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Facilitating professionals' work-based learning with context-aware mobile system



Bingxue Zhang^{a,b}, Chuantao Yin^{c,d}, Bertrand David^b, Zhang Xiong^e,
Wei Niu^{c,*}

^a School of Optical–Electrical and Computer Engineering, University of Shanghai for Science and Technology, Shanghai 200093, China

^b Laboratory LIRIS, Ecole Centrale de Lyon, Ecully 69130, France

^c Sino-French Engineer School, Beihang University, Beijing 100191, China

^d Research Institute of Beihang University in Shenzhen, Shenzhen 518057, China

^e School of Computer Science and Engineering, Beihang University, Beijing 100191, China

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ABSTRACT

Work-based learning refers to the learning process occurring at workplace as acquiring knowledge and skills or developing approaches to solve problems. It is a crucial approach to promote professionals' working efficiency. However, the majority of research on professional learning concentrates on holding trainings (off-the-job or on-the-job), seminars and workshops, or on implementing systems for distributing training materials or facilitating communication. Few effort has been paid to support work-based learning which has the characteristics like informal, spontaneous, work-related and just-in-time. The purpose of our work is to facilitate professionals' work-based learning with a context-aware mobile system. This system can guide professionals to engage in work-based learning activities, which are arranged properly based on our online survey results. It can also provide learning supports which are adapted to current engaged work, professionals' learning needs, personal characteristics, environmental situations, etc. In this paper, we present successively the work-based learning activity design, the system structure design, the system technical implementation, the system functionalities and evaluation of learning achievement, and the user attitude and acceptance about this system. With the proposed system, professionals can use their mobile devices to get personalized, adaptive and just-in-time learning supports in real working environment.

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1. Introduction

Learning is a process of changing or transforming, in the sense of expanding the range of possibilities and actions for individuals and groups [1]. Focusing on the learning process particularly engaged by professionals, two learning phases can be identified: (1) academic phase: the phase before starting a professional work, which happens mainly during school or university studies, or pre-professional training periods; (2) working phase: the phase during a professional occupation, which happens on the workplace. The knowledge generated and acquired in these two phases differs greatly [2]. In academic phase, learning is devoted to the assimilation of important theories and generic methodologies, which is more difficult to

* Corresponding author.

E-mail addresses: buaazhangbingxue@gmail.com (B. Zhang), chuantao.yin@buaa.edu.cn (C. Yin), bertrand.david@ec-lyon.fr (B. David), xiongz@buaa.edu.cn (Z. Xiong), wei.niu@buaa.edu.cn (W. Niu).

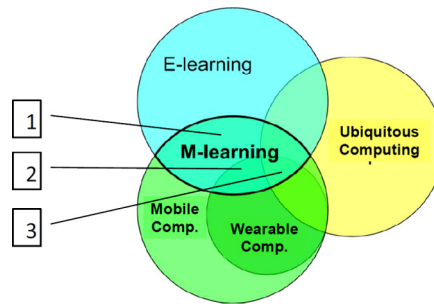


Fig. 1. Mobile learning cartography.

acquire on the workplace. On the contrary, in working phase, learning is devoted to the acquisitions of practical and precise behaviors, operations, and gestures, which is difficult to acquire at university. In our study, the professionals' work-based learning is situated in the working phase.

Workplace learning is a kind of learning happening in working phase. It is a key strategy to meet the challenges from the perspectives of both the individuals' employability and enterprise competitiveness [3,4]. Based on the degree from "learning" to "work", workplace learning can be divided into three phases [5]: (1) workplace as a site for learning, such as in-company training and work-related off-the-job training; (2) workplace as a learning environment, which should be organized and planned, for example, on-the-job training; (3) work-based learning, which is informal, spontaneous, work-related, just-in-time, and location-based.

Work-based learning refers to the learning activity that occurs on a day-to-day basis at work when professionals acquire new knowledge and skills or develop new approaches for solving problems [6]. In this process, work activities cause the occurrence of learning activities, determine the needs and provide the context; learning activities, arising from work mission, provide supports and ensure work continuation. Many research groups proposed their own definitions of work-based learning, for example, European Commission defined work-based learning as "a fundamental aspect of vocational training" [7]. However, there is no unified and acknowledged definition of work-based learning. In our study, we adopt the definition of work-based learning in reference [6]. Work-based learning is a crucial approach to increasing professionals' work efficiency by supporting them with particular knowledge and skills related to engaged work according to [8]. So far, more and more attention and efforts have been focused on work-based learning.

The majority of research in professional learning concentrates on holding trainings (off-the-job or on-the-job), seminars and workshops, or implementing systems for distributing materials or facilitating communication. The report [9] listed several learning systems which are used to help the design, development and delivery of learning programs in companies: Learning Management Systems [10], Course Management Systems [11], Learning Content Management Systems [12], Content Management Systems [13], and Talent Management Systems [14]. These systems were designed originally to support some specific aspects of professionals' informal learning, such as distributing learning materials and building communication among learners and helpers. However, few of them have capacities to provide just-in-time, personalized, contextualized and work-related learning supports in real working situations.

EPSS (Electronic Performance Support System) is also a kind of system aiming at offering professionals just-in-time information and tools to enable optimum performance when and where needed [15]. For example, PHelpS [16] is an EPSS that can support workers to solve problems encountered in their work by providing a list of peers who are ready, willing and able to help. The main problem of current EPSS systems is that they rarely consider the learning context, such as environment, personal characteristics, etc. This cannot enable EPSS to offer complete adaptive learning content according to different learning situations.

The significance of work-based learning and the limitation of current learning systems stimulate us to study on a system to facilitate professionals to achieve work-based learning. This system should be designed according to professionals' practical working processes, in order to cater to their just-in-time learning need, and to integrate adaptive learning resources, services and tools for providing proper and sufficient learning supports. With these objectives, our work focuses on studying the methodologies and technologies for designing and implementing an innovative work-based, context-aware, and mobile learning system, named WoBaLearn.

Context-aware mobile learning is the principle approach used in our research. In the previous study, we identified mobile learning cartography [17] in relation to ubiquitous computing, mobile computing, and wearable computing (shown in Fig. 1). Four essential characteristics are proposed to describe mobile learning situations: devices, mobility, context, and location. Three categories of mobile learning can be identified based on the variations of these characteristics. (1) Case 1: intersection between e-learning and mobile computing, in which mobility is much more general. Users' working/learning environment even can be accessed by devices proposed in different situations. (2) Case 2: intersection between e-learning and wearable computing, in which mobile technology is based on wearable devices (Tablet PC, Smartphone, etc.) usable anywhere in mobility. (3) Case 3: intersection between e-learning, wearable computing and ubiquitous computing, which allows ones to take into account context and location in ambient intelligence view. In our research, we consider the third case as contextual mobile learning or context-aware mobile learning.

Table 1
Work-based learning approaches [18].

Work-based learning approach	Average rating (out of 5)
Reading manual and book on the job	4.2
Working alongside more experienced colleagues	3.9
Working as part of a team	3.7
Self-analyzing or reflecting	3.6
Learning from client/customers/patients/etc.	3.5
Networking with others doing similar work	3.4
Getting supports from mentors	3.2
Using a role model	2.6

Table 2
Traditional and new technology work-based learning approaches.

Traditional ways	New technology ways
<ul style="list-style-type: none"> • Ask a neighbor • See the boss • Talk to an expert • Look at a manual or a book 	<ul style="list-style-type: none"> • Learn in workflow • Search the Internet or Intranet to find online knowledge sources • Email an individual • Instant Message or Skype someone • Listen to a Podcast • Interact with others online via discussion forums

Benefiting from context-aware mobile learning approach, WoBaLearn can provide professionals with work-related, personalized and environment-adapted learning supports whenever and wherever they encounter difficulties. Supported by WoBaLearn system in real working environment, professionals can easily enhance their awareness, expose the knowledge structure and trigger the reflection, and then develop their competence. A significant characteristic of WoBaLearn is good generality. That is to say, WoBaLearn not only points at a specific scenario, but also has the ability to provide learning supports independently from the application domain.

In this paper, we present respectively the design, implementation and evaluation of WoBaLearn system. In the following section, we state how context-aware mobile system can improve work-based learning, and then we review several typical context-aware mobile learning systems and summarize the main issues about the system design work. Section 3 involves the main part of our work. In section 3.1, we present our online questionnaire for surveying work-based learning needs and process, and analyze its results. Our designs on learning activities and system structure are introduced respectively in section 3.2 and section 3.3, and the implementation approach of WoBaLearn system is described in section 3.4. In section 4, we present two learning scenarios, in which we can carry out the user study for evaluating WoBaLearn system, and then, we elaborate and analyze the evaluation results of users' learning achievement, attitude and acceptance about the system. Finally, in section 5, we conclude this paper and propose our future work.

2. Related work

In this section, we review some existing approaches applied on professionals' work-based learning. In section 2.1, we first state the related work, and then comparing with the work, we put forward the advanced effect of work-based learning with context-aware mobile system. Then, in section 2.2, we introduce several typical context-aware mobile learning systems, identify their main design issues which can provide us the guidance for the design and implementation of WoBaLearn system.

2.1. Work-based learning improved by context-aware mobile system

A survey in 2001 presented the specific learning methods used in work-based learning. By interviewing 80 professionals from 20 different professions, and analyzing a questionnaire survey of 372 professionals from 6 selected professions, professionals' work-based learning approaches and ratings are obtained and listed in Table 1 [18]. Summarizing from this survey, we can identify that acquiring just-in-time work-related instructions on paper and collaborating with others face-to-face (discuss or get helps) are professionals' essential work-based learning approaches.

With the development of technologies, especially network technology, the learning methods used in work-based learning have changed a lot. Technology provides new services to help professionals to access to knowledge and collaborate with others, which increases the learning opportunity. Both traditional and new technology approaches for work-based learning are listed in Table 2.

The widespread of mobile devices and the growth of mobile communications industry promote the development of mobile learning. Mobile learning can provide flexible on-demand access to learning resources, experts, peers and learning services from any place [19,20]. Recently, mobile learning is applied increasingly for assisting professionals to achieve their work-based learning. Benefiting from mobile learning, professionals can continually contact with experts, look at digital

Table 3
Enhanced work-based learning effect by using context-aware mobile learning system.

Work-based learning approaches	Enhanced work-based learning approaches
Ask a neighbor	Find available and experienced neighbor.
See the boss	Make an appointment with the boss according to his available time.
Talk to an expert	Find available experts.
Look at a manual or a book	Decrease the range of manuals and books according to current activity.
Learn in workflow	Find the content adapting to current workflow.
Search the internet or intranet or find on line knowledge sources	Save online sources searching time, and increase results' accuracy.
Email an individual	Establish communication with experienced and available person, provide appropriate communication platform according to their status.
Instant Message or Skype someone	
Interact with others online via discussion forums	
Listen to a Podcast	Provide related podcast content.

manuals or books, and find sources or interact with others online, without the limitation of place and time. Furthermore, the multiple integrated sensors and highly personalized digital mobile devices provide an excellent platform for the development of contextual and learner-centered learning experience. By taking advantage of the context-aware feature, a mobile learning system can better understand the just-in-time learning situation, and then provide learners with adaptive and personalized learning supports.

Pointing at work-based learning field, the context-aware mobile learning system has the predictable abilities to fit behaviors and functionalities to professionals' current learning needs, personal characteristics and particular workplace circumstances. Professionals, carrying multiple heterogeneous wearable and handheld devices, are able to obtain just-in-time and context-adapted learning supports, move and interact with other appropriate professionals, hardware and software resources in his neighborhood or on remote locations via networks. We list several benefits of the usage of context-aware mobile system for assisting work-based learning as: (1) enabling the on-demand access to learning resources and services; (2) enabling the learning and performance support by exploiting real-work context; (3) enabling the on-demand access and communication with experts, peers and communities of practice.

Comparing with the items listed in Table 2, the enhanced work-based learning effect by using context-aware mobile learning system can be characterized as Table 3.

Moreover, from the pedagogical viewpoint, context-aware mobile learning approach can provide personalized scaffolding, and support professionals to observe and experience real-world situations to construct personal knowledge. The professionals, as a result of interaction with work-related context, can conduct independent thinking and enhance their learning motivations to further promote learning achievements.

2.2. Main issues in context-aware mobile learning system

Context-aware mobile learning systems aim to provide learning supports delivered via mobile devices and tailored to learning needs, personal characteristics and particular circumstances of individual learners or a group of interconnected learners [21,22]. Mobile devices are used to sense, track, and monitor the surrounding environment and transmit the context information to the system; then the system uses the context information to make dynamic learning adaptation decisions for the benefit of learners [23]. Many efforts have been undertaken on the design and implementation of context-aware mobile learning systems. We cite here several typical systems in the following part. An in-depth analysis is helpful for us to summarize the main issues about the design of context-aware mobile learning systems.

mCALS [24] is a context-aware mobile learning system developed for supporting Java programming learning. Its goal is to select appropriate learning objects for learners based on their current context and preferences. Its architecture composes three layers: (1) Learner Model Layer, which collects, organizes and manages learner's context to characterize learning situation; (2) Adaptation Layer, which is in charge of selecting appropriate learning objects based on current context with a series of adaptation mechanism; (3) Learning Objects Layer, which stores and manages learning objects in a learning object repository.

CAMLES [25] aims to support English language learning and adapts the sequence and navigation of its educational content based on the combination of learner's previous knowledge, needs, preferences, availability, current location and temporal information. CAMLES architecture includes three layers: (1) Context Detection Layer, which identifies the context factors such as location, time interval, manner of learning, and learner's knowledge; (2) Database Layer, which consists of context data, content data, the learner's profile, and test; (3) Adaptive Layer, which includes an adaptive engine for selecting learning content according to current context based-on a set of if-then rules.

UoLmP [26] is developed for delivering adapted activities and content through every step in the learning flow, and it is presented by a language learning scenario. It focuses on generating adapted individual learning activities, as well as offering adaptations to supportive educational content, tools and services, based on processing different criteria derived from learners' contextual elements. Its architecture includes three parts: (1) Capture/retrieval part, which captures or senses the current situation properties, and detects current device capabilities; (2) Adaptation process part, which executes the adaptation mechanisms, including filtering mechanism and polymorphic presentation mechanism, based on IMS Learning Design Specification; (3) Delivery/adjustment part, which delivers the adapted learning content and learning activities to learners.

P-LearNet [27], pervasive learning network project, is interested in TEL systems integrating context-aware corporate learning and working activities for e-retail in shops and supermarkets. The main issues of the P-LearNet are: provide work-integrated learning and customer learning support whatever the place, the time, the context of learning, and working processes. The main parts of system architecture contain: (1) current situation, which characterizes learner's current learning situation and learning activities; (2) entities, which contain the learning materials needed during the learning process; (3) adaptation method, which adapts entities according to current situation.

The majority of existing systems are conducted on course learning, like the first three systems, which have the pre-defined learning goals and pre-planned learning process. Skills training with the support of context-aware mobile learning system attracted scholars' attention until recently. However, the considered application fields and learning scenarios for training skills are not sufficient enough. P-LearNet, with the aim of facilitating professionals' work-based learning, rarely considered the personal learning characteristics in its adaptation. People may have different learning styles, and they may prefer different learning strategies in different conditions. P-LearNet provides the same learning supports if the learning needs are the same.

These existing systems cannot reach our research goals. However, an in-depth analysis can help us to propose our specific learning system with proper structure and functionalities. Synthesizing from the above systems and referring to the relevant work [26,28,29], we identify four aspects, which need to be considered when we design a context-aware mobile learning system, including: (1) what kind of information should be considered for characterizing a learning situation; (2) how to organize learning content in the system; (3) what kind of learning adaptations can be provided by the system based on the specific information; (4) how to implement these adaptations in the system. Consequently, four main research issues can be abstracted, including: contextual information model; learning content organization; learning adaptation strategy; adaptation engine development. We focus our attention on researching these four issues to develop a context-aware mobile learning system especially for work-based learning. The design and implementation of WoBaLearn system are presented in detail in the following part.

3. Design and implementation of WoBaLearn

In this section, we first state the results of an online survey that we carried out. This survey aims at identifying professionals' habits, needs and process in their work-based learning. The work-based learning activities provided by WoBaLearn system are designed based on the survey results. Then we present WoBaLearn system structure. This structure combines with the four design issues identified above for supporting the proposed work-based learning activities. Finally, we introduce the concrete system implementation technologies and system functionalities in detail.

3.1. Online survey about work-based learning

In order to design a proper work-based learning system, we set a questionnaire for identifying professionals' work-based learning needs and behaviors at the beginning. This questionnaire inquired four aspects: (1) what are main difficulties that professionals meet, (2) what are their habitual and expected learning process, (3) from where they get learning content, (4) how they collaborate with learning partners. By analyzing the results, we could: (1) construct the system architecture aiming at solving the problems of high frequency, (2) arrange learning activities in the system to organize a proper learning process, (3) identify learning resources concerned in the system, and (4) identify collaboration functions that should be supported by the system.

This questionnaire was posted online. It could be accessed from the site identified in the reference [30]. 164 professionals participated in the survey. These participants' professions are comprised of information technology (35%), industry (27%), teachers and researchers (5%), bank and assurance (4%), and others. The results of the survey could be concluded as follows.

3.1.1. Main difficulties in work-based learning

After summarizing the questionnaire's results, we can identify that, during work-based learning, professionals mainly meet four kinds of difficulty: (1) difficult to locate problem precisely (with 63% positive answers), (2) aware of the problem, but difficult to find appropriate learning content (with 71% positive answers), (3) difficult to find appropriate learning partners (with 56% positive answers), and (4) difficult to know the appropriate way to contact with their learning partners (with 43% positive answers).

Besides, there are answers pointing out that some difficulties caused by enterprise managements. This is a real difficulty impacting a lot on professionals' work efficiency but exceeding the scope of the learning system.

3.1.2. Habitual and expected learning process

After classifying the answers responding to habitual learning process, we can identify the professionals' main work-based learning activities, including: (1) learn from learning materials, such as, reading manual and book on the job, searching on the internet or intranet to find online knowledge resources, listening to a podcast, etc., (2) learn from others, such as, working alongside more experienced colleagues, learning from client/customers, communicating with others doing the similar work, supported from mentors, working as a part of a team, interacting with others online via discussion forums/social network, etc.

Table 4
Survey results about learning resource

Learning content resources	Positive	Neutral	Negative
Professional articles, reference materials on blogs and websites	77%	18%	5%
Information recordings of your organization (e.g., the supplier lists for a retail company)	75%	19%	5%
Materials at professional meeting	73%	24%	3%
Lessons resources used in professional training	73%	24%	3%
News, policies, procedure on line	67%	24%	7%
Employee manuals	66%	27%	8%
Books	59%	27%	17%
Discussions or opinions on line	53%	37%	10%
Article in professional magazine	51%	32%	17%

Table 5
Survey results about collaborating approaches.

Collaborating approaches	Positive	Neutral	Negative
Email	91%	5%	3%
Face to face	90%	9%	1%
Phone	90%	7%	4%
Forum	48%	27%	26%
Video Conference	46%	24%	30%
On-line Chat	29%	31%	40%
SMS	23%	20%	57%
Social Network	20%	25%	55%

Furthermore, in regard to the survey about the expected activities for supplementing work-based learning, 74% of participants agree that it is necessary to review new learned knowledge or skills to consolidate their learning, and 76% of participants agree that it is necessary to learn other related content to extend their learning, such as the content related to just learned content, and the content learned by their learning partners.

3.1.3. Scope of learning resource

In order to identify the scope of learning resource, the questionnaire surveyed professionals' attitude about the importance of 9 kinds of learning contents, and the results are illustrated in Table 4. The positive summarizes the choices of "Very important" and "Important", the neutral summarizes the choices of "Somewhat important", and the negative summarizes the choices of "Not important".

A few participants responded the open question to supplement learning resources. However, most of these answers pointed out the importance of learning from other people, such as experienced colleagues, experts or near-by person, which have already been considered in the fourth survey aspect. Thus, the listed items could be taken as the scope of learning content. Besides, the recommendation priority of learning content could be set according to the positive answers' percentage illustrated in Table 4.

3.1.4. Supported collaborating functions

Collaboration with learning partners is an important learning activity, from which professionals can acquire timely effective instructions or suggestions. The questionnaire surveyed the utilization frequency of 8 collaboration approaches. The results are illustrated in Table 5. The positive summarizes the choices of "Very often", "Often" and "Occasionally", the neutral summarizes the choices of "Rare", and the negative summarizes the choices of "Never".

According to the percentage of positive answers in Table 5, the collaborating functions which should be provided by our system are identified. For example, the function about finding available nearby colleagues to encourage face-to-face collaboration and the function about providing distance experts' telephone numbers for assisting consulting should be considered. Besides, several participants proposed that the mail and chatting tools in enterprise inner systems are useful, which could be taken into account in accordance with specific enterprises.

The online survey results offer us an initial fundament about professionals' habits, needs and process in their work-based learning. Based on the results, we propose a series of work-based learning activities which should be provided by WoBaLearn. These activities are designed for enabling professionals to access to appropriate learning resources and partners. Professionals follow these activities to complete their current work and extend their knowledge and skills. Although 164 professionals is a small sample, in the future work, we will ameliorate the system functionalities according to the real experience of users, which is a "design-apply-redesign" process.

3.2. Design of learning activities in WoBaLearn

Work-based learning is a kind of just-in-time, informal and life-long learning. This learning process is usually unstructured and spontaneous. It is necessary to sequence professionals' work-based learning activities in a proper process, in

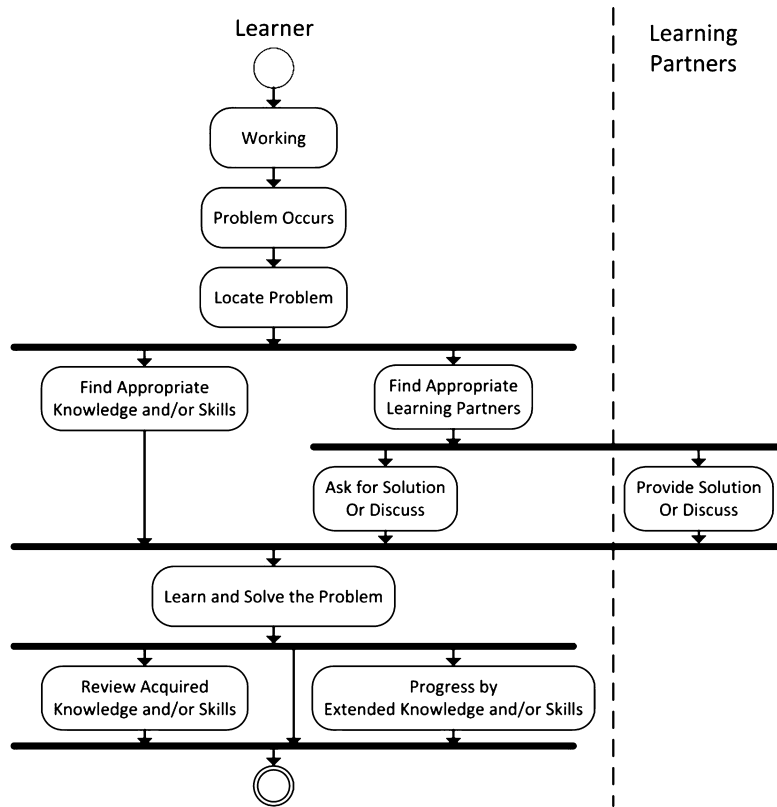


Fig. 2. Sequence of work-based learning activities in WoBaLearn system.

order to increase efficiency. According to work process and learning needs surveyed by the online questionnaire, we propose a series of work-based learning activities in WoBaLearn system. Firstly, we identify the actors involved in work-based learning their duties. Then, for the main actor, we propose a series of just-in-time and supplemental learning activities to support them to perform their work or consolidate their learning. Finally, following professionals' practical work process, we organize these learning activities into a proper sequence.

In the process of work-based learning, the professional who encounters a problem during his work and wants to acquire new knowledge or skills to find a solution, acts as a learner. Another role in this process is learning partner who collaborates with the learner to give instructions or suggestions. Referring to the online survey results, the learner's main activities can be identified as: (1) locating problems encountered during the work; (2) finding the knowledge or skills, which are work-related, personalized and environment-adapted; (3) finding and collaborating properly with the appropriate learning partners; (4) learning the new knowledge and skills, and, at the same time, finding a solution to solve the problem. Moreover, two additional activities for helping the learner to consolidate his knowledge and skills can be identified as: (1) reminding learners to review the newly knowledge and skills at an appropriate time several days later; (2) providing learners with extended but task-related knowledge and skills to help them to progress further. Since work-based learning is always spontaneous, these supplemental activities cannot be forced to happen. They should be designed in work-based learning activities. That would remind the professionals that, by following these supplemental activities, their knowledge and skills can be consolidated and their future work can be benefited. In WoBaLearn, the sequence of work-based learning activities is shown at Fig. 2.

This learning sequence is triggered by the professionals' need of solving a work-based problem. Work and learning activities take place at the same location within the same period. Learning appropriate knowledge and skills or collaborating with appropriate learning partners provides the learner necessary supports to complete his current work. The learner can interrupt his learning at any time and record current learning status. Once the learner achieves his work supported by learning, he can choose to learn further some extended knowledge or skills, or reserve a time to review the learned knowledge and skills later, or finish his learning directly. This learning sequence aims to ensure professionals to obtain guidance for current work, practice the knowledge and skills with the real tasks, and further consolidate and extend their competences.

Extending from the sequenced work-based learning activities, we propose the principle functionality in WoBaLearn. The system functionality provides a complete learning process, including explanation, engagement, reflection, expansion, etc. We will present the system functionality in detail in section 3.4.

3.3. Design of WoBaLearn structure

Four main research issues about context-aware mobile learning systems have been presented in section 2.2. In our study, we consider the characteristics of work-based learning into our system design. We will propose the conceptual design bases for WoBaLearn, which specializes these designing issues in corresponding to the characteristics of work-based learning. We also propose a system structure combining systematically these conceptual design bases. Constructed on this structure, WoBaLearn has the ability to adapt learning resources, partners and activities according to professionals' learning needs, personal characteristics and particular circumstances. Therefore it can provide professionals the personalized, just-in-time and problem-based learning supports in real working situations.

The conceptual design bases for WoBaLearn system are as follows.

3.3.1. Learning content organization

According to the results of the online survey [30], we identified the work-based learning content scope as listed in Table 4. For a specific work, particular learning content should be decided by the domain experts and collected from this scope. Relevant learning content should be organized into a learning unit. Learning units are labeled with corresponding metadata by which they can be recognized and can be recommended once required. In our study, we propose to use AM-LOM metadata for labeling the learning content. More details about AM-LOM can be referred to [31].

3.3.2. Contextual information model

We propose an initial context model, named WbML, for describing the contextual information about work-based mobile learning. WbML adapts a hierarchical designing approach which enables this model to not only share information and services among different application domains but also cover all the work-based learning situations. Moreover, WbML is built based on ontology approach with OWL language which enables this model to describe context semantically. More details about WbML model can be referred to our former work [32].

3.3.3. Learning adaptation strategies

Five adaptation strategies are proposed to provide context-adapted supports for work-based learning: (1) adaptation of learning units: the learning units related to learner's current work activity can be selected; (2) adaptation of learning units sequence: the selected units can be sorted by priority according to the learner's personalized settings; (3) adaptation of learning units navigation: adaptive pedagogical units are made based on the learning unit with highest priority and its relative learning units; (4) adaptation of learning partners communication: the people nearby and the experienced colleagues are recommended as the learner's potential learning partners, and also different communication approaches can be selected according to the partners' locations and availabilities; (5) adaptation of learning activities generation: the adaptations above are organized into a just-in-time learning activity ending with a learning summary, and also a review activity and a progress activity are made to assist the learner to reinforce his learning and to progress.

3.3.4. Adaptation engine

We implement an adaptation engine which carries with the proposed strategies to execute adapting process. The input of this engine is the learning contextual information specified in WbML context model. Combining with the adaptation strategies, this engine selects, processes, consolidates and displays the appropriate work-based learning supports, including learning units, learning partners and learning activities.

All the four conceptual design bases from A to D are designed in a domain-independent fashion. That is, these bases neither point at a specific work process nor just embody certain domain knowledge. Thus these bases constitute a generic design approach for work-based learning environments. In order to create a domain-specific work-based learning environment for a specific company, the context in the specific work layer of WbML context model should be extended, and the domain knowledge has to be added with AM-LOM metadata and provided in the form of learning unit.

We have proposed a system structure combining systematically these conceptual design bases. The WoBaLearn structure is shown in Fig. 3. Professionals' learning context which is collected according to WbML context model is the input of WoBaLearn. In WoBaLearn adaptation engine selects and processes learning supports based on adaptation strategies. Learning supports could be learning units indexed by AM-LOM metadata and learning partners indexed by their status and former experience. According to users' feedback, adaptation engine can also consolidate the learning activity by requiring more accurate learning context. Constructing on this structure, WoBaLearn has the ability to provide context-adapted work-based learning supports properly.

3.4. Implementation of WoBaLearn

For simplifying system load and reducing the cost and effort of system maintenance and upgrade, we implemented WoBaLearn system in a web server on B/S (Browser and Server) structure. The main business logic of WoBaLearn system is implemented on server side. System interfaces can be achieved by learners' mobile devices via wireless network. Mobile devices can collect context from users' inputs and multiple sensors, and transmit them to system. The system uses these contextual information to make dynamic learning adaptation decisions. The system network structure is shown at Fig. 4.

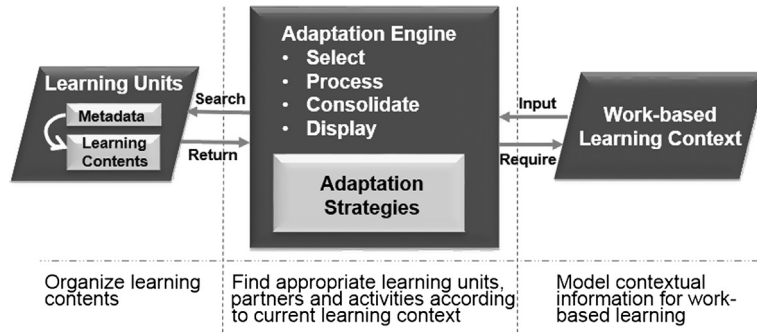


Fig. 3. System structure of WoBaLearn.

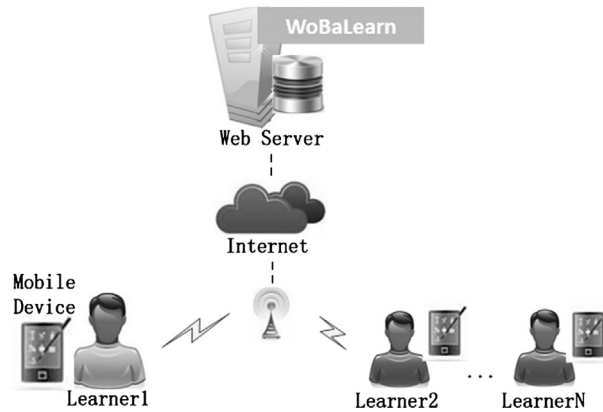


Fig. 4. Network structure of WoBaLearn.

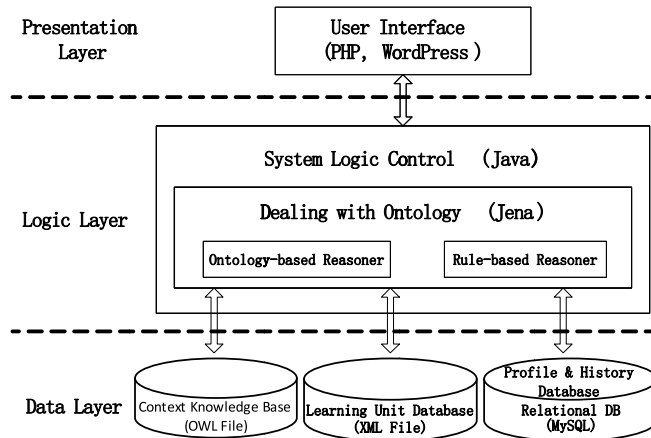


Fig. 5. Technical implementation of WoBaLearn.

WoBaLearn is implemented with three layers: presentation layer, logic layer, and data layer. Each layer is achieved based on concrete technologies as shown at Fig. 5.

3.4.1. Presentation layer

This layer provides learner-oriented services, such as, delivering learning supports to learner, and managing learner’s interaction with system. Also, this layer is in charge of transmitting and formatting learner’s operation information to the logic layer for further processing. In this layer, PHP is applied to create system interfaces and achieve system certain logics, such as registering, logging in, managing learner information, etc. WordPress is used to construct learner’s personal space.

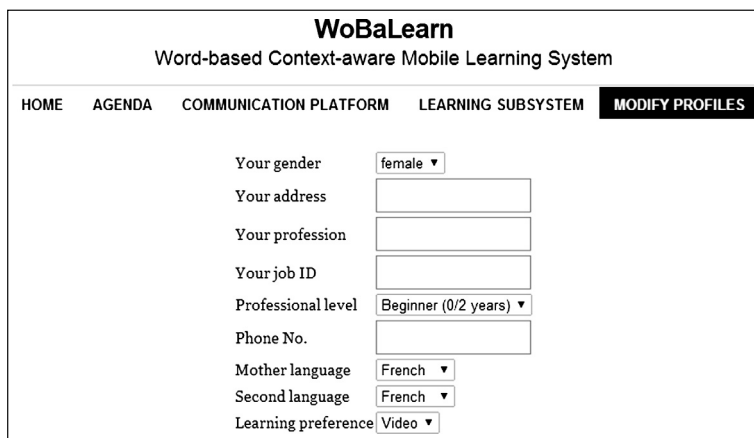


Fig. 6. Interface of learner profile setting.

3.4.2. Logic layer

This layer implements the core functionality of WoBaLearn. It encapsulates the relevant logic. Logic layer receives the information from presentation layer and access the data stored in data layer. It executes the pre-defined logic to process information and data, then generates appropriate learning supports and delivers them to presentation layer. In this layer, Java is applied to implement system logic control, including manipulating data base, adapting learning supports, managing learners' interfaces, etc. And, Jena is applied for manipulating learner's contextual information written in OWL, and also for inferring indirect context aspects and a part of learning supports with rule-based reasoner.

3.4.3. Data layer

This layer provides the access to data which is hosted within system boundaries. The stored data contains context information, learning units, learners' profiles and learning history. In this layer, the applied techniques are: OWL, XML and MySQL. As stated in the section 3.3, WbML context model is expressed by ontology written in OWL-DL language, which is also stored at this layer as an OWL file. According to the elements defined in WbML, the system collects learning context and stores them in a new OWL file. What's more, the metadata of learning units are written and stored in XML files. Depending on the machine-readable format, the system can find the required learning unit by searching the values of relative metadata recorded in XML files. Moreover, learner's registration information, profile and learning histories are stored in MySQL.

The abundant functionalities implemented in WoBaLearn include: the functionalities for managing learner information, such as register, login, learner profile setting; the functionalities for supporting learning process, such as agenda, online chat, email; and the learning adaptation functionalities to provide context-adapted learning supports. The interface on Tablet device of learner profile setting is shown in Fig. 6, which allows the learner to set and update different aspects of his learning profile. Learning profile is recorded in system database. It is applied by the system as the context value for selecting the personalized learning supports. The interface of online chat is shown in Fig. 7. On this interface, the learner can talk with his online and available learning partners, which facilitates the just-in-time learning communication.

Among these functionalities, learning adaptation functionality is the most important. We focus on explaining the details of this functionality in this paper. The entrance interface of learning adaptation functionality is shown as the lower part of Fig. 8, which displays the learning history of current learner. This functionality runs as a Java Applet.

The flow chart of the learning adaptation functionality is shown at Fig. 9.

The learning adaptation functionality constitutes a complete learning process. Entering this functionality, a learner can review his particular learning histories recorded in Learning Activity History Database, which can help him reflect on their past activities.

Learning opportunities raise from real work activities. Professional sends a learning requirement to start a new learning process. At the beginning, the learner sets the values about current work activity context. These values will be combined with other context and be used by adaptation engine for selecting work-related learning units and experience-related learning partners. In addition, the learner can also set the parameters of units sequencing rules. These parameters can influence the displaying order of the selected learning units. After the operation of adaptation engine, the context-adapted learning units are displayed and the appropriate learning partners are recommended. These learning units are formed into pedagogical units, which not only include the necessary knowledge and skills, but also indicate the learning objective, the expected learning time, and a learning outline containing the titles of the proposed learning units, the prerequisite knowledge and the intensive knowledge, etc. At the same time, the learner can contact with his learning partners with system recommended communication approaches. After pedagogical units learning, a learning summary is displayed by illustrating the time used, the titles of the learned units and also the titles of not learned ones.

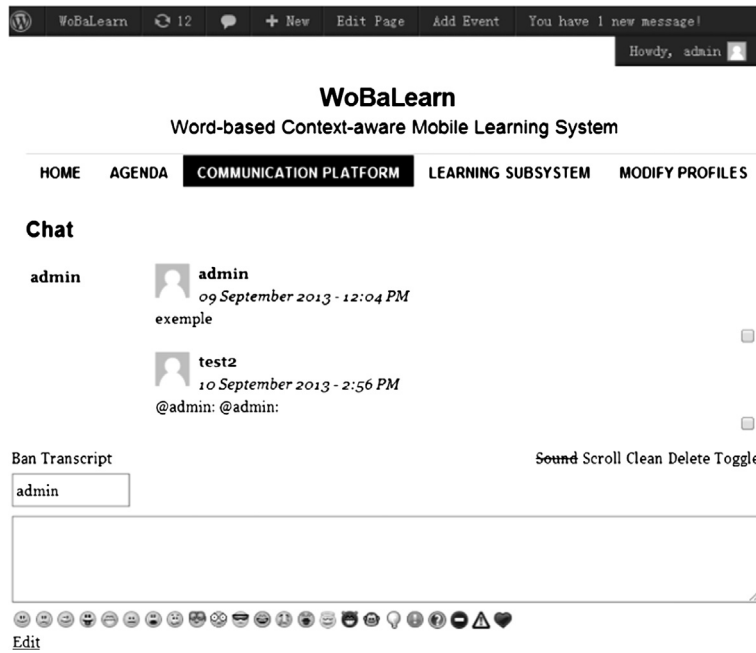


Fig. 7. Interface of on-line chat.

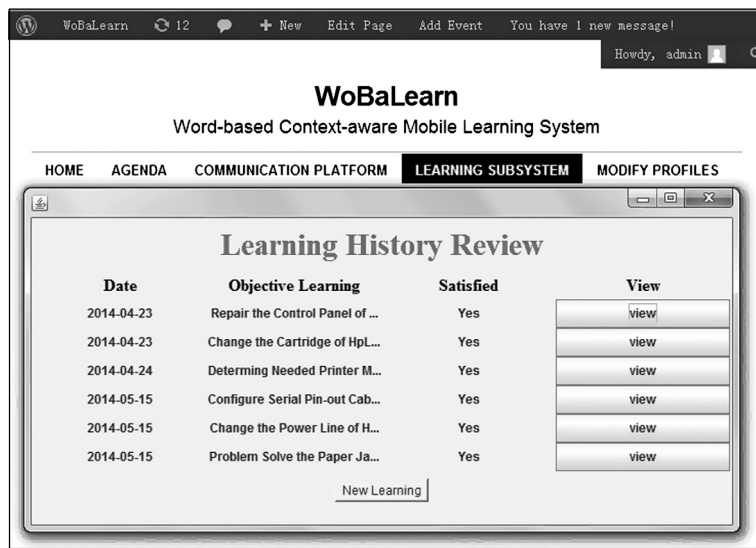


Fig. 8. Interface of learning adaptation functionality.

With this just-in-time learning supports, professionals are enabled to expand their knowledge and to achieve current work.

The learner can evaluate his learning process according to his experience. If the learner is not satisfied, he will be proposed to consolidate the learning process by resetting his work activity context and his profile, or to search for learning content by himself from the internet. Otherwise, he will be proposed to enhance his learning with some related knowledge and/or by reserving a review time. The relatively extensive knowledge can help professionals to develop their competence systematically. It can also help to constitute relevant learning goals for the future. The review activities can provide professionals with an overview about their experience and trigger reflection.

When the learner decides to finish this learning process, his learning record is stored in Learning Activity History Database, and the system returns back to display learner's learning histories. During this process, the learner can interrupt his learning at any time. The learning information is recorded in the database. When the learner requires to resume his learning, the recording is reloaded, then his learning continues.

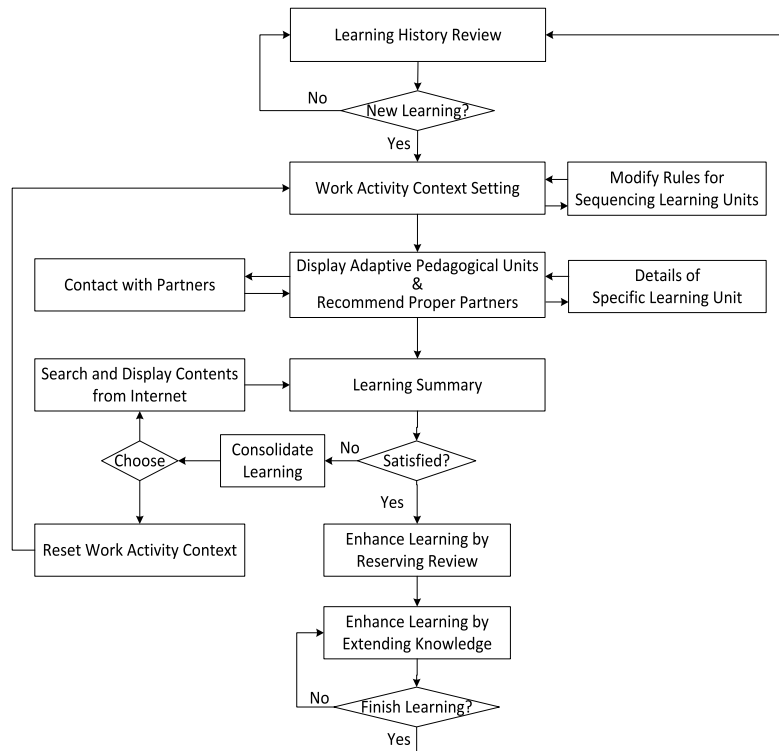


Fig. 9. Flow chart of learning adaptation functionality.

4. Evaluation of WoBaLearn

In our research, we carry out the user study in two real work-based learning scenarios to evaluate our WoBaLearn system. These two scenarios concern different working conditions and different task difficulties. In the scenarios, professionals' learning and doing can be supported by WoBaLearn system. Many aspects about the system have been evaluated in our research. In this paper, we focus on discussing two aspects in the evaluation, including: users' learning achievement, and users' attitude and acceptance about WoBaLearn system.

The first scenario considers the professionals working in office environment. Professionals use office equipment to carry out work. During their work, they usually have to maintenance simply these office equipments. The work task in this scenario is about re-configuring IP address of a printer according to new intranet setting in the organization. To cause a real-time learning activity on workplace, we should make the task more difficult and complex to achieve. To this end we set a control panel display problem of the printer in this task, which is caused by panel cable's disconnection. To complete the assigned task in the first scenario, professionals should firstly find the solution for the control panel display problem. And then, they need to finish the reconfiguration of the printer IP address.

The second scenario considers the workers in the factory of Maped. Maped is a French manufacturer of scholastic and office stationery. Maped becomes our research partner for developing the advanced professional learning system. The work task in this scenario is about the change of blade guillotine of a test bench for staplers and punches. The test bench contains sophisticated components. The blade guillotine is an internal part of the test bench. This task is much more complicated than the first one. Considering the factory environment and task security issues, we should grasp more knowledge and skills in this scenario.

A total of 31 participants voluntarily participated in the evaluation. Among them, 23 involved in the first scenario, and 8 involved in the second. The 23 participants in the first user study include laboratory researchers and secretaries. They use printer in their daily work and general printer maintenance is an unavoidable task in their work. The 8 participants in the second user study include interns and workers who have worked for less than 6 months. Therefore, in this group, workers need more and regular supports to finish their work. For all the 31 participants, according to their knowledge background and their practical experience about using or maintaining the corresponding devices, they can be considered as Beginner or Experienced for their professional level.

Three approaches are usually applied for evaluating a learning system, including, pre-test and post-test, log, and questionnaire [33–35]. Differ from the course learning, the performance of work-based learning cannot be assessed only by the score differences of the pre-test and the post-test. In our research, we use log tool to record users' learning behaviors to analyze their learning achievement. Also, we use the questionnaire to survey several aspects about WoBaLearn.

In both of the learning scenarios, at the beginning, the participants received a 5-minutes instruction concerning the corresponding mission. Then participants received another 10-minutes instruction concerning the operations of WoBaLearn system. Afterward, the participants carried out the assigned mission with the supports of WoBaLearn system. The system collected the learning context and recommended the adaptive learning supports. More details about the context concerned in the scenarios, context collecting approaches and learning support adaptation process are described in the part 7.2 of the reference [36]. During this evaluation process, participants' learning performances were recorded on video. After finishing the mission, the participants filled the questionnaires about learning attitude, acceptance of learning system, etc. One week after the first work-based learning, the participants were asked to re-operate the same mission but without system supports. We also recorded their performances on video.

What follows we focus on discussing two aspects about our evaluation, including: users' learning achievement, and users' attitude and acceptance about WoBaLearn. Although our user study concerned two different learning scenarios, we notice that no significant differences exist concerning these evaluation aspects. In our analysis, we put all the experiment results together to draw our conclusion.

4.1. Analysis of learning achievement

We recorded and analyzed all the 31 participants' work-based learning performances. 26 participants completed their corresponding mission successfully, while the other five participants failed. The mission completion rate is 84%. From the performance record, we summarized three kinds of reasons causing failure as:

- Three participants were unfamiliar with operating on the touch-screen mobile device. During the experiment, they always made mistakes and were led to the interfaces they didn't want to go, which interrupted and disturbed their learning. In the interview after the experiment, they said that she rarely used the touch-screen mobile device. And also, they preferred to learn new knowledge with paper materials.
- One participant can operate on the system correctly and get the exact solution of the problem set in the scenario. However, he is a left-hand operator, and he was confused by the learning content originally designed for right-hand operators.
- One participant is only-French reader. We made a French version of the system for her, and also translated the learning content into French. However, the mistranslated learning content caused confusion which forced this participant to interrupt the experiment.

Apart from individual differences and content statements, none of these reasons above points to the design defect of WoBaLearn system and the irrationality of work-based context-aware mobile learning approach. This observation shows positively that such learning approach and learning system could contribute to the professionals' achievement in their work-based learning.

For evaluating the long-term learning achievement, we asked the 26 participants who completed the assigned mission to redo it in one week later, but without the support of WoBaLearn system. All the 26 participants recompleted the mission successfully. This proves that learning with WoBaLearn system has positive effect on participants' working task achievement.

4.2. Analysis of learning attitude and system acceptance

For the 26 participants who have completed the assigned task, we asked them to fill out a questionnaire after their first experiment. In the questionnaire, we set up questions to survey users' learning attitude and their acceptance of WoBaLearn. The questions are presented using a five-point Likert scale, in which "5" represented "strongly agree" and "1" represented "strongly disagree". The questions proposed in the questionnaire are referred to the related existing work [37]. The questions and the corresponding statistical results are listed in Table 6.

The first three items analyze the participants' attitude about obtaining work-based knowledge and skills with context-aware mobile approach. The means of all the three items exceed 4, which shows that the participants can accept this approach and agree that it could facilitate their learning in actual work-based learning situation. Meanwhile, from the three standard deviations which are all less than 1, we get that these participants' answers do not have a great difference, which proves that all the participants have the positive learning attitude.

The 4, 5 and 6 items aim at querying the easiness of the system. These three items have the mean values 4.2, 4.1 and 4.1 respectively, which represents that the participants evaluated the easy use of the system positively. It was also observed that, during the 10-minutes instruction concerning the system operations, after being taught once or twice, the participants were well familiar with the system operations. However, from the standard deviations of these three items, which exceed 1, it was found that not all of the participants highly accepted the system easiness. This observation implies that interfaces and operations need to be more carefully designed if they are to encourage more professionals to use this system, and in particular those who have little experience in using mobile devices. And also, more effort should be devoted to improve the system response speed to match with the professionals' learning progress.

The items 7 and 8 focus on evaluating the participant's acceptance of context-aware adaptation. The mean values of these two items exceed 4 with standard deviations less than 1. These responses provide us the evidences that the majority of the

Table 6

Analysis of user's learning attitude and system acceptance.

Scale	Questionnaire item	Mean	S.D.
Attitude about the learning approach	1. I am comfortable with this learning approach.	4	0.78
	2. I think this learning approach is effective.	4.3	0.61
	3. I prefer to learn in such approach in my future learning.	4.2	0.80
Easiness of learning system	4. It is easy to operate the interfaces of the learning system.	4.2	1.21
	5. The response speed of learning system is well-matched with the learning progress on the site.	4.1	1.21
Attitude of context-aware adaptation	6. I think that device operation of the learning system is easy.	4.1	1.14
	7. The adapted learning content assist me to complete learning activities according to my contextual information.	4.1	0.62
Usefulness of learning system	8. Combining the mobile learning system and the real-world context is helpful to learning.	4.1	0.83
	9. The progress provided by the learning system can benefit my learning achievement.	4.1	0.62
	10. The guidance of the learning system is quite clear and effectively assists me to understand the learning content and steps.	3.9	1.03
	11. According to my experience I would use this system if relevant to my work-based learning needs.	4.2	0.65
	12. I would recommend the system to others.	4.1	0.83

participants strongly agreed with the valid adaptation of learning content based on their contextual information. The participants also agreed that the adaptation of the learning content facilitated them to complete successfully the assigned task.

The items 9 to 12 aim at evaluating the usefulness of the system. The items with a mean exceeding 4 include 9, 11 and 12. This represents that the participants found the system was useful to support their appointed work-based learning, and they were eager to use this kind of system in their future actual work and also share it with others. However, 4 in 26 participants gave 2 points to the question 10, which caused its mean value to be 3.9. In the after-test interview, mostly of these 4 participants pointed out the system guidance is easy to cause confusion. This suggestion will be taken into account in our future work.

The evaluation results above prove that the WoBaLearn is very useful for professionals in appliance maintenance work domain. It could offer the professionals a satisfactory learning experience and assist them to achieve a well learning effect. More evaluations in a variety of work domains will be carried out in our future work. We can expect that WoBaLearn system would be recognized widely by professionals, and have a good prospect of practical application.

5. Conclusions and future work

The significance of work-based learning and the disadvantages of existing learning supports call for more effort to be paid in this field. Comparing current learning systems applied in professional learning field, the advantages of our work lie in providing: real-time supports, work-related supports, personal-adapted supports and comprehensiveness of supports. The main contribution of this paper is to propose an initial context-aware mobile learning system dedicated to professionals' work-based learning, named WoBaLearn. WoBaLearn can provide professionals with just-in-time learning supports tailored to their learning needs, personal characteristics, device capacities and also particular circumstances. This system possesses a good generality to provide learning supports independently from the application domain. With the benefits of this work, professionals can use their mobile devices to access personalized and adaptive learning supports whenever and wherever they run into problems. In this paper, we focused on the design and implementation of WoBaLearn system, including: the online survey results about work-based learning, the design of learning activities, the design of system structure, the system implementation and the system functionalities. Two real work-based learning scenarios were carried out for evaluating WoBaLearn. The evaluation for learning achievement and the evaluation for users' attitude and acceptance are discussed in detail. The evaluation results provide us with evidence that WoBaLearn system can offer professionals a satisfactory learning experience and facilitate their work activities.

In our future work, we would like to carry out more evaluation and case studies in different domains. (1) More evaluation: we will continue the present evaluation with more professionals especially in the second scenario. This work enables us to obtain abundant data and get more reliable analysis results. Also, we will design and carry out a comparison evaluation for examining whether the work-based context-aware mobile learning approach is better than other learning approaches. (2) More case studies: we will construct the experimental environment combining with various sensors. This work will enable our system to collect more context defined in our context model, and help to examine the conflicts and the consistency of the context relationships in our context model, also to check the system efficiency in a more complex situation. We will also extend the system application field to more work-based learning scenarios, which helps to examine the coverage and the scalability of WoBaLearn.

Acknowledgements

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Appendix A. Questionnaire of work-based learning

Questionnaire

Bingxue ZHANG
University of Lyon, CNRS,

Ecole Centrale de Lyon, LIRIS, UMR5205, France

Instruction:

According to your experience about work-based learning (learning activity that occurs on day-to-day work activities as you acquire new knowledge and skills to develop new approaches to solve problems), select the choice to indicate your answer. Choose only one answer for each question.

Thanks.

Basic information:

Gender: Male Female

Company type: _____

Professional Role: _____

Questions:

1. How often are the listed difficulties you get into?

I don't even know what's wrong, it's difficult to locate the problem precisely.

Very often Often Occasionally Rare Never

I know the problem, but it's difficult to find appropriate learning contents.

Very often Often Occasionally Rare Never

I don't know who can give me instructions or suggestions.

Very often Often Occasionally Rare Never

I don't know how to contact with them.

Very often Often Occasionally Rare Never

Are there any other difficulties you met?

Very often Often Occasionally Rare Never

2. If you have difficulties to locate problem precisely, measure the frequency of listed reasons. If not, go to 3.

I am lack of learning experience or relative information about my work.

Very often Often Occasionally Rare Never

I have learning experience and know relative information, but lack of practical experience and can't recognize the problem in my work.

Very often Often Occasionally Rare Never

Are there any other reasons?

3. As the sources of your learning contents, measure the importance of the listed items.

Books.

Very Important Important

Articles in professional magazines.

Somewhat Important Not Important

Employee manuals.

Very Important Important

Presentations and materials at professional meetings.

Somewhat Important Not Important

Lessons resources used in professional training.

Very Important Important

Information recordings of your organization (e.g., the supplier and custom lists for a retail company).

Somewhat Important Not Important

Professional articles, instructions or reference materials on blogs and websites.

Very Important Important

News, policies or procedures published on line.

Somewhat Important Not Important

Discussions or opinions published on line.

Very Important Important

Are there any other sources?

Somewhat Important Not Important

Very Important Important

Somewhat Important Not Important

Very Important Important

Somewhat Important Not Important

Very Important Important

Somewhat Important Not Important

Very Important Important

Somewhat Important Not Important

4. Based on the impact on you finding learning contents, measure the importance of the listed factors.

Matching my current working activity.

- | | |
|---|--|
| <input type="checkbox"/> Very Important | <input type="checkbox"/> Important |
| <input type="checkbox"/> Somewhat Important | <input type="checkbox"/> Not Important |
| <input type="checkbox"/> Very Important | <input type="checkbox"/> Important |
| <input type="checkbox"/> Somewhat Important | <input type="checkbox"/> Not Important |
| <input type="checkbox"/> Very Important | <input type="checkbox"/> Important |
| <input type="checkbox"/> Somewhat Important | <input type="checkbox"/> Not Important |

Based on my previous knowledge.

Content is displayed in my preferred format, e.g. text, video or audio, etc.

Are there any other factors?

5. Based on the impact on you finding learning partners, measure the importance of the listed factors.

He/she should be someone who has relative experience.

- | | |
|---|--|
| <input type="checkbox"/> Very Important | <input type="checkbox"/> Important |
| <input type="checkbox"/> Somewhat Important | <input type="checkbox"/> Not Important |
| <input type="checkbox"/> Very Important | <input type="checkbox"/> Important |
| <input type="checkbox"/> Somewhat Important | <input type="checkbox"/> Not Important |
| <input type="checkbox"/> Very Important | <input type="checkbox"/> Important |
| <input type="checkbox"/> Somewhat Important | <input type="checkbox"/> Not Important |

He/she should be someone I am familiar with.

He/she should be someone who can give me immediate responses.

Are there any other factors?

6. Measure the frequency of using the followed approaches as learning communication ways.

Face to face

On-line Chat

Discussion boards on websites

Email

Social Network

Video Conference

Phone

SMS (short message)

Are there any other communication ways?

- | | | | | |
|-------------------------------------|--------------------------------|---------------------------------------|-------------------------------|--------------------------------|
| <input type="checkbox"/> Very often | <input type="checkbox"/> Often | <input type="checkbox"/> Occasionally | <input type="checkbox"/> Rare | <input type="checkbox"/> Never |
| <input type="checkbox"/> Very often | <input type="checkbox"/> Often | <input type="checkbox"/> Occasionally | <input type="checkbox"/> Rare | <input type="checkbox"/> Never |
| <input type="checkbox"/> Very often | <input type="checkbox"/> Often | <input type="checkbox"/> Occasionally | <input type="checkbox"/> Rare | <input type="checkbox"/> Never |
| <input type="checkbox"/> Very often | <input type="checkbox"/> Often | <input type="checkbox"/> Occasionally | <input type="checkbox"/> Rare | <input type="checkbox"/> Never |
| <input type="checkbox"/> Very often | <input type="checkbox"/> Often | <input type="checkbox"/> Occasionally | <input type="checkbox"/> Rare | <input type="checkbox"/> Never |
| <input type="checkbox"/> Very often | <input type="checkbox"/> Often | <input type="checkbox"/> Occasionally | <input type="checkbox"/> Rare | <input type="checkbox"/> Never |
| <input type="checkbox"/> Very often | <input type="checkbox"/> Often | <input type="checkbox"/> Occasionally | <input type="checkbox"/> Rare | <input type="checkbox"/> Never |

7. After solving problems with new knowledge or skills, whether it is necessary to review them later for consolidating?

- | | |
|---|--|
| <input type="checkbox"/> Very necessary | <input type="checkbox"/> Necessary |
| <input type="checkbox"/> Somewhat necessary | <input type="checkbox"/> Not necessary |

8. After solving problems with new knowledge or skills, whether it is necessary to learn other related content to extend your learning?

- | | |
|---|--|
| <input type="checkbox"/> Very necessary | <input type="checkbox"/> Necessary |
| <input type="checkbox"/> Somewhat necessary | <input type="checkbox"/> Not necessary |

9. If the answer of 8 is positive, measure the necessity of the listed further learning.

The topics related to the knowledge and skills which I just learned.

The knowledge and skilled learned by my learning partners.

- | | |
|---|--|
| <input type="checkbox"/> Very necessary | <input type="checkbox"/> Necessary |
| <input type="checkbox"/> Somewhat necessary | <input type="checkbox"/> Not necessary |
| <input type="checkbox"/> Very necessary | <input type="checkbox"/> Necessary |
| <input type="checkbox"/> Somewhat necessary | <input type="checkbox"/> Not necessary |

10. Are there any other supplemental activities could facilitate your learning?

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