A Framework for the Design of Ubiquitous Learning Applications

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Abstract

The article presents a framework for the design of ubiquitous learning applications that considers four main elements: the knowledge about learner's profile and needs; the context (physical, temporal and social) that surrounds mobile learners; the educational paradigm or model considered and the possibilities and limitations of mobile and wireless technologies. The proposed framework is applied in the analysis of a case of development of a virtual learning environment designed to support the competence development of mobile workers. The design experience is detailed, showing lessons learned and indications for future research.

1. Introduction

The growing development and application of mobile and wireless Information and Communication Technologies (MWICT) opens new opportunities for processes improvement and redesign in organizational and educational settings.

MWICT can support informal and in-process learning, as opposed to traditional training activities in formal and fixed settings such as classrooms or training rooms. Ubiquitous learning is a recent approach that considers this new scenario, where the learners can choose the way, the time, and the context in which they wish (and need) to learn [29].

This perspective is particularly relevant if we consider trends such as the increasing number of mobile workers and the fast diffusion of a diversity of handheld and wireless computing devices [12]. MWICT can support learning by mobile workers, allowing them to spend more time where they really need to be – in the field, seeing clients, doing business, developing projects.

This possibility represents a significant change in the learning process logic. Learning needs are emergent, dependant on the context where learners are acting; the perspective is of a lifelong learning [29], in order to deal with a complex, dynamic and unpredictable labor market.

In this scenario, learning processes can not be limited to information assimilation; they must involve competence development, which means to develop the individual capacity to integrate and to apply a set of cognitive resources, including knowledge, skills and attitudes [20] in a situated manner, most of the time in the face of unpredicted, emergent events. Competences are developed, by definition, in situated actions.

In order to deal with these demands of professional education, new technologies have been designed. One of them consists in virtual learning environments for ubiquitous learning [19] [2].

For the development of this type of application, it is necessary to consider basic design principles, starting with the recognition of learner's profiles and needs; the consideration of contextual elements (physical, temporal, social) that surround the mobile learner; the educational paradigm adopted, as well as the possibilities and limitations of the available MWICT.

This article presents and discusses a framework that attempts to integrate these elements. The framework is applied to analyze a case of development of a virtual learning environment for ubiquitous learning called COMTEXT (the name that stands for competence in context), designed to support competence development of mobile workers.

This work attempts to make a contribution to the literature about mobile and ubiquitous learning, as well

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as to generate insights for researchers and developers of this type of applications.

The article is structured as follows: first, we present the framework and its theoretical foundation. We then present and discuss the experience of designing the COMTEXT environment, considering the framework as analytical lenses and highlighting the lessons learned in this process. The final section is a synthesis of the article and indicates future research issues.

2. Framework for the design of ubiquitous learning applications

The framework is a result from three distinct processes: (1) literature review; (2) an exploratory research of the state-of-the-art and future perspectives of mobile/ubiquitous learning in our research context [26]; (3) the collaboration/cooperation in an interdisciplinary research team during the practical and reflexive experience of designing the COMTEXT environment.

This interdisciplinary research team is formed by researchers and students from three different areas: Education, Computer Science and Management.

The framework (figure 1) considers four main elements and their interdependencies that inform the design process of ubiquitous learning applications:

- Learners' profiles and needs;
- The context surrounding the mobile learners;
- The adopted educational paradigm;
- The possibilities and limitations of MWICT.

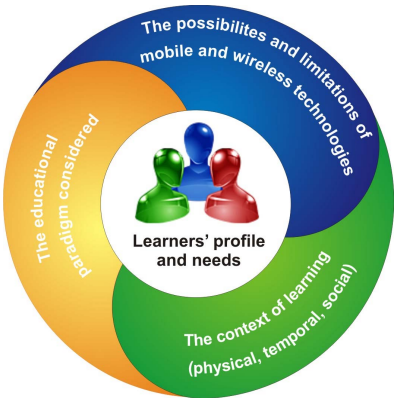

Figure 1. The framework proposed

Knowing learners' profiles and needs is considered the core element in the proposed framework, since the main questions to be asked when designing a solution for ubiquitous learning are: who are the learners and what do they need to learn?

A virtual environment for ubiquitous learning is a tool at the service of learners in a context of mobility. Although it appears to be an obvious statement, we have realized (empirically and via research [26]) that many current applications for mobile and ubiquitous learning are concerned mainly with the technology itself, instead of focusing on the learners' features and needs.

We define ubiquitous learning as the learning processes that, supported by MWICTs, occur in different contexts, not only in formal and fixed learning spaces (such as classrooms or training rooms) but specially in those situations when the learner is mobile – traveling, visiting, wandering in certain areas. These processes are continuously supported by MWICT, allowing the individuals to access and share information, to communicate and to interact, actions that are essential for learning [19] [29] [2].

The concept of ubiquitous learning considered goes towards the definition of pervasive learning in the sense that it is about "using the technology that a learner has at hand to create relevant and meaningful learning situations, that a learner authors herself, in a location that the learner finds meaningful and relevant" [31].

Ubiquitous learning is not the simple reproduction of traditional Distance Learning practices via mobile devices, since it is based on the assumption that the technology and applications are context-sensitive to attend the learner needs.

This assumption highlights the relevance of considering another element in the framework, which is the ***context surrouding the mobile learners***. This element brings a set of challenges to the design, since the notion of context involves not only the physical location of the learner, but also his or her temporal and social environments [11] [30] [22].

Using MWICT allows, for example, to increase process polychronicity, i.e., the possibility to deal with several tasks simultaneously. There is also a social context that includes different cultural formations, situations and moods, degrees of proximity and mutual recognition among people, etiquette and other elements that define what is or is not allowed in certain situations.

Thus, the context that surrounds a mobile learner is defined dynamically; it emerges from the activities that the actor performs, most of the time in a social network, involving motivations, planned and unplanned actions [32]. What is considered "normal" or adequate to be done in a specific context (including learning) is socially negotiated [5]. Therefore, these

challenges for the understanding of ubiquitous learning processes go beyond the traditional concept of Distance Learning.

In order to address these challenges, the design of ubiquitous learning applications has to consider, clearly, ***an educational model or paradigm***, which will define the pedagogical methodologies and practices to be applied.

Paradigms are defined here as a set of basic assumptions or beliefs that shape the way we understand reality; it is a world view, or, in this case, a view about the way people learn. For instance, two main educational paradigms are empiricism and interactionism, from which approaches such as the behaviorism and the constructivism are derived [7]. The way we understand the educational process, the role of teachers and learners and the relationships between these actors, must guide the methodological and technological choices to support ubiquitous learning processes.

It is essential to consider this fundamental design principle, since we have verified that, many times, a technological emphasis is adopted, with little reflection and consideration for epistemological and pedagogical elements involved [26].

Therefore, it is necessary to define clearly what type of educational model or paradigm is going to inform the technological choices, which will lead to another element of the framework, ***the consideration of the possibilities and also the limitations of MWICT***.

MWICTs are emergent technologies, in the sense that they still have a set of problems to be solved. One of them concerns the search for friendly and accessible interfaces, since existing mobile devices still have many ergonomic limitations (such as small screens and keyboards).

As in most emergent technologies, there are no widely adopted standards (hardware or software); in many places the wireless networks are still unstable and lacking reachability; the costs of mobile devices and connectivity (for instance, via mobile telephony) are still high in many countries, among others issues.

However, it is necessary to consider that, although MWICTs have all these limitations, they do afford us to engage in communication, in accessing information and interacting in a very innovative way, due to their portability and connectivity capabilities.

The trade-off between the possibilities and limitations of these new technologies has to be at the service of learner's profiles and needs, their context, and the pedagogical model/paradigm considered to design ubiquitous learning applications.

Considering the proposed framework as a tool for analysis, in the sequence we present and discuss a concrete experience of designing a virtual learning environment for ubiquitous learning – the COMTEXT environment.

3. The Framework applied in a concrete experience: designing the COMTEXT environment

Considering the core element of the framework, that is the ***identification and consideration of learner's profile and needs***, the COMTEXT environment was created to support learning activities of mobile workers. To reach this purpose, a current approach for organizational development was considered: the competence perspective that has been adopted by many organizations around the world [23] [10] [13] [17] [25]. Although this perspective is widely diffused, few Distance Learning applications – not to mention ubiquitous learning applications – have been designed to address the needs of this specific perspective [15].

The COMTEXT was designed to be a tool for testing concepts related to competence development and ubiquitous learning, aiming at contributing for the understanding of the possibilities that MWICT can bring to theses processes [8].

At the organizational level there is the competence perspective that can be defined as an organizational strategy [15] by which the organization identifies the competences that are essential for reaching its mission and objectives; these competences guide the way the resources and people are managed - the way people are recruited, developed, oriented, supervised, evaluated and rewarded.

Organizational competences are formed through integration and synergy between functional or collective competences (from different areas or teams inside the organization). These collective competences are the result of the integration and synergy between individual competences; they are not the simple sum of individual talents [13], since they involve the parts (individual competences) but also the relationship between them.

According to a competence perspective, competence requirements are defined in a top-down approach: the guiding competences are organizational and will define the required functional or collective competences (teams' competences), and then the individual ones.

However, the development of competences is

cyclical, since the individual competences are the basis for attaining the collective/functional, and, by consequence, the organizational competences. Even when we define competences in a top-down approach we must be prepared to, based on individual competences, to rethink and redesign these competence definitions (in a bottom-up approach). In fact, individuals can and frequently do bring new competences or skills for their process and work in organizations. Lindgren, Stenmark and Ljungberg [14] highlight the importance of considering individual interests as a source for competence identification. Van der Vorst [33] argues that the process of identifying competences can create “blind spots” affecting organizational strategic flexibility. The whole effort to define and to uptade competences definitions must be considered, above all, as a reflection and learning exercise, since competences are dynamic, not static. All levels of competence interact in practice [4].

Altough time-consuming, this exercise is strategic; otherwise the organization can spend time and effort investing in educational or instructional activities that do not contribute for achieving organizational goals (in a top-down approach). At the same time, the organization can ignore and loose individual competences that could support innovation and create new opportunities inside organization (in a bottom-up approach), as well as to stimulate people in their personal activicties or projects.

The concept of individual competences considered in this paper refers to the capacity of each individual to act effectively in a certain situation, putting into practice, and with synergy, several complementary cognitive resources such as: knowledge, skills and attitudes [20].

Considering the competence perspective and mobile workers as the learners at the center of the process, COMTEXT was designed as a virtual learning environment that attempts to reach learners' needs according to this perspective [15]. The COMTEXT logic considers a competence development cycle in four modules created to support this cycle (figure 2).

The first module is called "PROFILE", allowing competence identification and possible gaps that need to be filled. There is a second module called "PLANNING", that supports planning all educational or instructional activities; the third module is the heart of the environment, called "LEARNING", which offers a set of tools to support learning activities; and, finally, there is a module called "ASSESSMENT" that provides instruments to check if the competences or gaps were effectively developed, as well as whether the learning process was appropriate. These assessments send feedback to the module "PROFILE", completing the cycle.

This competence development cycle operates in constant interactions between the four phases (and modules). Therefore as previously stated, competence definitions and development have to be dynamic, not static, and new gaps or learning opportunities can lead to new development cycles.

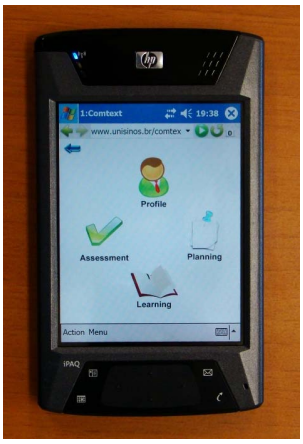

Figure 2. COMTEXT - main modules

As mentioned before, initially the COMTEXT allows, inside the module called "PROFILE", to insert and access a "tree" or "map" of organizational competences, which unfolds the competences from the organizational level to the individual level.

The module allows registering the status of each individual in relation to the competences of his/her role in the organization. It also indicates who are the "experts" in certain competences, helping a community of learners to share their expert knowledge and experiences. This functionality also helps in the creation of ad hoc teams (ex: project teams), since it can indicate expertise that can be combined or integrated. In this sense, the environment can support not only the development process of individual competences, but also the development of collective ones, which will form the organizational competences.

Beyond a simple process of competence mapping, developing competences implies developing individual knowledge, skills and attitudes articulated in concrete actions, and in collaboration/cooperation with others. This process demands the consideration of a coherent educational paradigm.

The educational paradigm considered in the COMTEXT design is interactionist-constructivist, strongly influenced by the work of Piaget [21].

According to this reference, a new knowledge is

constructed by the subject in action, during the interaction with an object of knowledge. Learning is an internal process, involving the creation of a network of relations by which the subject creates meaning about new information, transforming it into knowledge. Although internal, this process occurs in social interaction; the construction of knowledge occurs during collaboration and cooperation processes among individuals. Therefore, learning is translated into movement, action, interaction [27] [28].

Therefore, we consider the learning processes at the organizational level according to an interactionist perspective of knowledge construction, in which the learner is an agent with previous knowledge, a thinker capable of acting in his/her own environment, interacting, establishing relationships and articulating knowledge: "knowledge creation occurs anywhere, anytime, inside a network society, this process is not linear, nor predictable, it is incompatible with the idea of progressing from the easier to the hardest part" [27].

Regarding the use of Information and Communication Technologies (ICT) for educational purposes, there are tools more appropriate for information sharing; there are others more appropriate for sharing knowledge, ideas and experiences, as well as tools that allow cooperative/collaborative work. These technologies, when combined, can improve the processes of teaching and learning.

The learning tools inside the COMTEXT environment aim at supporting the competence development, promoting interaction among a community of learners and practioners, focusing on knowledge sharing and the development of skills and attitudes. Interaction is also essential for the creation of collective competences, not only individual ones.

In this virtual community of learning and practice it is possible to create the role of a tutor, teacher, instructor or coach that can act as a mediator or facilitator inside the community, depending on the nature of each learning activity.

The environment can also be used to support a community of practice. According to Wenger [35] [36] communities of practice are groups of people sharing common interests and knowledge about something that they practice. According to Brown and Duguid [3] within these communities people share their experience and learn in an informal way by narrating their previous experiences and tales of work, by collaborating in problem solving processes and by socially constructing an understanding of a problem as well as of possible solutions.

Therefore, the COMTEXT environment can be applied as a platform to formal educational or instructional activities as well as an environment to support a community of practioners in informal learning processes.

The learning tools inside the environment are (in the module called LEARNING, see figure 3):

Diary – this is a tool that allows each individual learner to register his/her observations, comments, doubts, difficulties faced and feelings during the learning processes. It constitutes a space for individual guidance: a coach, teacher or instructor can read each individual diary and make comments or help solving particular problems or doubts. The use of a Diary as a pedagogical tool has the intention of promoting reflexivity and meta-cognition, meaning, "to think about one's own thinking", helping in the processes of continuous auto-assessment. The Diary also provides information for monitoring the educational or instructional process, allowing improvements or redesigns while it is still developing.

Discussion forum – is a tool for asynchronous and collective interaction, supporting the discussion of a wide range of issues in educational/instructional practices or in informal interactions in communities of practice.

E-mail – this tool allows learners to access their own e-mail providers via Internet. The COMTEXT does not impose a specific e-mail tool; the learner can receive all messages related to educational/instructional activities in his or her particular e-mail box.

You Tube® - This is an important tool for sharing information. Videos are considered to be an adequate media considering the ergonomic limitations of mobile devices. Videos can be created specifically for each educational/instructional, or this popular repository can be used to access a variety of types of videos such as, for instance, product or process demonstrations, institutional/promotional videos, etc.

Skype® - this is also a very popular tool that can be used for synchronous interaction via chats or direct conversation.

Mind maps – is a tool for individual or collective interaction, which allows the creation of mind maps that can be used to express individual or collective understanding about specific concepts and the relationship between them, or a general understanding of a particular reality. This is considered to be an important tool since "a map is better than one thousand words", and it helps to reduce the need of typing text (a task difficult to be performed on the small keyboards of mobile devices).

Files (repository) – is a tool that allows inserting and accessing learning objects of different types (word

documents, spread sheets, figures, pictures, videos, podcasts, etc.). Each individual learner in COMTEXT can insert and access resources in this tool. Each file to be uploaded must be identified, with the following attributes [2]: (1) uploading date; (2) expiration date (if applicable) (3) object classification according to a knowledge area or competence related with the object (4) key-words, to facilitate indexing and searching (5) the file itself or a web address where it can be accessed.

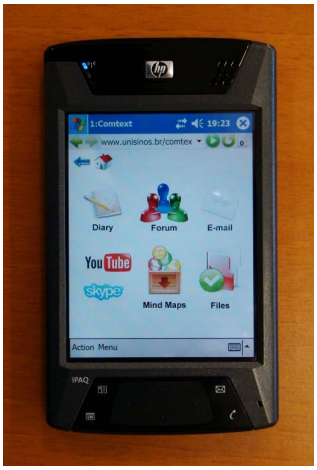

Figure 3. Learning tools inside COMTEXT

The learning objects can include maps, simulations, presentations, demonstrations, a manual about processes or procedures, and all types of documents related to the context of work.

The tools in the LEARNING module can be used in different ways, according to the profile of the users and the educational goals. For instance: in some educational or instructional activities learners can be travelling, with different time schedules, so it is not possible to use synchronous communications tools such as chat as support for learning activities; foruns for asynchronous, collective discussions and Skype® as a tool for interacting with some specific workmate for collaboration and/or with the instructor to solve doubts can be more adequate. Learning objects such as tutorials or cases can be studied; mind maps can be applied to make a synthesis of learning, and so fort.

COMTEXT offers this set of tools in order to allow flexibility and, in the research process, to support experiences with different types of communicational and instructional resources, in order to understand which one is more adequate according to different situations and goals in ubiquitous learning. Tools that are adequate in fixed e-learning situations can be inadequate when accessed via mobile devices and in a context of mobility.

The set of tools inside the LEARNING module is integrated with the ASSESSMENT module. This module captures historical registers of all the interactions occured inside the learning tools available. Therefore, it is possible to have an individual *portfolio* with all the contributions and interactions, as well as all the tasks and projects done by each participant in the learning community. It allows to check the way each individual has progressed (or not) towards filling the competences.gaps previously identified in the PROFILE module.

The ASSESSMENT module also allows the creation and application of assessment instruments. These instruments can hold quantitative scales or open (text) questions for quantitative and qualitative analysis. Each participant in the process can express his/her own point of view based on the assessment principles defined by the community of learners.

The module allows the generation of multiple assessment instruments that can be applied according to the dynamic of each learning activity, for instance, it is possible to make a "360º evaluation" (about individual learners, tutors/teachers/instructors, assessment of the activity and the environment itself, auto-assessment, etc.).

This EVALUATION module provides feedback information for the "PROFILE" module, specifying in what degree each individual learner or a specific team has reached the desired level of competence, or has filled the competence gaps previously identified.

We consider that the set of learning and assessment tools in COMTEXT is parsimonious, but even so, to develop and to integrate these tools was not an easy task. Each tool was considered according to the educational paradigm adopted (the interactionist-constructionist paradigm) and also according to the ***possibilities and limitations of mobile and wireless technologies for ubiquitous learning***, another important element of the proposed framework.

In the development of COMTEXT, we adopted HP iPAQ® PDAs, with the Microsoft Windows Mobile® operating system. Pocket Internet Explorer® is the system's default internet browser.

An aspect that deserved attention during the development process was the reduced processing and storage capability of the mobile device we employed. This limitation was decisive for choosing a client-server access model. As such, we used webservices [16] to create a simple, standard and multiplatform system.

To develop the system's web interface we used the

PHP language (PHP Hypertext Preprocessor). Content is dynamically generated, in the server, making the system cross-platform. For the communication between the interface and the webservices, we adopted the SOAP (Simple Object Access Protocol) protocol and XML (eXtensible Markup Language). This was done in order to standardize the data structures used for communication and to delegate most of the processing tasks to the servers, allowing the system to run in different types of mobile devices and platforms (except for particular restrictions related to multimedia content, for instance).

Besides hardware limitations, such as the reduced screen resolution and lack of a physical keyboard, as well as reduced computational power, the research team faced the limitations of the built-in software of the mobile devices. One of the main limitations was that the built-in browser did not allow accessing the true full-screen resolution of the mobile devices (480x640). The browser also has limited support for the CSS standard and does not provide tabbed browsing, which is an essential feature to allow the user to perform other tasks without leaving the environment. For these reasons, another browser was adopted: Opera Mobile®, which supports a variety of web standards currently in use (such as the CSS 2.1, XHTML 1.1, HTML 4.01, WML 2.0, Web Forms 2.0, AJAX, ECMAScript, DOM 2, Canvas and SVG 1.1.) Opera Mobile® shows web pages the same way they are presented in desktops browsers. This feature allows the user to access a more complete content in a simpler manner. This browser also supports bookmarks, cookies, tab navigation and Adobe Flash® content.

The mobile versions of Skype® and Pocket Mind Map® have only a subset of functionalities of their desktop versions. Skype® also has limitations related with the use of wireless networks: it demands a broadband connection (when using Wi-Fi), and there are extra fees charged for data transmission (when using a 3G-based device, such as a mobile phone).

Attempting to overcome the ergonomic limitations of mobile devices, the COMTEXT interface is based on big, touch sensitive icons, to minimize the use of text. With this same goal, some resources were created to avoid typing, such as automatic form filling and components for selection, improving the interface usability.

The adopted mobile device also has limitations in the access to multimedia content, as for example, on demand audio and video streaming over the Internet; special font sizes, etc. Some supporting tools were used by the research team, such as the independent tool ytPocket (http://www.ytpocket.com/), that facilitate the access to YouTube® content (FLV videos) in mobile devices using Windows Mobile®.

Another issue is that the size (in bytes) of the software used creates constraints for the type of mobile device adopted: some devices do not accept extra memory/storage cards, others have reduced internal memory. The mobile device adopted allows for expanded memory via SD cards, yet this constraint is still an important issue to consider.

The web interface for the COMTEXT environment brought an extra challenge for the optimization of the website loading time in mobile devices. For this reason, the website uses a clean HTML markup, loading CSS style sheets from external files. Besides that, the images used (the icons) were optimized to reduce the amount of loading time: the COMTEXT main menu has only 40 kilobytes, images included.

This is only a small subset of the technical issues that have challenged the research team during the design process.

Another element indicated in the framework also demands developing innovative technological solutions, in order to support the ***consideration of the context that surrounds mobile learners***.

Location systems [9] can inform the physical location of a mobile device. This information can be obtained via satellite positioning systems (such as the GPS) and/or via wireless antennas [9]. The efficacy of location based on satellites is severely reduced in urban areas (crowded with buildings) or indoors. In this sense, new alternatives to the use of satellites have been created, such as the integration between the GPS and mobile telephony (A-GPS [1]), as well as positioning systems based on wireless antennas [6], on WiFi [24] or both of them [9]). Some recent developments demonstrate that the current location precision do already allow the implementation of commercial applications. Besides that, the fast diffusion of wireless antennas stimulates the proliferation of location based services [18].

Our research team has created a location system described in [2], based on a generic architecture. This location system has been incorporated into COMTEXT, working with two modules: (1) a Personal Assistant (PA) and (2) a location module. The PA comes with the mobile device and presents the following functionalities: (1) authentication, keeping track of the learner´s connection status; (2) access to the the location module, allowing for turning it off at will.

The location system supports different methods of determining users' physical locations. The system ties physical location data to symbolic names (contexts).

This allows real time mapping of mobile device positions. As the learner authorizes the location module in its PA, it begins to determine the device's position and physical context changes, along with the time and date of such changes. With this data, it is possible to completely track the learner's movements. User profile data, alongside context information, can be used in the learning process.

The location module has two parts: (1) a web service created in C#, which supplies generic location data and (2) a database that stores context information. The PA was developed in C#, using the .NET Compact Framework.

In order to create context-aware learning activities, the next version of COMTEXT is going to incorporate a module called *virtual tutor*. This module (already tested on [2]) uses profile and location data to find learning opportunities for each user. It can act in two ways: sending learning objects and stimulating interaction between learners. This resource uses learners' profile data to create bonds between them. There are two forms of interaction: 1) similar interests or competences: the virtual tutor finds learners with similar interests/competences in the same context, and stimulates interaction. This approach can be used in the creation of workgroups in a training room, for example; 2) Complementary interests or competences: the virtual tutor finds learners with complementary interests/competences. For example, a learner who wishes to learn more about a particular subject or a competence element is paired with an user who wishes to teach or is an expert on the subject. This way, the virtual tutor can be used, for example, to suggest pairs of officemates who complement each other.

The virtual tutor uses a messaging service to establish contact with learners, notifying them of new learning opportunities. This service can be controlled automatically, or by an operator using the administrative interface to COMTEXT. Users are contacted by textual notifications in the system. The notifications are sent according to profiles, objects, location and event data. The following services are supported: (1) sending messages to a specific user in the system, wherever he/she is; (2) sending messages to a specific context (everyone in the context receives the notification); (3) sending messages to a user, but only if he/she is inside a particular context; (4) sending messages to all users, regardless of context. The messages also have an associated date of expiration, delimiting a time interval after which the message loses its validity.

The location system and the virtual tutor were both tested in an academic environment, as described in [2]. However, the research team is skeptical about the acceptance of such type of tool by mobile workers in learning activities. The seminal work of Weiser [34] already indicated peoples' resistance against tracking systems in an organizational environment.

Therefore the research team is searching for new models of location systems and context-aware services, more user-centered, that would give users the freedom to define the way they want to be found, and with richer resources to explore contextual opportunities for learning. This is a very important issue for future research, and a priority in our research agenda.

Considering the temporal context that surrounds the mobile learner, COMTEXT allows, in the module "PLANNING" to register learning activities that are going to be carried out by the community of learners/practioners, such as: forums, informal chats, workshops, projects development.

After this registration, the module has an alert functionality, meaning that the system sends reminders to the members of the learning community (via e-mail) about the scheduled activities or virtual meetings.

Although each individual learner is free to learn at the time and location he or she wants or need to, it is very important for the collective context that learners can have a kind of "compass" to guide and remind them about specific events or activities for knowledge/experiences construction and sharing.

Previous experiences in Distance Learning have showed us the importance of proactive features in a virtual learning environment, in the sense of reminding learners about events or deliverables. It helps in keeping the rhythm of learning and avoiding the sensation of loneliness and abandonment often felt by distance learners.

We must consider that the activities happening in a virtual learning environment compete with a series of other events and appointments in the learner's physical context, also demanding their attention.

This aspect related to the temporal context that surrounds the mobile learners is going to be studied during the practical application of the developed prototype. Only through the concrete usage of COMTEXT by a community of learners will it be possible to understand how they will share their time between the learning activities proposed in the environment and all their daily work activities.

This aspect also refers to the social issues implicit in the notion of context. The forms by which the application will be used (and accepted, or not) in different locations and work situations, as well as during "dead times" that the users choose to learn, can

only be verified in situated applications of the tool, our goal for the next phase of this research in progress.

4. Final comments

In this paper we have discussed several challenges concerning the competence development for mobile workers via ubiquitous learning process.

The framework proposed and the report of a concrete experience of developing an application for this purpose had as their main goal to promote discussion and reflection about the core elements that are supposed to guide the design of ubiquitous learning applications.

As mentioned before, this article results from a research in progress. The current phase involves the application of COMTEXT in a real organizational setting. Only through its use in concrete and situated learning activities will it be possible to understand to what degree this type of tool can actually contribute to competence development of mobile workers.

Hopefully, this practical application will provide new insights and ideas for the elements considered in the framework. The elements highlighted can then be checked, detailed and improved, specially the element that involves the context that surrounds the mobile learners (as mentioned before, a very relevant issue for future research).

Another issue that deserves future research is the way in which ubiquitous learning applications can effectively support communities of practice.

We believe that a set of innovative tools can be designed to address specific needs of this type of learning community, especially regarding informal, emergent learning activities.

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