Content management in a ubiquitous learning environment

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Abstract: Currently, the mobility of users who carry mobile devices and access resources through wireless networks brings up the need of providing uniform and immediate access to their information. In this scenario, a new model of education called ubiquitous learning is being explored. Therefore, the educational processes are related to the situation involving the learner (i.e., they are context-aware), allowing the access to educational resources to be adapted according to his/her profile and context. GlobalEdu is a computing environment that aims to support ubiquitous learning, being aware of the context and mobility of the learners. This paper presents the GlobalEdu content management model, as well as its model of interoperability among repositories of learning objects that are used throughout the educational processes carried in the system.

Keywords: ubiquitous computing; ubiquitous learning; learning objects; content learning model; context-awareness learning.


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1 Introduction

The user who carries mobile devices has the possibility of using the facilities of wireless technology, such as access resources anywhere. However, to provide this scenario it is necessary to offer uniform and immediate access to this information. The ubiquitous computing (Abowd and Mynatt, 2000; Satyanarayanan, 2001; Weiser, 1991) is a computational model that aims to pro-actively serve the needs of users, acting in an invisible way (background). The goal is to provide a continuous integration between technology and the environment, helping the user in his daily tasks. In this model, the applications are available regardless of place and time. The access to the network and the computing environment is continuous, independent of the device and the physical location of the user. From this scenario, a new model of education called ubiquitous learning (Barbosa et al., 2008; Ogata and Yano, 2009; Ogata et al., 2010; Rogers et al., 2005; Yin et al., 2004, 2010) is being explored. In this model, the mobility of learners and the perception of the elements that are near them (context) are part of the learning process and this process can occur in a continuous, comprehensive and transparent way. Therefore, these environments support learning processes related to the situation involving the learner [context-aware (Dey, 2001)], allowing learning resources to be accessed according to the profile and the context in which learner is.

We have been investigating how mobile devices and location technology could be used to improve learning. The GlobalEdu project (Barbosa et al., 2005) considers four elements and their interdependencies:

1. learners’ profiles and needs
2. the context surrounding the learners
3. the adopted educational paradigm
4. the possibilities and limitations of ubiquitous technology.

The educational paradigm considered is interactionist-constructivist, which is strongly influenced by the work of Piaget (1995). According to this reference, the subject in action constructs a new knowledge 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. Therefore, a ubiquitous learning application must support the integration among learners and their context, allowing the access to contextualised information and learning objects.

GlobalEdu uses two pedagogical strategies:

1. context-aware content distribution using learning objects
2. stimulus to the interaction among learners.

So, GlobalEdu is a ubiquitous learning architecture that is aware of the context and the mobility of the learner. In this model of education, context awareness has a key role, since it allows exposing to the learners aspects of their interest that relate to where they are in the moment. The mobility allows the system to act pro-actively in the various places where the learners are. Because of this, one characteristic of our architecture is to explore content (learning objects) related to the context of the learner and his profile. GlobalEdu adopts a distributed organisation, considering the access to a global network. This network needs to support wireless access, interconnected to a wired network that provides the structure of services and equipment on a global scale. This structure can interconnect GlobalEdu servers scattered in different contexts. The model requires a ubiquitous middleware. For this reason, the system is being integrated to an environment that supports a ubiquitous computing called ISAM (Augustin et al., 2004).

GlobalEdu has been tested at Unilasalle University in order to support ubiquitous learning. We have created a large-scale ubiquitous learning scenario based on GlobalEdu and we used it to evaluate the systems functionality. In this evaluation we involved learners of the university.

This paper is organised in seven sections. Section 2 discusses issues related to ubiquitous learning and learning...
objects. Section 3 presents previous work in the area of ubiquitous technology used to create pedagogical applications, and how it relates to our research. Section 4 details the GlobalEdu proposal. Section 5 presents the content management educational module, which is the focus of this paper. Section 6 describes the scenario in which the module of content management was evaluated. Finally, Section 7 describes a conclusion and indicates possible future works.

2 Ubiquitous technology, ubiquitous learning and learning objects

Location (Hightower and Borriello, 2001; Hightower et al., 2006) is an important topic related to mobile computing (Diaz et al., 2009; Satyanarayan et al., 2009) and ubiquitous computing (Abowd and Mynatt, 2000; Satyanarayan, 2001; Weiser, 1991). This research front proposes the determination of the physical location of mobile devices (for example, a room in a building, or a specific address in a street).

Location technology is as useful as it can be continuous, anytime, anywhere (Hightower et al., 2006). There are many different ways to get location data in mobile computing (Hightower and Borriello, 2001). Nowadays, new alternatives to the use of satellites are appearing, like integration between GPS and mobile telephony (FCC, 2011) and positioning based on wireless antennas (Hightower et al., 2006). Moreover, the proliferation of wireless hotspots suggests that in the future this precision will grow, providing sophisticated location-based services (Dey et al., 2010). Location technologies can be used to explore nearby opportunities [context-aware computing (Dey, 2001)].

Based on these studies, one can consider a medium term scenario where society will be permeated with mobile devices always connected to a communication network and with available precise location data. This proliferation of ubiquitous technology will significantly impact society in several areas. Between these areas, one of the most prominent ones is education [ubiquitous learning (Barbosa et al., 2005, 2008; Ogata and Yano, 2009; Ogata et al., 2010; Rogers et al., 2005; Yin et al., 2004, 2010)]. In this scenario, new educational models should arise since pedagogical resources would be accessible anytime, anywhere.

Barbosa et al. (2005) define ubiquitous learning as a process that can occur anytime and anywhere and that is adjustable, continuous and integrated with the learners’ daily activities. The essence of ubiquitous learning is to realise which information is presented throughout the learners’ daily tasks, in different forms and places, and to link this data with the learners’ educational process. Technologies that support ubiquitous learning should provide these aspects through mechanisms that allow knowing learners, contexts involving them, and how learners relate to contexts.

Ubiquitous support provides the construction of learning programmes related to dynamic information based on learners’ physical context, allowing for links between contexts and pedagogical goals. In this scenario, education is dynamic and educational resources are distributed in contexts.

We investigated which subset of functionalities is needed to achieve the benefits of large-scale ubiquity. As conclusion, we assumed that it is possible to develop ubiquitous learning applications using ubiquitous computing support. Therefore, it is also possible to implement distributed, mobile, context-aware, adapted and follow-me applications (Augustin et al., 2004). We considered that the use of context-awareness (Dey, 2001) with ubiquitous computing support enables the exploration of large-scale ubiquitous learning.

The new class of context-aware systems opens prospects for development of applications that explore the dynamic nature and the mobility of users. The contextual information comes from many sources, such as location sensors, temperature sensors, users’ profiles and network monitors. In addition, while supporting learning, context-awareness allows relating explicit information of the learners (for example, preferences and goals) with implicit information of their physical location (for example, temperature and people in the same location). For us, the daily context of the user can be connected with the local context, joining current information with educational objectives. In our work, local context is the information about persons, relations, places and resources in the specific location. Software agents can understand this information.

Using ubiquitous learning support, applications can proactively notify learners about events or resources of their interests available in the context. In this scenario, it is possible to look for learning objects according to the learners’ contexts and profiles. Learning objects (LOM, 2011) are defined as any digital or non-digital resources that can be used to support learning processes. These objects are building blocks for constructing the context of learning. An important aspect is the use of standards to catalogue the objects, such as IEEE/LOM (2011). These standards aim at facilitating exploration of issues related to accessibility, interoperability, durability and flexibility. These aspects are important in ubiquitous computing environments because learners can access resources anywhere and with any device.

3 Related works

Some projects are investigating the use of ubiquitous computing to provide new learning perspectives. Nonetheless, there are few proposals using learning objects to represent pedagogical content. The integration between contextualised user profiles and context technologies is the key to ubiquitous learning environments. For instance, this type of integration allows features like the distribution of contextualised learning objects in a specific location and the match of students with common interests within a learning context. Therefore, we introduced into GlobalEdu the match
between context technology and user profiles. This match is a central feature of GlobalEdu.

The technologies used to create ubiquitous learning environments can be used to support specific applications. For instance, JAPELAS (Yin et al., 2004) is a system created with the goal of supporting learning of polite expressions in Japanese. The students, using handheld PCs, are assisted in the identification of the correct polite expressions to be used in a particular context. JAPELAS only allows the contact between two users. A new version called JAPELAS2 (Yin et al., 2010) is oriented towards supporting the interaction between many people, with a collaborative/social approach. Both systems use location technology and user profiles, but they represent a specific application. In order to support several university courses, a generic infrastructure should be available. This infrastructure should provide applications that use location technology aiming at supporting particular tasks. GlobalEdu uses local information and learner profiles in a generic approach, in order to explore pedagogical opportunities in a context-aware environment. With GlobalEdu’s content Management it’s possible to learn about any kind of content.

The ambient wood project (Rogers et al., 2005) is dedicated to the design and building of pervasive environments. WiFi and sensor-based technologies are connected with a variety of mobile and standalone computing devices. The proposal is that digital augmentation offers a promising way for enhancing both indoor and outdoor learning processes. GlobalEdu uses the social and physical information to improve the learning process. With ISAM integration GlobalEdu intends to explore both indoor and outdoor applications.

Other approaches explore radio frequency identification (RFID) technology to integrate the real world in the pedagogical experience. TANGO (Ogata et al., 2010) allows placement of RFID tags on real objects. The tags can be detected when a learner visits an environment. A mobile device can be used to interact with objects, in order to improve the learner’s vocabulary through the questions and answers previously registered in each object. Moreover, Mobio threat (Segatto et al., 2008) is a pervasive game that represents another pedagogical approach based on RFID technology. In Mobio threat, RFID tags are implanted in game objects, such as trees and rooms, to allow learners to interact with these real objects using their mobile devices. Its main goal is to support learning about epidemics and disease control. During the game, the players have to work with pathological agents and chemical reactions. The pedagogical contributions are centred in the areas of chemistry and biology.

TANGO and Mobio threat use the same strategy to improve the pedagogical experience, i.e., they integrated the real world in the educational process using RFID technology. Differently from GlobalEdu, both proposals focus on specific pedagogical areas. GlobalEdu is a generic ubiquitous learning model. Moreover, the integration between GlobalEdu and ISAM is general enough to support the interaction with real objects using RFIDs or any other kind of technology.

Few projects in the area of ubiquitous learning use learning objects to represent pedagogical content. JAPELAS (Yin et al., 2004, 2010) was designed for a specific purpose, and does not use learning objects. The ambient wood project (Rogers et al., 2005) does not support learning objects. Its focus is specifically on pervasive environments based on digital augmentation. Yang (2006) proposes a peer-to-peer access to content in a ubiquitous learning environment. The proposal also does not specify how the content is going to be represented. Unlike these works, GlobalEdu employs the notion of learning objects and uses the content management module to support a generic management of LOs.

Schmidt (2005) summarises the characteristics of context-aware learning systems and presents a case study that uses learning objects based on the SCORM (2011) standard. GlobalEdu uses the LOM standard (LOM, 2011). SeLeNe (Rigaux and Spyrratos, 2010) and Elena (Simon et al., 2002) also use the LOM standard, however, they do not consider the adaptation of content according to the learners’ current context, as GlobalEdu does. LOCAL (Barbosa et al., 2007) uses the LOM standard and support location-and-context-aware computing environments in a small-scale ubiquitous learning model but GlobalEdu aims to a large-scale management of content based on interoperability among distributed repositories of learning objects.

Previous publications of GlobalEdu describe the first GlobalEdu architectural (Barbosa et al., 2005; Nino et al., 2007). Considering the related works and the previous publications we can emphasise, as main contribution of this paper, the proposal of large-scale management of learning content. This proposal is mainly based on interoperability among distributed repositories of learning objects.

4 GlobalEdu

The GlobalEdu (Barbosa et al., 2005) uses profile, context and profile learners data to find learning opportunities. It can act in two ways:

1. sending learning objects (the focus of this paper)
2. stimulating interaction between learners.

It uses the learner profiles and content data to create bonds between learners. There are two types of interaction:

1. Similar interests: the GlobalEdu finds learners with similar interests in the same context and stimulates their interaction. This approach can be used, for example, in the creation of workgroups in a classroom or to study about the same content (context-aware content distribution using learning objects).
2. Complementary interests: the GlobalEdu finds learners with complementary interests. For instance, a learner who wishes to learn more about a particular subject is
matched with a user who wishes to teach or who is an expert on the subject.

GlobalEdu investigated how to expand the ISAM architecture to learning domain. ISAM (Augustin et al., 2004) considers that ‘the computer’ is the whole network. The computing environment (data, device, code, service, and resource) is spread in composed cells. Users can move around, having both their applications and the virtual environment following them.

The GlobalEdu architecture proposes a layered organisation as Figure 1 shows.

**Figure 1** GlobalEdu architecture

### 4.1 The application layer

The application layer is represented by a *pedagogical agent*, which follows the learners throughout the environment and assists in their interactions with the system. The pedagogical agent module runs on the mobile devices of the learners assisting the educational process in the ubiquitous environment. Pedagogical agent contains an interface to the system layer and provides a ubiquitous vision through the ISAM environment. The pedagogical agent characteristics are the following:

- The agent state migrates to the learner devices through the ISAM services. This is an ISAM middleware feature that allows an application running in a disconnected mode. Because of this, the pedagogical agent also controls disconnection operating normally, despite some access restrictions to the GlobalEdu system layer. So, ISAM guarantees that the pedagogical agent follows learners providing some educational process even when the learner is disconnected from the GlobalEdu environment.
- Communication between learner and educational modules obtaining information of the environment.
- Accessing control of the learning objects. It helps the learner with the search and presents the learning object according to context information and learner’s model.
- Information about context related to the learner’s location and learning goals.

Figure 2 shows pedagogical agent’s architecture organisation. The agent presents two basic types of activities: a cognitive structure based on beliefs and a reactive structure based on events. The beliefs, considered the knowledge of the learner’s current state, are handled by the education modules in the composition of the production rules being this the formalism used by the pedagogical agent for reasoning. Events constitute the stimuli necessary for the reaction to the specific transformations that occur during processing, characterised by the messages exchanged internally by the agent.

**Figure 2** Pedagogical agent’s architecture (see online version for colours)

### 4.2 The system layer

Educational modules and support modules compose the system layer. They provide support for execution of the pedagogical agent in the ubiquitous environment. Furthermore, they enable the identification and the adaptation of resources according to the learners’ profiles and contexts. The educational modules and the support modules are heavyweight execution units, thus they are executed on the network servers. Otherwise, the pedagogical agent component is a lightweight execution unit, thus it can be executed on the learners’ mobile devices. Both pedagogical agent and system layer use ISAM middleware services for communication (Figure 3). So, the GlobalEdu components use ISAM feature for all services that need ubiquitous support.

**Figure 3** GlobalEdu and ISAM communication (see online version for colours)
4.2.1 Educational modules

The educational modules are responsible for performing functions related to the contexts and the content management. They also are responsible for manipulating the learners’ model. GlobalEdu has the following educational modules: profile management, content management and context management.

4.2.1.1 Profile management educational module

When learners move around contexts their learning models can change. The profile management educational module generates the learners’ model, which is represented by a metadata. This stores information about each learner, and provides this information to the other subsystems. The profiles can be used to customise the user’s learning.

In the scope of ubiquitous learning, profiles allow the exploration of resources based on the characteristics of the learners and the contexts in which they interact. The profile learner metadata uses some categories of the PAPI (2011) and LIP (2011) standard and the learning styles (Felder and Silverman, 1998). The metadata also supports trails (Levis et al., 2008). It is due to:

1. **Flexibility**: the standards was designed in order to be freely extended since its components are optional an can be redefined if needed.

2. **Modularity**: each profile field and/or section can be handled separately, allowing for part of the profile to be stored in the personal assistant, while another part is tied to each context visited by the user.

The PAPI categories used are the following:

1. **Personal information** – stores basic user data, such as name, address, phone number and e-mail.

2. **preferences** – helps the model to customise the user experience, storing configuration data related to the preferred media type (audio, video and/or text). If the learner has some type of physical disability GlobalEdu can provide content in different formats.

3. **Relations** – stores data that specifies relations with other users in the same context (for example, ‘student’, ‘teacher’ or ‘researcher’).

4. **Security** – stores credentials (names and passwords) to allow different access levels in specific contexts.

The LIP categories used are the following:

1. **Goal** – follows the knowledge areas defined in the ACM Computing Classification System (ACM, 2011), having a general knowledge area (for example, ‘Math’) and a specific interest topic (for example, ‘group theory’). The specific areas are then classified according to the learner’s goals (for example, ‘to learn’ or ‘to teach’).

2. **Competency** – refers to proposed goals and evaluations conducted in a context.

The learning styles are based on the proposal of Felder and Silverman (1998). A trail contains the history of the learners’ actions in the ubiquitous environment storing information related to locations, devices, applications, and contexts accessed. Therefore, it is possible to know any change in the learners’ models. The learners’ metadata also has information of relations that is generated as a learner meets other learners in the ubiquitous environment. This presupposes the existence of other learners with the same goals, competencies and preferences.

4.2.1.2 Context management educational module

The context management educational module manages the learners’ contexts monitoring any change in the contexts where the learners are. The learners’ contexts are composed of social context and physical context. So, this service perceives changes of context elements in the different locations where the learner is. His/her social context and physical context compose the learner context.

The social context has the information about location context and presence of other pedagogical agents in the currently context. Location context is the information about people (name, e-mail, commitments, and role), events (type, description, and location) and resources (name, type, description, and commitments) related to a specific location. The presence of other personal agents presupposes the existence of other learners with the same goals, competencies and preferences, so the learner may access those learners for contact or not. This information can also be used for the creation of learner groups in the same context.

The physical context represents the resources accessed by the learner, such as network, locations and devices. We consider that the ubiquitous computational environment monitors physical context elements. Besides, any element state changes are informed to the context management educational module.

Management context in GlobalEdu is the capacity to know how to locate the learner in an environment (cell) that he/she is currently, to identify a learner in the corresponding context and to provide interest information adapted to the device. In the same way, each location is modelled as a geographic region and has information about location context. This information is stored in a repository (location context repositories) in each geographic region (see Figure 4), represented as XML metadata. So, for GlobalEdu, cells compose the ubiquitous environment and these have different contexts. For example, a university can be considered a cell and their buildings, different contexts.

The access to the environment by the learner is done with an authentication, and the context management educational module notices this event. With a new learner’s entrance in the environment the social context changed. In this case, the service takes two actions:
1 notifies other learners in the corresponding context (location context)
2 sends to the new learner adapted information about that context that the learner is currently.

A comparison is accomplished with the learner’s profile in order to define learners with the same goals, competencies and preferences whose information the learner may access for contact or not.

For the adaptation process, there is a relationship between context management educational module and the others elements of the GlobalEdu architecture. With this, the learner can ask explicitly information about the social context that he/she is in or still to extend the research for other contexts. For example, the search for learning objects becomes more productive if done in several different contexts.

The content management educational module is responsible for managing the learning objects according to the learners’ models. Section 5 describes, in details, this component.

4.2.2 Support modules

The support modules assist the execution of the educational modules and the pedagogical agent and manage aspects of communication, adaptation of interfaces to devices, users’ access, and persistence. The support modules act as interfaces between the educational modules and the ISAM environment (Augustin et al., 2004). The support modules use the migration and the physical mobility support of the ISAM environment to manage the mobility of the pedagogical agents among devices. In addition, the support modules manage the messages interchange among the educational modules, the pedagogical agents and the ISAM environment.

4.3 The runtime layer

The runtime layer monitors elements of the physical context. Each location is modelled as a geographic region and has information of context. The context data is stored in a repository and is represented by a metadata in the XML format.

The ubiquitous environment is composed of cells, each cell with different contexts (see Figure 4). For example, a University can be considered a cell and its buildings different contexts.

The runtime layer is represented by a middleware that supports the execution of educational applications, providing the necessary elements for the system. These elements are: perception of elements of the contexts, migration of code and mechanisms for communication.

5 Content management in GlobalEdu

In GlobalEdu the content management educational module (content management, for short) is responsible for the learning objects management, identifying and providing these objects according to the learners’ profiles and the limitations of their physical context (for example, devices and networks bandwidth).

The objects are categorised by the IEEE/LOM (2011). They are managed according to a network of distributed repositories of learning objects. These repositories are integrated through a middleware to provide a unified view of the objects. Therefore, learners have access, anywhere, to all objects that are within the GlobalEdu network in a transparent and personalised way. The interaction of the learners with the content management EM is made through the pedagogical agent.

5.1 The content management educational module

Among the tasks of the content management, this work specifically focuses on the following:

- Metadata management – all content in GlobalEdu is stored in repositories called content repositories. The content is represented in XML, according to the LOM standard. The metadata management controls the insertion, deletion and modification of the learning objects. Each location in GlobalEdu can provide its own content repository.

- Content selection – the selection of a specific content to present to a learner considers three requirements. The first is the content related to the pedagogical strategy, which must be in accordance with the learners’ preferred style of learning, as specified in their profile. The second analyses whether the target content is related to any of the learners’ goals. The third considers the learners’ physical context, so that they receive content adapted to the device and the network bandwidth.

- Content discovery – the learners, using the pedagogical agent, can request information of the learning objects available in the environment. This query can be made according to learners’ profiles (mediated by the system) or via keywords (free search). Figure 5 shows the use case diagram of the basic functions of the content management.

Figure 4  A ubiquitous environment of GlobalEdu (see online version for colours)
The actors involved are the following:

- **administrator** – represents the user who can add, edit and delete learning objects
- **context manager** – characterises the context management EM
- **pedagogical agent** – represents the pedagogical agent
- **content repository** – illustrates the content repositories.

Each repository is aware of all registered repositories in the GlobalEdu network. The repositories are responsible for forwarding queries made by learners, thus enabling the learners to have a single vision of all objects. The operations are the following:

- **Manages learning objects** – represents the operations of content management in each repository. The supported operations are the following: add, delete and update learning objects.
- **Searches for learning objects** – represents the searches for learning objects in the GlobalEdu repositories. In the filtering process of the searches, objects whose format matches the physical context (device and network) receive higher priority. The available searches are the following:
  1. Queries guided by profiles, which consider the description of the learning objects matched with the learners’ style of learning and goals.
  2. Queries guided by keywords, which enable learners to search for objects based on keywords, allowing them to look for the objects that are not strictly related with their declared goals.
- **Manages the repository registry** – contains three basic operations:
  1. Registers repository advertises the existence of a new content repository in the GlobalEdu network.
  2. Shudowns repository advertises that a repository is leaving the network for maintenance or repairs.

3. Exchanges list of repositories and enables the repositories to update their local views of the network, requesting the list of the remote repositories. The list contains the identifier, the address of access and the current state of the repositories. Periodically, each repository updates its list, consulting other repositories. The frequency of the list exchange is a configuration parameter of the system.

### 5.2 The content management educational module architecture

The architecture of the content management educational module is service-oriented. Figure 6 shows the components of each content management educational module server in the GlobalEdu network (see Figure 4).

The architecture of the content management is based on a network of interconnected servers. The components of the architecture are the following:

- **Content manager server** – represents each repository server in the GlobalEdu network. Each server is independent of the others and they can run even disconnected from the GlobalEdu network. While it is offline, the queries of objects are processed in the local repository.
- **Content manager repository** – represents the persistence of the learning objects. Different implementations can be provided, whereas the implementation to be used is defined in the repository configuration file. The default implementation of the content management repository is based on the JCR API (Java Content Repository), which is provided by the Apache Jackrabbit Project (2011).
- **Descriptors list** – maintains interconnected the repositories in the network keeping a list of the repositories known by each server.
- **Listeners** – enables operations to be connected to the server life-cycle.
• **Service executor** – maintains compatibility among different devices. The service executor packs and transports parameters between the client node and the node hosting the service implementation, as well as any result in the opposite direction. Currently, it is possible to invoke remote services either through sockets or web services.

• **Services** – represents the services provided by the content management. These services are divided into two groups:
  1. the former is responsible for providing the integration and interoperability among repositories in the network
  2. the component is responsible for the implementation of these services is the list of the repositories.

The latter group is responsible for exporting functions related to the handling of the learning objects. These services can include, remove, update and find an object in the repository.

6 Evaluation scenario

The prototype of the content management educational module was integrated with the remaining modules of the GlobalEdu architecture. Currently, the system has the pedagogical agent and the context management educational module prototype. The pedagogical agent was implemented with the U-inContext application (Nino et al., 2007). Basically, this is a simplified version of the pedagogical agent that relates social context with learner using his/her position and the learner profile. The platform used by implementation is Java in the J2SE and J2ME versions. To provide content information to the learner the content management educational module communicates with U-inContext and ISAM environment. All these elements are executing in the same GlobalEdu server (see Figure 4). Aspects related to the learner’s profile use the PeLeP system (Levis et al., 2008).

The U-inContext application performs a subset of the functionalities originally conceived by the GlobalEdu model. The U-inContext has a graphical user interface which is adapted to the device in use (for instance, PDA, smartphone or desktop). Figure 7 shows the U-inContext Interface (as can be seen in figures, the interfaces are in Portuguese) for PDA Zaurus SL-5600 [Figure 7(a)] and desktop [Figure 7(b)]. This figure shows that when the learner starts the pedagogical agent is possible to select his visual mode. When learners access the environment they can choose to be invisible to other learners, available to other learners or unavailable. In the last case, the learner does not receive context information of the GlobalEdu.

In the U-inContext application the learners can insert profile information about their interests and competences. This information is used for the distribution of the learning objects and can be changed at any time either by the learner or automatically by GlobalEdu.

Figure 7 U-inContext interface, (a) PDA Zaurus SL-5600 interface (b) desktop interface (see online version for colours)
can select a resource item [‘Recursos’ in Portuguese in the Figure 8(a) or Figure 8(b)].

**Figure 8** Learner’s context information, (a) PDA interface (b) desktop interface (see online version for colours)

We present a scenario that involves some aspects of GlobalEdu system. The objective is to evaluate the selection of learning objects according to learners’ profiles or to explicit keywords. In this case, we decide that the experiment aims at evaluating the context-aware filtering of learning objects, accessing the learning object information hosted in remote repositories and using GlobalEdu as an tool in the classroom.

The case study was conducted at the Unilasalle University. This university was considered as a cell, which is composed of different contexts. The devices of the learners received an instance of the U-inContext application. The learners, carrying different types of devices, had access to the services available in the GlobalEdu network. When the learners entered the university the system detected them and considering their profiles, sent learning objects information to their devices. The learners moved around the contexts of the university. Each visited context had different content information available.

The implementing platform consisted of mobile nodes comprising notebooks and PDAs Sharp Zaurus SL-5600. The test was conducted with a sample consisting of six professionals of the computing field and other areas. We presented the purpose of the work and the basic operation of the prototype. Subsequently, the individuals, using the pedagogical agent, registered their data and were invited to use the prototype for one day. At the end of the experiment, the learners were asked to answer an evaluation survey.

The test was conducted in a specific building at Unilasalle University (geographic region). In this building, we have mapped two contexts: the hall and the computer science lab (location context).

The learning objects information (metadata) was inserted into GlobalEdu server. We used simple classroom learning objects, such as presentations (in PPT format) and documents (in PDF format). Evaluating the GlobalEdu context-aware feature was important for us. So, we did not contemplate the search by keyword in evaluation. We only contemplated the search according to context-aware and learner’s profile.

Even knowing that the number of individuals involved in the experiment was small (six individuals), analysing the results we can note that GlobalEdu is a good tool for interacting with learning objects in a context-aware environment. Figure 9 summarises the individuals’ perceptions regarding the system adequacy for learning any kind of content and the system uses as an assisting tool in classrooms. The results indicate a good acceptance of the individuals about the evaluated items. The persons classified, in general, the system as good or excellent for aiding in the learning process.

**Figure 9** Aspects of analysis in the evaluation (see online version for colours)

The users noted that the system would be helpful to the daily use. An interesting comment made by a user, regarding the capacity of the system in assisting the learning process, was the following: “I think that in the future this system will replace the distance-learning systems used in institutions”. The perception of this individual is that the system could be used to access all information currently available in the distance-learning system of the university.
7 Conclusions

Studying the elements that involve the learner in a virtual world is a task approached in virtual environments research, particularly in distance education. Considering a ubiquitous learning, this perception transcends the virtual and reaches the real world of the learner. Thus, one of the main problems in this research is the perception of the context in which the learner is. This influences the learner’s profile and the educational content that he handles.

So, in the field of education, ubiquitous computing has been proving itself as a useful tool, facilitating the interaction between learners and computer systems’ infrastructures and resources. This is done through the mapping of the learners’ location and profiles in a large-scale environment. In this paper, we discussed how ubiquitous computing technologies could be useful in this new scenario. The following general conclusions can be underlined:

1. it is possible to develop content management in a ubiquitous learning system using ubiquitous computing support
2. ubiquitous technologies stimulate the use of mobile devices as learning tools
3. user profiles and context-awareness allow to address personalised content according to different contexts
4. advances in this area will allow new approaches to manage content in educational ubiquitous environments.

This paper presented the content management educational model proposed for the GlobalEdu as well as its model of interoperability among repositories of learning objects handled during the educational process. The development of the system provided a single view of all objects available on the GlobalEdu network, providing to the user learning objects according to his/her profile and context. The results of the experiments show that GlobalEdu can be used in a specific classroom-learning situation and in generic learning object manipulation. Through a pre-evaluation of the system developed, it was possible to realise the efficiency of the system and the satisfaction of the users during their use.

Specific conclusions about the proposed model can be highlighted:
1. GlobalEdu contains basic modules to support large-scale ubiquitous learning.
2. The profile learner, the content information and the context-awareness, by providing location data, is a key component of the contextualisation process. Therefore, improvements to these technologies will benefit GlobalEdu as a whole (and the learner experience as well).
3. The prototype and initial results attest the usefulness of the model.

GlobalEdu is an initial proposal. As future work, we intend to extend the content management educational module, providing extensions to work with other standards of learning objects, such as the SCORM (2011). The work presented is not too distant, whereas it is possible to create converters to import and to export learning objects in various formats, without changing the operation of the system core. New applications (for example, distance education applications) could be created to access the GlobalEdu network of learning objects. Finally, we intend to analyse the GlobalEdu performance and acceptance with a larger number of individuals.

References


