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A Survey on Context-Aware Ubiquitous Learning Systems

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Abstract: Ubiquitous computing is currently emerging as an important element of wireless communication and sensing technologies. It builds an intelligent environment to support learning such that the users share learning services without the awareness of underlying technologies. This intelligent environment in ubiquitous computing is mainly achieved through context-awareness. A wide range of context-aware schemes has been proposed over the last decade. Those contributions are restricted to specific task only. They did not support a complete context-awareness in ubiquitous computing environment. It becomes a necessary to identify the reasons for those issues. Hence this paper reports the overview of context-aware ubiquitous learning environment systems with its types. It also concludes with pros and cons of ubiquitous learning environment systems noticed from the literature.

Keywords: *Ubiquitous computing, U- learning, Smart devices, Context-awareness, Ubiquitous learning environments.*

1. INTRODUCTION

Ubiquitous computing is a new computing paradigm shift where technologies become visually invisible in our daily lives [1]. It plays a vital role in building an intelligent learning environment to support learners, where learning process can happen at anytime, anywhere and in any devices. In ubiquitous learning environment this intelligence is mainly achieved by context-awareness, a technology that assists ubiquitous computing applications to timely sense contextual information and adapt to the changeable contexts. Contexts refer to the any information that can be used to characterise the situation of an entity, (*e.g.*, user *id*, name and location) [12]. Research on context-awareness has grown dramatically since ubiquitous computing came into begin. From the beginning, context-aware research was determined by integrated sensing, hardware integration and object localization in smart spaces (*e.g.*, meeting rooms, campus and houses). The challenges breadths of the field have been enormous. In the mobility computing learning environment, the learners move from one location or situation to another and their context triggered and changes at runtime in real -world learning environment. The handling contexts in this mobility computing environment would be extremely tedious and error-prone. These arise a sharp gap between the high level requirements from ubiquitous learning applications and the

operation complexity in handling contexts from the environment. They are mainly concerned with how to continuously satisfy the needs of individuals in the presence of mobility and heterogeneity. The ubiquitous computing application requires various aspects, such as flexibility, high adaptability and intelligence. The rapid development in ubiquitous computing makes the gap becomes more and more obvious.

A variety of real-world projects and applications bridging the gaps and removing the development obstacles in designing ubiquitous learning environment. However, they partially support context-awareness. This leads to the development of context-aware ubiquitous learning environment for learners to detect their real world context and their status to provide needed information at right time and at right place. Finally, this survey presents an overview on systems and their approaches of context-aware Ubiquitous learning (U-learning) environments.

The remaining part of this paper is organized as follows:

Section 2 introduces preliminary knowledge about smart learning environments such as Electronic learning (E-learning), Mobile learning (M-learning), Ubiquitous learning (U-learning), contexts and context-awareness in ubiquitous computing.

Section 3 presents an overview of existing context-aware ubiquitous learning environment systems and their approaches.

Section 4 discusses challenging issues and points out future research directions.

To this end, Section 5 concludes this survey.

2. BASIC CONCEPTS

2.1. Smart Learning Environments

Smart Learning Environments (SLEs) is nothing but the transformation of traditional learning space into Smart learning space. SLEs are physical environments that improve better and faster learning by enriching the environment with context-aware and adaptive digital devices which provide the situations, events, interventions and observations needed to stimulate a learner to learn, to know and deal with situations (identification), to socialize with the group, and to practice and reflect.

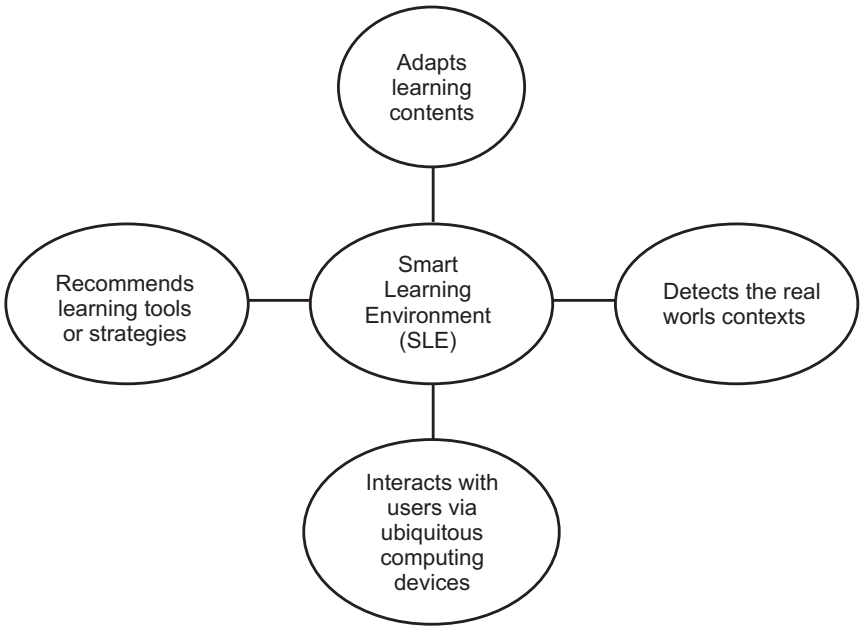

Figure 1: Smart Learning Environment

A Smart Learning Environment [14] consists of one or more digital or sensor devices embedded into physical location of the learner.

1. The sensor devices must be aware of learner's location, situation and context.
2. The sensor devices must provide the learners learning functions such as needed information, assessment, remote collaboration, feedbacks etc.
3. The devices should monitor the progress of the learners and provide the appropriate information to the learners.

According to Hwang et.al., SLE is a technology-supported environment that can adopt and provide support such as guidance, feedback, hint or tools in the right place and at right time based on learners needs which may be determined through analysing students behaviour and performance through online and real world context in which they are located [16].

2.2. E- Learning

E-learning ('Electronic learning') is also known as 'online learning' in general it refers to computer-enhanced or technology enhanced learning [11].It is a purposeful use of electronic system or computer in support of the learning process (Allen, 2003). E-learning is a broad set of applications and processes, such as computer-based learning, Web-based learning, virtual classrooms and digital collaboration.

Elliott Masie defines E-learning "As the experience dimension of E-learning, which includes such factors as engagement, curiosity, simulation and practice".

2.3. M- Learning

Mobile learning, sometimes called M-learning, [11] is learning acquired with the use of small, portable computing devices. It is the idea that a student can learn from any place at any time using portable learning devices. Pinkwert et. al defines M-learning as ". . . E-learning that uses mobile devices and wireless transmission."

Santosh defines M- learning as "acquiring of any knowledge or skills through using mobile devices like smart phones, personal digital assistants (PDAs) etc at anytime, anywhere."

2.4. U- Learning

"Ubiquitous computing" was first termed and coined by Mark Weiser [1]. Ubiquitous computing refers to seamless integration of physical devices into user's everyday life to make computing anytime and everywhere and at any device.

Saadiah Yahya defines "Ubiquitous learning or *u*-learning is a new learning standard, which is said to be an expansion of previous learning standards as we shift from traditional learning to electronic-learning (*e*-learning) and from *e*-learning to mobile-learning (*m*-learning) and now we are shifting to *u*-learning" [5].

$$\text{U-learning} = \text{E-learning} + \text{M-learning}$$

According to Boyinbode et.al., Ubiquitous learning environment (*u*-learning) is a learning environment that anyone can access anywhere, anytime or any device. U-learning environments are supported by mobile and ubiquitous computing technologies which include mobile devices, embedded computer devices such as GPS, RFID tags, pads, and badges, as well as wireless sensor networks and devices.

2.5. Sensor Technologies in U-Learning

A sensor is a device that receives physical stimulus and converts it into a signal which can be used by other instruments [2]. Sensors seem to be major part of *u*-learning as they detect dynamic relations between users and objects. They describe users' state in term of time and location aspects which makes a learning supporting application context-aware. At the same time modern sensors are small enough to be embedded in all everyday devices and become invisible companions of a learner.

2.6. Context Awareness

Context is the powerful tool in encoding the information. Schilit, Adams and Want in 1994 defined "context-aware" with respect to location, identities of nearby people, objects and changes to the objects [12]. Simply, a context can be defined as any information that can be used to characterise the location or situation of an entity. Context awareness means the ability of the system to sense or detect different context of learners during learning process and implement the activity of the system with the user [16].

2.7. Context Awareness in U-Learning

A Context-aware ubiquitous learning is a learning system that detects the real- world status of learners using sensing technologies, interact with them via wireless networks and present learning guidance, materials or feedback to them [16]. During the learning process, the learners' real-world learning status and interactions between learners and the system can be recorded for further analysis of the learners.

The essential criteria of a context-aware u-learning environment [3] are as follows:

1. The learning environment should be context-aware, which is able to provide adaptive and personalized supports to the learners in the right way, in the right place and at the right time. By detecting their learning behaviors and contexts in both the cyber/digital world and the real world. Based on the environmental and personal contexts, profile and learning portfolio of the learner in the real world.
2. The learning environment should enable seamless learning from place to place within the predefined area.

3. OVERVIEW OF CONTEXT-AWARE U-LEARNING SYSTEMS

Researchers, practitioners and scholars in recent years have proved the benefits of applying wireless communication, mobile and sensor technologies to outdoor learning activities. Such a learning environment is able to sense the situation of learners and provide adaptive and personalised support, and has been referred to as ***context-aware ubiquitous learning***. Here, in this section we list out various context-aware ubiquitous learning systems surveyed for this paper.

3.1. Context-Aware Writing System (C-Writing)

Tzung-Shi Chen et.al proposed a Context-Aware Writing System (C-Writing) in ubiquitous learning environments. C-Writing system [4] (information system) allows learners to write, read, observe, and discuss. It consists of three-tier architecture, which includes a client, a server, and a database as shown in Fig. 2.

1. On the client slide, system allows learners to assess learning content in any time and any where via PDA (Personal Digital Assistant).
2. On the server side, context-aware writing servers detect position of the learner through RFID technology and provide appropriate learning content for learner.
3. On the database side, a Learning Content Database (LCD) sub-system and a Portfolio sub-system stores the data in a database. The data in LCD sub-system includes essay of model, multimedia, idiom and example sentence. The portfolio sub-system stores learning portfolio and writing of learner.

In this writing environment, learner not only can obtain related information in different place but also can observe and perceive background information and communicate with other peoples to acquire inspiration of writing and proceed with their writing. Therefore, learners are able to write still more vivid, original through stimulation of realistic environment.

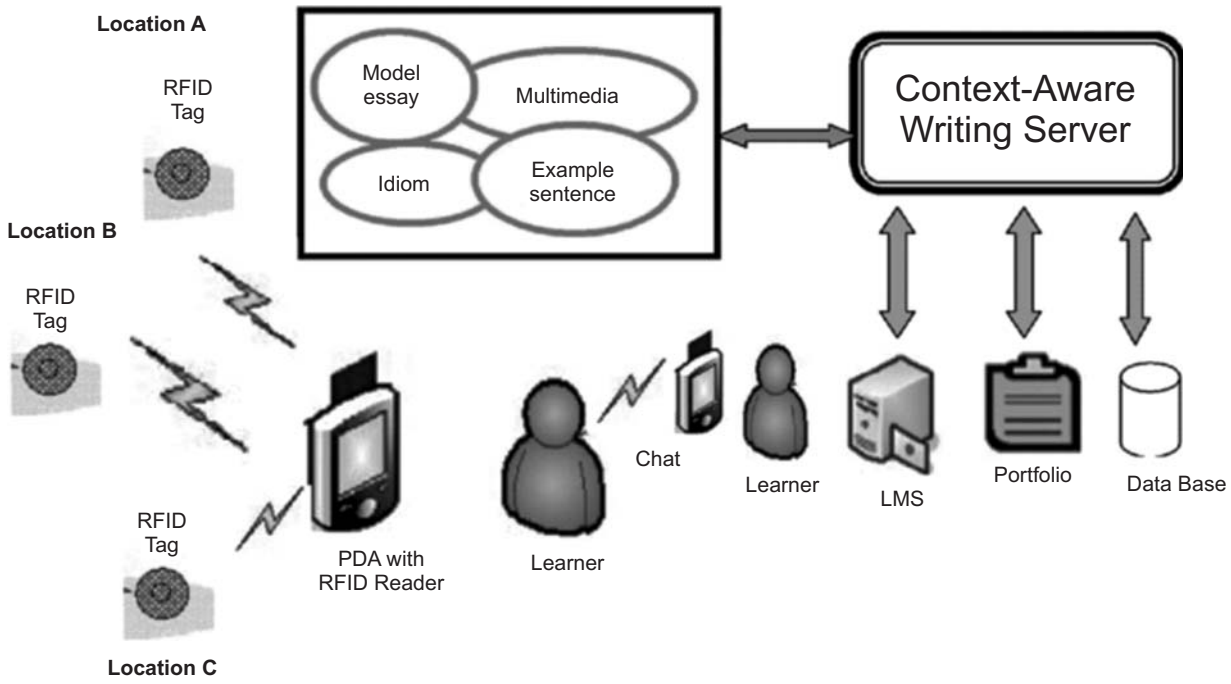

Figure 2: System architecture of C-Writing

3.2. Context-Aware U-Learning Environment System using Repertory Grid Approach

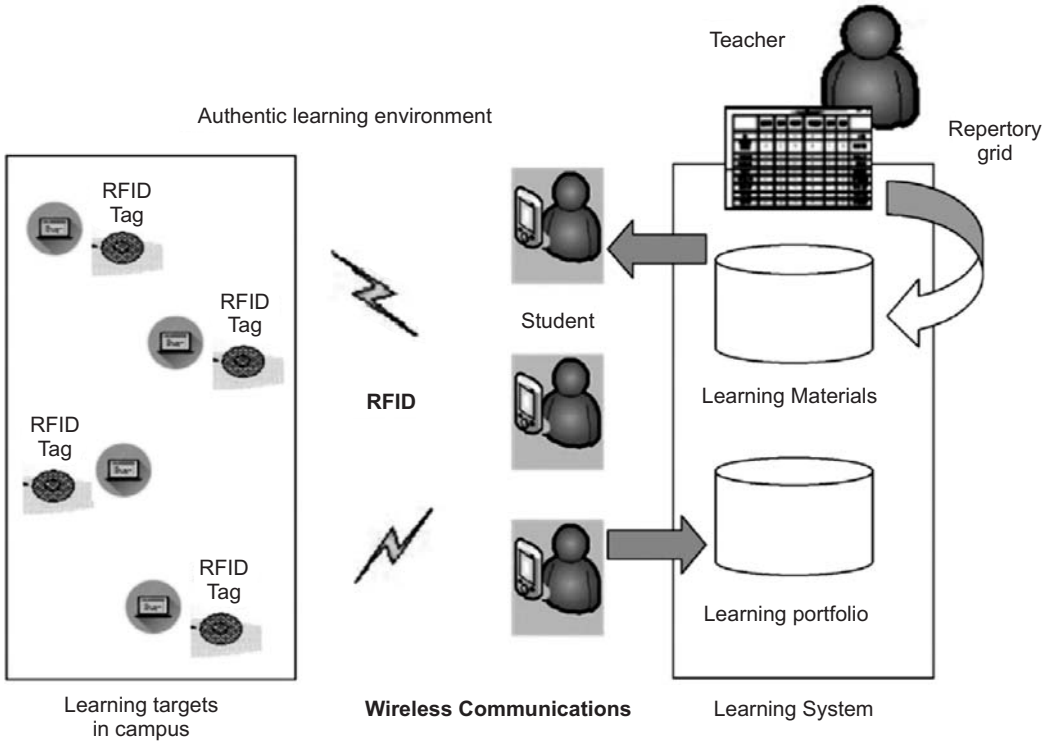

Figure 3: Structure of context-aware *u*-learning system

Ju-Ling Shih et.al developed a context-aware *u*-learning environment system for learning about learning targets in a campus based on [7] an innovative approach by employing repertory grid method in designing learning content. The structure of Context-aware U-Learning Environment system using repertory grid approach is shown in Fig.3. A repertory grid-oriented approach is used to guide the teachers and domain experts to classify the characteristics of the learning targets in a campus. The repertory grid technique is widely used in many fields such as decision making, medical, psychology, monitoring, diagnosing and training activities. This innovative approach enables the environment to be an expert system that guides students' learning and assists them in building their learning in a structured way. Therefore, an expert system is also developed and implemented to assist the design of learning activities.

The context-aware u-learning environment was established with a PDA for students, which detect the RFID tags that were preinstalled around the campus target. The content was presented through a web browser. The students used the PDAs to retrieve learning materials through the wireless network. The students' learning process and development were recorded in real time in the learning system.

3.3. Concept Map-Oriented Mindtool for Collaborative U-Learning (CMMCUL)

Hwang et.al designed a Mindtool, the Concept Map-Oriented Mindtool [6] for Collaborative U-Learning (CMMCUL), which assists students to cooperatively build their concept maps. The concept map editing functions of the CMMCUL are presented by the CmapTools developed by the Institute for Human and Machine Cognition (IHMC) (Novak & Cañas, 2006). CmapTools is a well-known tool that facilitates learners to construct, navigate and share knowledge models which is represented as concept maps. It allows users to construct concept maps in their personal computers and share them on servers via the Internet. The CMMCUL facilitate the students in developing and modifying their concept maps at different learning stages, it also provides dual modes (*i.e*, personal computer mode and mobile device mode) for developing the concept maps. This feature enables the students to compare the real-world learning objects with the concepts they have learned from the textbooks and they recorded in their concept maps.

If the students need to modify the concept maps while observing the learning objects, they can directly make the modifications on their PDA; alternatively, they can take notes on their PDA and make the modifications after discussing them with other learners. Moreover, they are allowed to share their concept maps via the wireless networks. In addition the learning system provides several functions for teachers. It also provides a learning portfolio management function to record both the online learning portfolios and real-world of the learners, as well as user profile management and teaching material management.

3.4. Personalized Navigation Support System (PNSS)

Chuang-Kai Chiou and Judy C.R. Tseng presented a Personalized Navigation Support System (PNSS) for context-aware ubiquitous based on the learning orientation theory to find out an optimal learning path for each student in real time to maximise the learning performance of the learners [9]. The system consists of three navigation modes for guiding the learners, namely linear navigation, semi-linear navigation and hyper-linear navigation. In that, learners are classified as Transforming, Performing and Conforming learners. Fig. 4 shows the learning targets of Navigation modes in PNSS. After considering the characteristics of the navigation modes and learning orientations, a personalized navigation strategy has been developed. In this strategy, conforming learners are assigned to the linear navigation mode, performing learners are assigned to the semi-linear navigation mode, and transforming learners are assigned to the hyper-linear navigation mode.

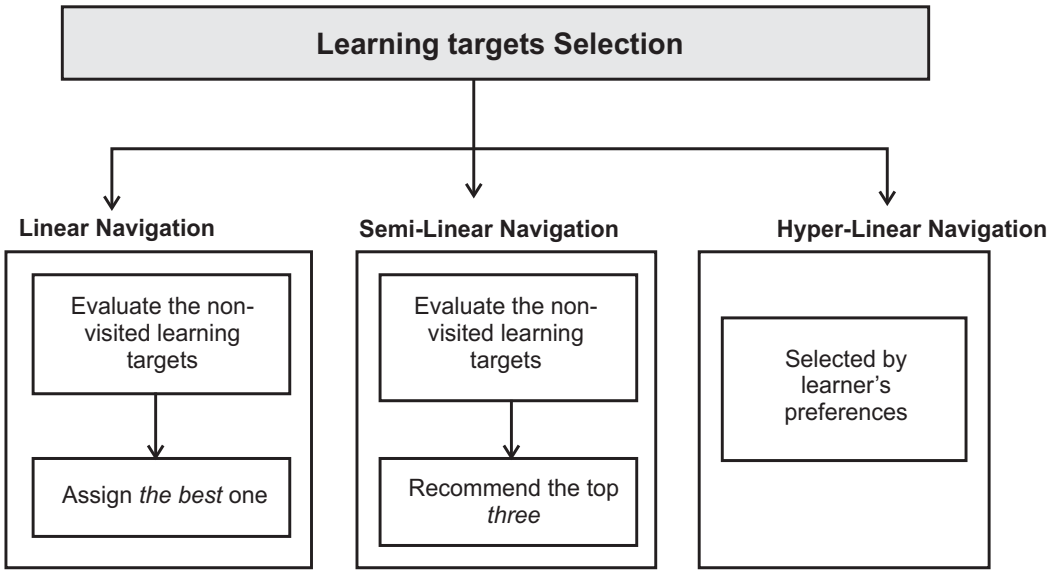

Figure 4: Learning targets of Navigation modes in PNSS

3.5. Context-Aware Ubiquitous Learning System (CAULS)

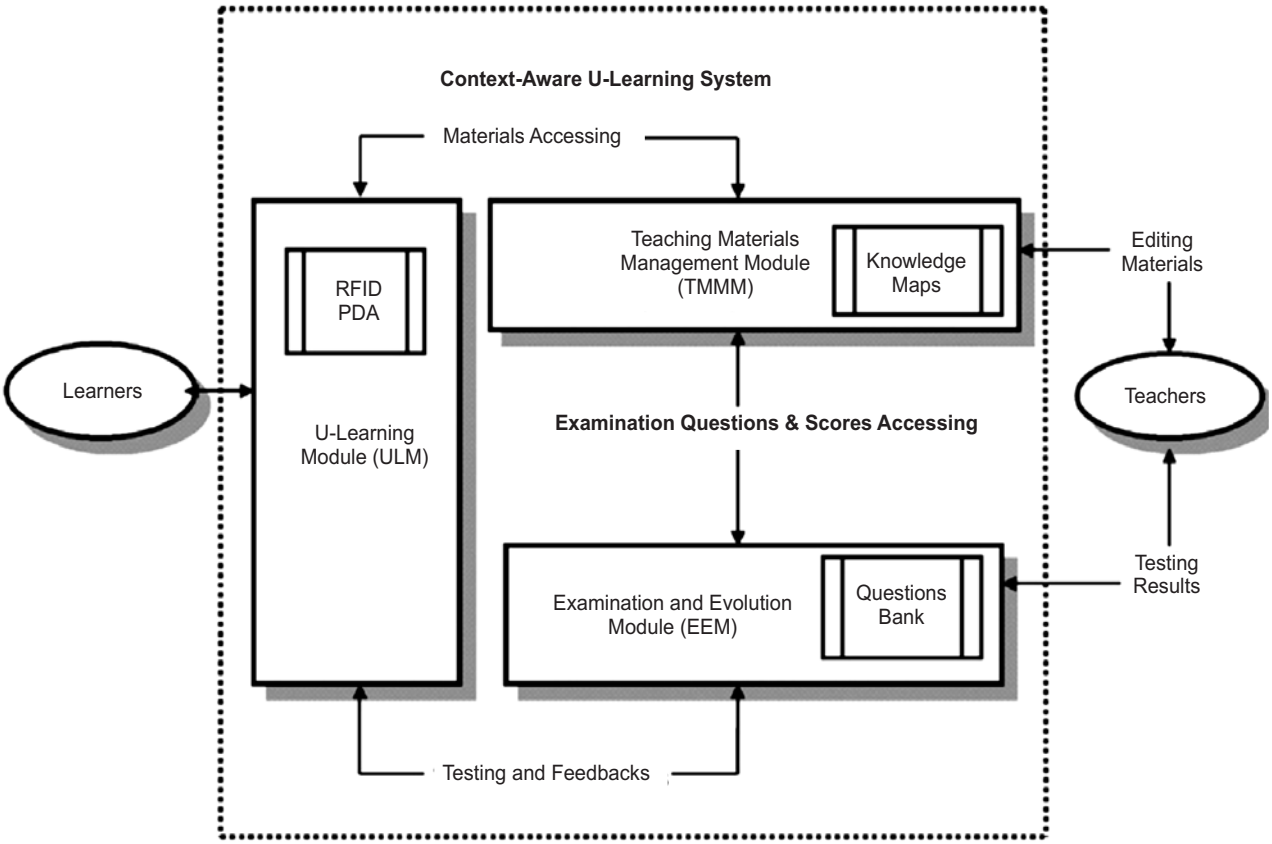

Figure 5: System architecture of Context-Aware ubiquitous learning system (CAULS)

Chia-Chen Chen and Tien-Chi Huang designed a context-aware ubiquitous learning system (CAULS) based on radio-frequency identification(RFID), wireless network, embedded handheld device and database technologies to identify and examine real-world learning behaviors of learners [10]. The architecture view of Context-Aware Ubiquitous Learning System (CAULS) is shown in Fig. 5. This system applies a three-tier teaching strategy such as U-learning module (ULM) for personalized situated learning with a PDA handheld reader, Teaching Materials Management Module (TMMM) for personalized learning path, Examination and Evaluation Module (EEM) for personalized learning situations and summative evaluation analysis to improve the teaching and learning process. Moreover, this system also designed learning materials through context-aware interfaces, and provided personalized learning support for learners. Finally, this system proposed an outdoor teaching tool CAULS, which supports learners in enhancing their motivations and performance with authentic and real-world activities.

3.6. Expert System-Based Guidance Approach for Context-Aware Ubiquitous Learning Environment

Po-Han Wu et.al proposed an expert system-based guidance approach. It is designed and developed for conducting effective context-aware ubiquitous learning activities based on the domain knowledge provided by experienced teachers [13]. Fig. 6 shows the structure of the expert system, which consists of an inference engine, a knowledge base and a web-based interface.

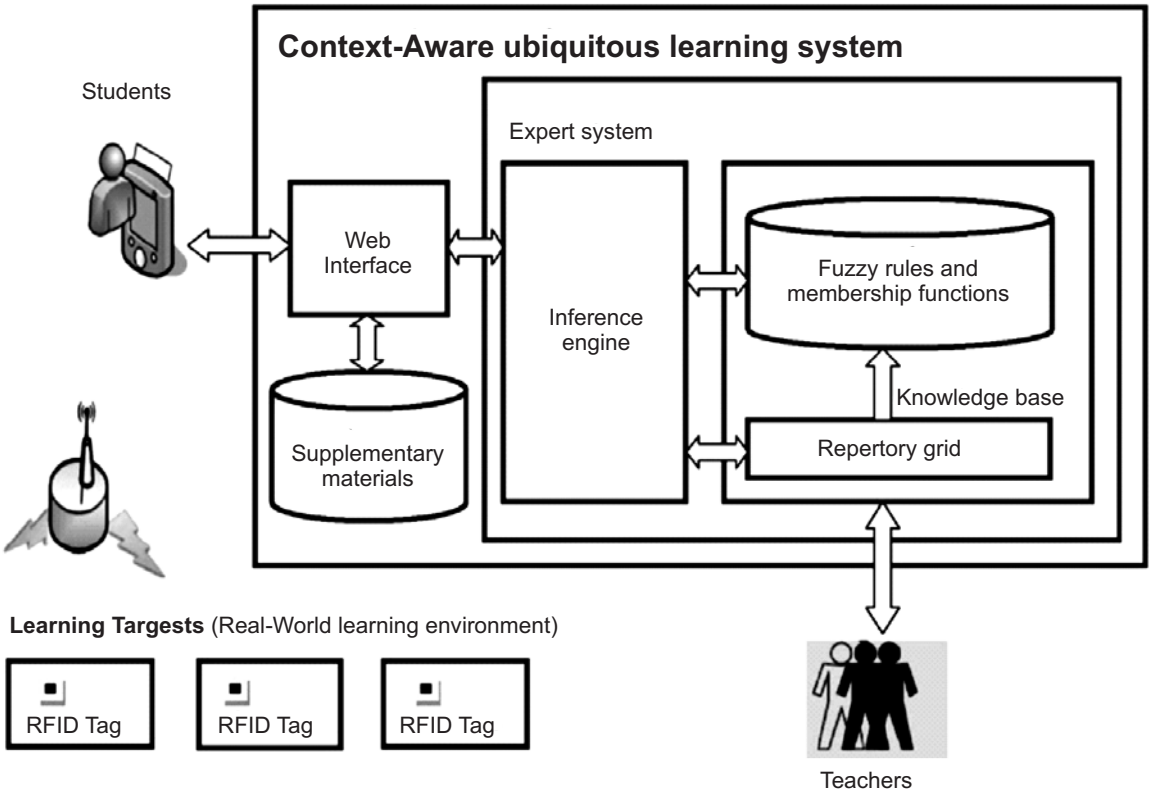

Figure 6: Structure of the expert system -based context-aware ubiquitous learning environment

The knowledge base of the expert system is represented by a tabular known as ***repertory grids***. The repository grid value ranging from 1 to *k*, where *k* is an odd integer, assigned to an element-construct pair, represents the relationship between the element and the construct. An element is a decision to be made, an object to be classified or a concept to be learned. A construct is a characteristic or a feature for describing or

classifying the elements. In repertory grid domain experts provide the knowledge for identifying the learning targets. The extracted knowledge is then used for guiding the students to build their own repertory grids and to clarify some misconceptions in the learning process. The content of the grid is then transferred to a set of fuzzy rules based on the system proposed by Tseng and Wu (2007), that is, then a rule is generated from each column of the repertory grid by using High, More or less high, Average, More or less low and Low to depict the rating values 1, 2, 3, 4 and 5 respectively.

Based on the knowledge provided by the domain experts (*i.e.*, teachers), the context-aware ubiquitous learning system is able to evaluate whether the students can correctly recognize the target by comparing their answers with those of the expert system. The grid-based interactive guiding mechanism can be seen as a *Mindtool* that assists students to collect and organize what they observed and learned in the real world, such findings conform to what has been reported in previous studies, namely that computerized *Mindtools* are able to engage students in higher order thinking, such as '*Analyze*' and '*Evaluate*'.

3.7. Applying Problem-based approach in Ubiquitous Scaffold Learning Environment

Noppadon Phumeechanya and Panita Wannapiroon came ot with an Ubiquitous Scaffold Learning Environment Problem-based Learning model to further develop problem-solving skills with context awareness [15]. It uses conceptual framework which integrates the ADDIE Model, problem-based learning, the scaffolding and Ubiquitous Learning Environment together as shown in Fig. 7.

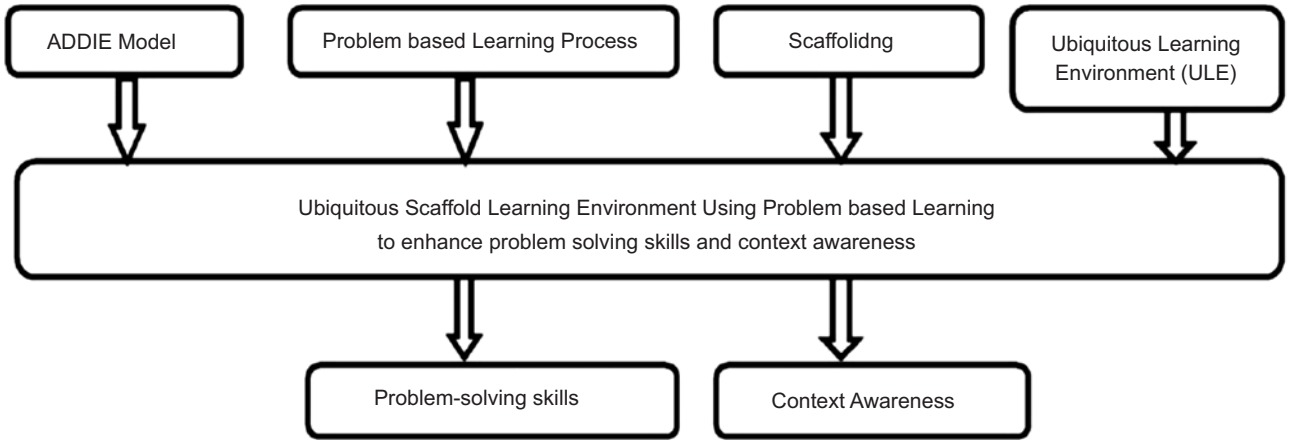

Figure 7: Conceptual framwork of Ubiquitous Scaffold Learning Environment using Problem-based Learning model

1. **Ubiquitous Learning Environment (ULE):** Here the Ubiquitous Learning Environment (ULE) is a management of learning environment in order to support problem-base learning.
2. **Problem-based learning (PBL):** Problem-based learning is a technique in *u*-learning environment, in which the learners will get a problem from the system to be solved. The learners can solve the problem anywhere any time.
3. **u-Scaffolding:** This scaffolding part helps the learners solve the problems that they cannot do by themselves in the process.
4. **This model is divided into two phases:** To enhance problem-solving skills and context awareness, the first phase designs a Problem-based Learning model for Ubiquitous Scaffold Learning Environment.
5. The second phase evaluates the proposed learning model.

3.8. Resource Organisation Model (Learning Cell) for Context Awareness of Ubiquitous Learning

Shengquan Yu et.al achieves context awareness of ubiquitous learning (*u*-learning) resources through Learning Cell [18]. It is designed for the defects of existing learning technologies in the following areas: sharing of processed information and social cognition networks, the intelligence of resources and the evolution of content. A resource aggregation model is represented in learning cell which is different from the other learning object model. It uses the cloud storage model to provide resources for *u*-learning. Fig. 7 shows how learning cell supports *u*-learning environment.

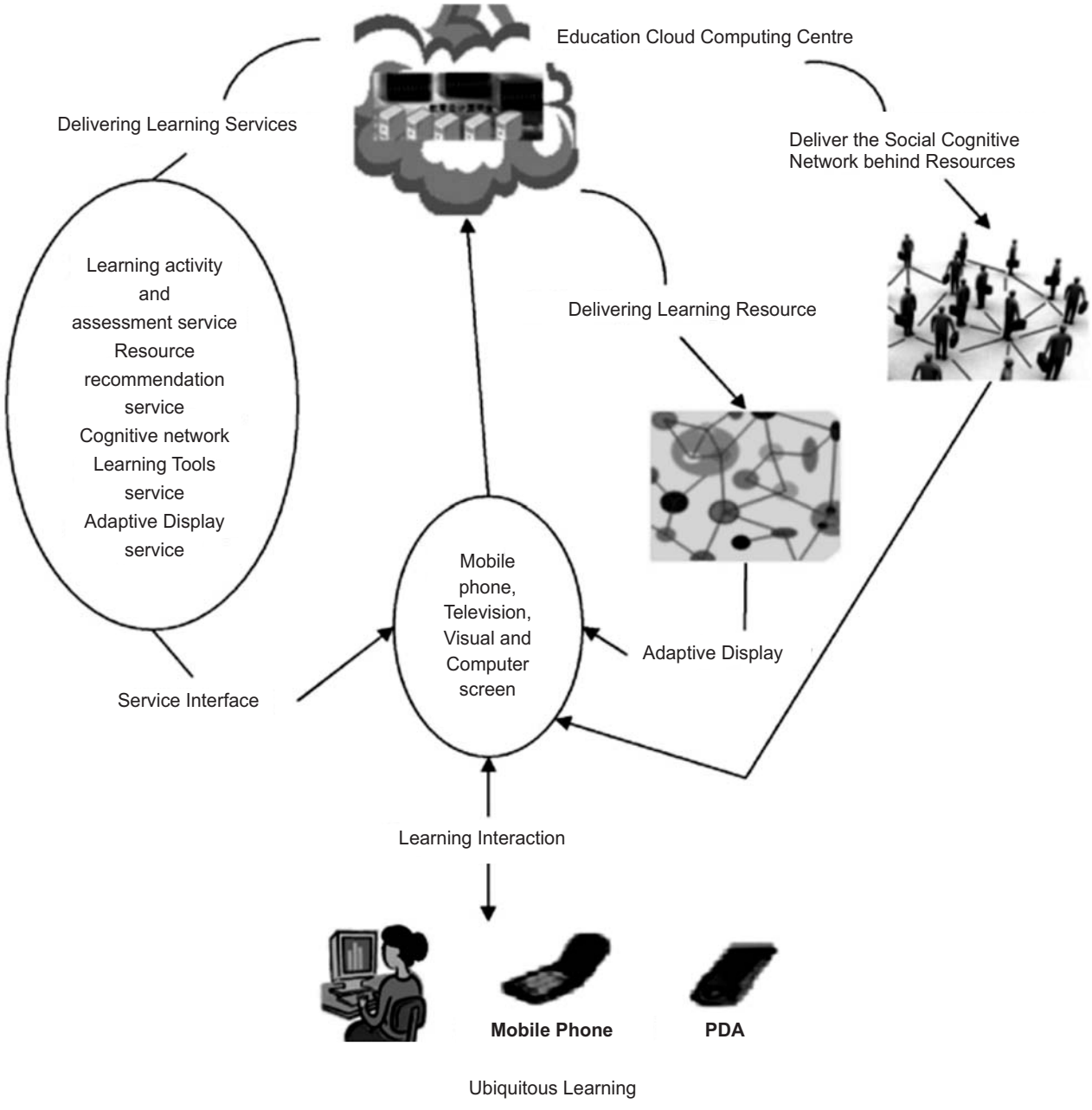

Figure 8: U-Learning supported by Learning Cells

Pervasiveness and context awareness are the two important characteristics of *u*-learning. To achieve these characteristics, the learning space needs to be based on an educational cloud platform, which consists of content-aware devices, evolvable learning resources, pervasive network connections, cognition networks, community networks and learning designs. The platform manages authentic knowledge and field experts and connects the experts in a social wisdom network, establishing knowledge networking social services (KNS) using collective wisdom-based algorithms. As shown in above Figure 8, a seamless learning space for *u*-learning can be achieved through coordination of cloud-computing and multi-media technologies.

When users encounter any problems, the intelligent terminals detect their needs and transform these needs to the educational cloud-computing platforms through pervasive communication networks. Moreover, this platform allows the learner to perform searches, computations and transformations of learning content to the learners and also allows the learners to attach the learning content to learning services and knowledge networks.

3.9. Context-Aware of Ubiquitous Learning System using an Innovative Visualization System

Kousuke Mouri and Hiroaki Ogata proposed an innovative visualization system [17] that integrates network visualization technologies with Time-Map based on Ubiquitous Learning Analytics (ULA). This system describes visualizing relationships between learners and ULL (Ubiquitous Learning Log) is defined as a form of knowledge recorded or learning experiences acquired from learner's daily life. The knowledge of the international students can add to a ULL that are gathered in cyber space by a ubiquitous learning system called System for Capturing and Reminding of Learning Log (SCROLL), and then SCROLL presents the learning contents to the learners to recall their knowledge based on their learning contexts. By using SCROLL system, one can learn interesting knowledge through other learner's experiences. Moreover the learners were able to detect relationships between knowledge and time.

4. DISCUSSION

Ubiquitous computing has evolved due to increasing possibilities offered by recent wireless communication and technological advancements. In Ubiquitous computing, context-awareness plays a major role to provide intelligent learning environment to the learners'. An intelligent learning environment is a learning space embedded with wireless communication and sensor technologies. When it is able to sense the situation of learners' and provide adaptive support without the awareness of underlying technologies, it is called as 'context-aware ubiquitous learning'. Though, a wide scope of context-aware systems has been proposed over the last decades. They only provide partial support to context-awareness in ubiquitous computing environment.

As described in the previous sections, various context-aware ubiquitous learning systems and their approaches have been developed to build intelligent learning environment in ubiquitous computing. Po-Han Wu et.al [13] represents knowledge in grids, which is easy to examine and interpret the structure and logic of the knowledge. It also allows the learners to identify the differences between the targets. Moreover, the students' learning performance with the use of *Mindtools* in a context-aware u-learning environment helps students in improving their analysis performance. Although, the performance of the learning system is desirable. Therefore, it remains a challenging issue to implement such an approach on the modern mobile devices (*e.g.*, smartphones and tablet personal computers) and with new sensing technologies, such as the QR (Quick Response) code.

Noppadon Phumeechanya and Panita Wannapiroon designed Ubiquitous Scaffold Learning Environment Using Problem-based Learning model enhance the problem- solving skills of the learners[15]. Though it increases the problem- solving skill, it should be tested with the learning achievements of the learners.

Tzung-Shi Chen et.al C-Writing system [4], the learners are able to write still more vivid, original through stimulation of realistic environment. Though the learning performance is highly efficient, there are several extended issues need to be addressed. The real-world learning behaviors of the students have not been fully recorded and analyzed. Therefore, it is worth investigating the real-world learning patterns of the students and the relationships between the learning patterns and the learning achievements. Second, it is worth applying this approach to other subject units to evaluate its effectiveness in depth.

CAULS [10] showed that the proposed approach is able to provide more interesting learning scenario to students, developing a positive attitude toward learning that improved significantly, which is even a challenging task for experienced teachers.

Shengquan Yu et.al successfully developed a resource organisation model (Learning cell) [18] for context awareness of ubiquitous learning. But it should be carried out a study on evolution control, contextual cognition, personalized resource recommendation, application modes and ecology-based knowledge construction.

The CMMCUL [6] enables students to build, share and revise concept maps during learning process in an authentic learning environment. Although the CMMCUL appears to be effective, there are some limitations in this approach. Moreover, the small screen size of the mobile devices limits the display and editing of large concept maps. Therefore the teachers need to avoid taking too many concepts into account when creating the learning activities. Furthermore, although the CMMCUL is supportive to the students, the teachers' burden when evaluating the concept maps developed by the students is heavy. Therefore, it is important to offer an automatic or semi-automatic evaluation technique to the teachers to evaluate the concept maps.

The challenge of context-aware adaptation skill is still required with the need of specialisation in instructional and system designs.

Hwang et al., [8] designed a context-aware u-learning guidance mechanism for conducting learning inquiry activities in the real world scenario. Although, the effect of the *u*-learning mechanism achieved satisfactory result from students. It still needs effective and efficient scaffolding tools for students to understand the complex learning problems.

In addition to that, many scholars and researchers provided effective learning tools, strategies, personalized learning support and adaptive learning techniques in context-aware ubiquitous learning. But, incorporating adaptive learning techniques and intelligent tutoring systems to context-aware ubiquitous learning has become one of the important research issues of technology-enhanced learning. Table 1. gives the summary of criteria fulfilment reported in various research contributions.

Table 1
Summary of Criteria Fulfilment

Researcher(s)	*Contribution*	*Adaptive supports to the learners*	*Personalized supports to learners*	*Seamless learning*
Tzung-Shi Chen et.al. 2009	Context-Aware Writing System (C-Writing)	✓	✓	✓
Ju-Ling Shih et.al. 2011	Context-Aware *u*-learning environment system using repertory grid approach	✓	✓	×
Gwo-Jen Hwang et.al 2011	Concept Map-Oriented Mindtool for Collaborative U-Learning (CMMCUL)	✓	✓	✓
Chuang-Kai Chiou and Judy C.R. Tseng 2012	Personalized Navigation Support System (PNSS) for context-Aware ubiquitous learning	✓	✓	×

Researcher(s)	*Contribution*	*Adaptive supports to the learners*	*Personalized supports to learners*	*Seamless learning*
Chia-Chen and Tien-Chi Huang 2012	Context-Aware Ubiquitous Learning System (CAULS)	✓	✓	✓
Po-Han Wu et.al. 2013	Expert System-based guidance approach for context-aware ubiquitous learning environment	×	✓	✓
Noppadon Phummechanya and Panita Wannapiroon 2013	Ubiquitous Scaffold Learning Environment using Problem-based Learning model	✓	×	✓
Shengquan Yu et.al. 2015	Resource organisation model (Learning Cell) for context awareness of ubiquitous learning	✓	✓	✓
Kousuke Mouri and Hiroaki Ogata 2015	An innovative visualization system for context-aware of ubiquitous learning system	✓	✓	✓

5. CONCLUSION

This paper presented the literature review of context-aware *u*-learning systems. This is an active research field that has been produced, since the last decades. We noticed that although, a large body of proposals covering the context-aware u-learning systems under various different perspectives and some proposals report further enhancements on learning systems, the field still suffer from the major limitation of context-aware u-learning systems. We believe that this survey will be useful for researchers and practitioners interested in the area of context-aware u-learning system to do research on new dimensions.

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