provide them the kind of experience where they feel that they have the options to choose and to take decisions on how they think they can make their learning experience better?

1.3 Overall Research Direction

The focus of the overall research in adaptive and personalized learning in ubiquitous environments is on improving learning experience of learners, whether they are online or in classroom. The aim is to increase the accessibility to education for all different types of learners in such kind of global environment that we currently

have. And then, the next question is, how can we bridge the gap between different learners? Different learners learn differently. Different learners have different backgrounds. They are at different stages of learning. How can we bridge the gap and how can we know about them as much as we need to? Subsequently, how can we provide the kind of learning that can bring the learners who are at lower stages to the same level or even higher than where typical educational environment would take them?

Next is to provide support for mobile and life-long learners. Online learners are generally working adults. In fact, nowadays regardless of any university or any educational environment, learners are engaged in different types of activities, and the question is, how can we, first of all, accommodate learning within their environment, and second, how can we harness the benefits they get from different types of activities they are involved in, to improve learning?

In terms of how can we change the educational system, so that it is something that is actually what learners start to like, that is the aim of this research: just-in-time learning, on-demand learning, and quite importantly, context adaptation, because learners are in different environments. Learners have different backgrounds. Not everybody learns in the same way. Not everybody learns, or understands, or has perspective in the same way. How can we understand them first, and then provide learning that works for that one particular student, and, then another student, and, then another student…? And, how do we do that, while not overburdening the teacher? There is no way that a teacher himself or herself can provide such kind of individualized learning to large number of learners. So, how can technology help in that process, so that without overloading the teacher, we can provide such kind of adaptive and personalized learning?

The vision is to make learning omnipresent and highly contextual. Learning does not remain just a classroom phenomenon. Because learning happens everywhere, so the definition of learning also needs to change, to include those components which are currently not count as actual as learning. These components have a rather significant impact on the learning process. For example, any informal discussions that take place during the course of day to day living, while they provide significant learning, are not treated as the moments of learning as such. Problem is that there is no record of what is learned in such situations, and when such knowledge is needed in other situations, without any formal records, the assumption would be that the learner did not have that knowledge.

Next issue is how do we use that information into future learning process, future learning experience? The term "learning experience" is used here to encompass various aspects of the learning process, and not just the learning content. Content is just one component of the overall learning process. Learning activity itself is not full learning either. A lot more goes around, both in forefront and in background that contributes to learning process, and learners—they do, regardless of the generation, a lot of different activities that contributes to learning process. How can we actually take account of that and use that to provide further learning?

First and foremost, we need to identify as much information as possible about our learners. Extensive modeling of what they are doing at any given time, what

interactions they are having with others, with the learning system, and with the content. In what kind of mood they are? Mood is something that changes very fast, but that also affects very significantly the way we learn or how much we learn. We also need to know their trends of preferences. People have different preferences but people actually change preferences also as fast. So it is important to understand their trends of preferences, so as to infer their possible preferences in near future. Another important piece of information is the kind of skills and knowledge levels learners have. People have changes in the levels of their skills and knowledge all the time. Some changes are explicit, such as in the classroom where learners are learning and the teacher is noting "OK, I have taught this", and some changes are implicit, such as those that happen during informal chat outside classrooms. The question is how to identify those changes that are implicit.

All these issues require real-time monitoring of a number of different parameters, such as learners' location, and learners' technology use—what technologies are available to the learners, and what technologies exist in the surroundings of the learners that can provide information about the learners' environment. Another parameter is the changes in learners' situational aspects—the changes in the context. Changes in the situation describe better what context means here, since it can provide us enough information to at least start working on providing adaptivity, providing customized learning, and providing personalized learning.

1.4 Learner Awareness

While there are several aspects that can provide insight about the learners, an important aspect is to know about the knowledge and skills sets possessed by the learners. What does the learner know about a certain topic? What does he/she know about the overall area in which that topic is situated? What kind of skill levels he/she have? What kind of knowledge decay there has been since the topic was learned last time? When was the last time the learner learned that topic? All those kinds of things are part of performance based model.

Performance based models have been researched extensively for more than 40 years (Self 1974). A number of very efficient and effective student modeling techniques have become available since then that can provide comprehensive information about students' domain expertise.

Another area of learner awareness is cognitive traits, which provide information about cognitive or mental capabilities of the learners. These capabilities are built-in; they are hard-wired. They are rather persistent and the rate of change is very slow. It can take decades to see any real changes in these capabilities. So, if we can identify somebody's, say, working memory capacity, which is one of the cognitive traits, we can personalize learning experience accordingly. Working memory capacity allows keeping active a limited amount of information (7 ± 2 chunks) for a short time (Miller 1956). Further analysis of this suggests that some people can keep $7 - 2 = 5$ chunks, while others can keep almost double of that number ($7 + 2 = 9$ chunks). So,

the question is, whether both types of learners should be given same kind of content and same kind of learning activities? Or, should we take advantage of this information and customize learning content and interaction to suit their working memory capacity? Similarly, there are many other cognitive traits, such as inductive reasoning ability which is the ability to construct concepts from examples, associative learning skills to link new knowledge to existing knowledge, and information processing speed that determines how fast learners acquire the information correctly. These are just some examples of cognitive traits that influence the learning process. There are many more cognitive traits that can be measured and used to customize the learning process. If we identify that someone has, say, low working memory capacity, high inductive reasoning ability, medium information processing speed, and high associative learning skills, we could probably provide them a package of instruction that works effectively for that particular set, compared to somebody who may be at the exactly same performance level, but has different levels of cognitive traits.

Learners also have different learning styles, and knowing about individual students' learning styles enables educational systems to personalized learning. Benefits of learning styles have been open to debate for decades. Majority of learning style models that exist in the literature attempt to classify learners into a particular type of category, such as active, visual, etc. However, people do not behave in one particular manner all the time. What people have is different tendencies that they exhibit as and when choices are available. So, a person with active tendency would still behave as reflective when needed. For example, Felder Silverman Learning Style Model (FSLSM) promotes the concept of tendencies by putting learners' preferences on four dimensions, namely, Active-Reflective, Sensing-Intuitive, Visual-Verbal, and Sequential-Global, where each learner has strong or moderate tendency toward one of the extremes of each dimension, or the learner may exhibit equal tendency for both extremes (Felder and Silverman 1988). FSLSM goes one step further by also analyzing what kind of learning activities and learning experience would work better for a particular learner with particular learning style tendencies. The teacher can then use this analysis to decide what to do. Teacher then has possibility to make informed decision whether to provide learning to suit a learner's learning style, or to provide content and interaction in a way that challenges learner's learning style tendencies, so as to encourage him/her to excel even outside of his/her comfort zone.

So, the first step is to identify those learning style tendencies. There are different methods available to analyze them. Typically, learning style models require completion of some sort of questionnaires to measure people's learning styles. For example, Felder and Silverman (1988) use 44-item questionnaire, where each of the four dimensions (Active-reflective, sensing-intuitive, visual-verbal, and sequential-global) is measured through 11 questions of the questionnaire. While questionnaires can provide a fairly accurate estimate of the learners' learning style tendencies, they suffer from two major drawbacks. First, they take time away from actual learning tasks. Second, they provide a snapshot in time, and any changes that may have occurred since the learner completed the questionnaire need re-completion of

questionnaire at regular interval, taking further time away from the learning process.

Research has been done to identify learners' learning style tendencies by observing their actions in the learning systems when learners are engaged in actual learning process. If we can identify learners' characteristics and tendencies through that observation, that would provide more reliable information. For example, Bayesian networks have been used to detect learning styles by monitoring learner action in learning management systems while they are learning the actual content (Graf 2007).

It is important to note that the application of pedagogy guides the learning process, but detection of attributes, such as learning styles, allow for finer interventions. Ubiquitous learning technologies play a significant role in such determination, as they allow teachers to understand learners' characteristics by analyzing learners' actions regardless of learners' location, time of study, and other similar parameters.

A dynamic learner modeling platform has been created as an example using various components of learner awareness, which mines the historical data of the learners and the real-time data of their activities to provide real-time adaptivity. The monitoring of learners' activities in the platform takes place in a very heterogeneous environment. It is not an environment where learners are sitting in a lab, or sitting at home. The learning is supposed to happen where learning actually happens. What it means is that learning happens when learners can relate to the learning. Learning happens in authentic environments. For example, for an arts student who is trying to learn about certain paintings, sitting at home and trying to learn about it, or sitting in a class and trying to learn about it, perhaps is not the best way to do it, compared to if the learner actually goes to a painting exhibition, or a museum or something like that.

In such kind of authentic environments, it is not possible to bring and use devices such as desktop computers. Even laptops would not be very comfortable. But with technical advancements, many other kinds of devices have become available, such as smartphones and tablets that are now so ubiquitously available. These scenarios are taking instruction into more complex learning environments where complexity is increasing not just by who the individual learners are, but also what kind of device they have, and what kind of technology they have available at their disposal? Are there any sensors which can help in learning process? How can they actually learn from real objects available in authentic environments if there is no teacher available at hand who can help there and then by looking at what the learner is currently looking at?

Several different parameters are used in the dynamic learner modeling platform to provide such kind of authentic learning. These include learning activities, learning styles, interests and knowledge, problem solving activities, what kind of learning objects and learning activities the learner has used, what kind of social activities he/she has engaged in as a learner, where he/she is now, where he/she has been, and what he/she did in previous locations so that the platform can analyze

what he/she should do in the current location. So for that we need to know about learners' location.

1.5 Location Awareness

If learners are using one of the newer cellphones, then it is very easy to identify their locations, because nowadays most of these devices come with Global Positioning System (GPS) navigation chip. Even if a cellphone does not have such navigation chip, it is still possible to identify its location, since all cellphones are connected to 'cellular network base stations' to facilitate users to make calls. At any time, the cellphone phone connects to multiple cellular network base stations. By doing so, it can provide connectivity even when the user is moving long distances, by seamlessly hopping from one base station to another. By identifying the intensity of the connection, it is possible to pinpoint learner's location. If the phone also has GPS, the information from GPS can be combined that with the information from cellular network base stations in order to triangulate learner's location even more precisely. Of course, GPS technology does not work well inside the buildings. There are other technologies available that can work inside. For example, if there are Wi-Fi access points nearby and/or the device is connected to Internet, there are other location calculation methods that can be used. Google maps, for example, use such methods to identify users' location.

Once the learners' locations are known, various methods can be used to improve learning experiences of the learners. For example, location based optimal groups of the learners can be created. Such learning groups or study groups can be based on a number of different parameters that are available about different learners, for example, learners' location information can be combined with their learning profiles, learning styles, and their learning interests to create different types of groups. An example is the complimentary groups, where learners with different knowledge and skills come together and help each other; or learners with a similar kind of information but at different levels, so that they can mentor each other (Tan et al. 2010).

1.6 Environment Awareness

Once the location of a learner is known, in order to create authentic learning environment, we also need to identify what are the real life objects that are available in the learner's vicinity that can be used in the learning process. Such environments are typically outside of classroom and need to be created on-the-fly in order to support opportunistic learning, so the location of the learner is not known in advance. In such situations, there are different ways to dynamically identify real life objects. There are public databases of points of interest. For example, Google maps

Fig. 1.1 Ubiquitous learning at flower expo

allow users to upload images at certain locations and then they become accessible to everyone who searches for that location. Quick Response (QR) codes can be used to very cheaply tag different objects.

For example, Fig. 1.1 shows a photograph taken by the author at an international flower expo in Taiwan. While looking at the flowers, the nearby board provides some further details of that particular flower in three different languages. More importantly, the board contains a QR code on top right corner, which once accessed, takes the user to a website that contains more information about that particular flower. So, for a learner, the situation provides watching the real flowers, reading some basic information about those flowers on the board, and then getting further information from the Internet within the context of that real situation. Such scenario enables learners to actually experience the learning. Similar scenarios can be created within any other learning context, such as for factory processes, or any law firms. The sky is really the limit there.

So there are a number of ways to identify real life objects for learning purposes. Besides QR codes, if there are Wi-Fi access points available, certain objects can be annotated to them. In that case, as soon as the learner's mobile device approaches a Wi-Fi access point, it would be able to deduce that certain real life objects are available in nearby area. Active and passive radio frequency identification tags (RFIDs) are other technologies that can be used for the purpose of real life object identification.

1.7 The Research Framework—5R Adaptation Framework

Based on various learner, location, and environment awareness parameters, adaptive and personalized learning can be reliably provided in ubiquitous environments. An example of this approach is illustrated by the 5R Adaptation Framework, which identified these different components and then provides learning based on that. There are five different dimensions in the framework (Tan et al. 2011): timing of learning, learners' location, the device being used by the learner, learning content, and learner's individual characteristics.

The first component of the framework is *the right time*, where the date, time, and learning progress decide what kind of learning can and should happen. So for a law student, for example, who wants to learn about what happens in the Alberta legislature, then depending on the current time and the opening and closing time of the Alberta legislature, the systems built using the framework will either recommend the student to go there and provide related content, or otherwise will notify something like "No point giving you this particular content at this time because Alberta Legislature is closed at the moment". Similarly, the second component of the framework, the current geographical location of the learner, will enable the systems to show learners the content based on GPS Coordination match.

Then third component of the framework, namely the *device being used by the learner* dictates what kind of content and interactivity can be presented to the learners, based on the functionality available on different devices. For example, certain devices do not support Flash content. So, if the learners carrying those devices receive Flash content, it will not only not contribute toward the learning process but may also create serious obstacles in ubiquitous learning environments where learners rely on such content in the absence of immediate availability of teachers. The more we can find out about the technology that a learner is using, the better we can customize learning experience.

Another component of the framework is the *right content*, which indicates the kinds of objects available in the vicinity of the learner, what kind of learning activities that can be created using those objects, and what kind of learning instruction can be provided so that learner can get correct context.

The final component of the framework is the characteristics of the learners themselves. Different learners have different requirements. Different learners have different capabilities. When they are learning different things, they need different kind of content. So identification of who the learners are, and their different characteristics are then used to provide correct content.

1.8 The Vision Toward the Future

The more we know about the learners, the technologies available to them, their locations, the more there is need to understand the context of learning by analyzing all the available information. With context, we can identify, first of all, how to

structure learning content, learning experience, learning activities, interaction, and so on, to suit that particular context. Then it can help in identifying what kind of learning objects, be them real life or virtual, the learners are actually interested in. This can then lead to proposing learning activities using that content, followed by leading the learner around the ubiquitous learning environment to undertake those learning activities. An early example of this approach is the context-aware mobile role playing game (Lu et al. 2014), which uses ubiquitous knowledge structure, and creates a storyline that uses that context-aware sequencing of learning objects and learning activities, based on learners' location, location of physical objects, and other parameters related to the learners.

Such ubiquitous learning environments have potential to provide effective learning to different types of learners in different situations. For example, active learning scenarios can be created for learners who have aptitude toward exploratory learning. Such environments can be created using passive technologies, such as QR codes, passive RFIDs etc., that enable learners to explore the environment and undertake various problem solving tasks. On the other hand, passive learning can be provided to those novice students who require more observational learning. Using active technologies, such as active RFIDs, Bluetooth access points, etc., the ubiquitous learning environments can guide the learners to the exact location of the learning objects and provide guided learning activities. In both types of learning scenarios, adaptive and personalized learning processes have potential to automatically assemble learning content to build the learning activities and learning path dynamically, to facilitate opportunistic learning.

In future, it is hoped that the emerging Big data analytics techniques will also play significant role in the learning process, and the lines between formal and informal learning will blur even further. Future ubiquitous learning environments will be able to use advanced data mining techniques to identify relevant patterns such as where and when the learners have difficulties and where their strengths lie. These information nuggets could then be presented to the teachers using advanced visualization techniques and smart technologies to enable them to naturally interact with the learners remotely using rich interfaces, and investigate and analyze learners' behavior, activities, and performance in truly ubiquitous learning environment. Such scenarios will enable teachers to intervene in the learning process in real time and provide learners with advice and support such as explaining the topic/tasks, pointing to particular learning material, providing learners with the activities that could help them in understanding the particular topic/task, and creating teams on-the-fly with complementary strengths. Furthermore, such environments may even help in gathering data about how different teachers respond in certain situations, which kind of support they provide to their learners, as well as how a particular teacher previously responded in certain situations. Based on this analysis, the adaptivity and personalization approach may even be able to offer suggestions and guidelines to the teachers themselves when a similar situation is identified in the future.

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