*Journal of Universal Computer Science, vol. 19, no. 7 (2013), 965-983*
*submitted: 31/8/12, accepted: 31/1/13, appeared: 1/4/13 © J.UCS*

# A Proposal of an Architecture for Educational Environments

**Juan Enrique Garrido**
(University of Castilla-La Mancha, Albacete, Spain
juanenrique.garrido@uclm.es)

**Víctor M. R. Penichet**
(University of Castilla-La Mancha, Albacete, Spain
victor.penichet@uclm.es)

**María D. Lozano**
(University of Castilla-La Mancha, Albacete, Spain
maria.lozano@uclm.es)

**Abstract:** Current technology allows educational environments to offer teachers and students the functionality and the information required at any time, whatever the place and circumstance. Concretely, these environments mix three remarkable features: ubiquity, context-awareness and collaboration. Accordingly, a system which is developed with these three features can avoid oversights when performing tasks. Additionally, many aspects of learning fundamentals can be improved, such as collaboration and cooperative learning or students' behaviour. In this paper, we present the definition of a system architecture, which is the first step in obtaining our proposed environment, as the adequate support is not found in any other related works. The architecture presents both a software architecture and a hardware architecture. The software architecture shows the layers in which the system distributes functionality and information. The hardware architecture shows the hardware components to be used, such as smartphones, server, communication elements, etc.

**Keywords:** Education, Learning, Ubiquity, Context-awareness, Collaboration
**Categories:** I.2.6, K.3.1, K.3.2

## 1 Introduction

Computer users do not use systems based on knowledge of how they function but in order to perform their tasks. Users need systems with a simple and easy way to work; they automatically give increasingly more importance to systems that provide help completing tasks. In this regard, present technology allows us to offer environments with systems where users can automatically obtain information and functionality based on their status (i.e. location, current task, etc.). Accordingly, the development of ubiquitous [Weiser, 1991][Bick, 2008], context-aware [Anagnostopoulos, 2006] and collaborative [Greenberg, 1991] [Poltrock, 2005] systems is currently a feasible fact.

Daily needs make educational tasks management essential for proper work in the educational centre. Teachers and students can be affected negatively without the correct management of their tasks. In this sense, a collaborative, ubiquitous and context-aware system will help them track the appropriate protocols which users have to complete in any situation and task. The system will allow users to perform their tasks collaboratively. Collaboration will unify efforts and will improve the coordination between students and teachers. Ubiquity will allow to access to information and functionality offered by the system at any place and any circumstance. Therefore, these systems improve mainly the management of educational tasks which are out of the classroom. Context-awareness will provide the system with the capacity to adapt its functionality and content based on the user´s context. They will not be required to have exhaustive knowledge of the operation of the system; it will help and guide them every time by offering information in their devices, facilitating the functionality and information that users need according to their location and current task. Therefore, teachers will be able to use a new non-invasive technological environment in despite of using traditional methods. These users may then centre their efforts in their pedagogical aspects without wasting time in technological matters. For example, if a student cannot find the book he needs or he has doubts about his current homework, the system will indicate the teachers or classmates who can help and a way to contact them. The system will identify the teacher responsible for the related matter and the classmates who are working or have worked on a similar task.

Regarding the information that users need, awareness [Bardram 2010] [Endsley, 1995] is a key concept which means knowing what is going on, which is essential in a collaborative environment. Teachers should know how each student develops, always considering adequately the privacy of users [Langheinrich, 2010]. In addition, the students are able to find out who can complete tasks with them or who can help. Moreover, the system will reduce human errors and oversights related to tasks, timetable, tutorials, etc. For example, it will remember important tasks and the steps to be followed. The purpose will be always to improve the operation of such environments. The system is able to motivate students in their studies through new technologies, which will be a user-friendly way of working. Furthermore, if awareness feature is accomplished jointly with ubiquity one, an environment is created where students may come across some tasks faster , since they are able to interact with the system while they keep moving. This capability is important in order to offer a solution in which the students' problem is the time.

Taking into account the aforementioned needs, authors have detected the necessity of a collaborative, context-aware and ubiquitous architecture offering adequate support. In this respect, related works have been studied but for one reason or another, in educational environments they have not been able to offer an adequate tool to create a ubiquitous, context-aware and collaborative system. With the objective of offering the required support in educational environments, in this paper we present an architecture as a solution that makes use of current technology. Additionally, the architecture is adaptable to other environments with similar needs.

Specifically, two parts compose the architecture: the hardware architecture, which describes the hardware distribution; and the software architecture, which shows the layer distribution of the components' system where each layer has its own information and functionality.

The document is organized as follows: the next section presents educational fundamentals of the proposed architecture with its improvements, an overview of previous related works and a comparison to the proposed one. The third section explains the architecture proposal for educational environments with an evaluation. Finally, the last section presents conclusions and future projects.

## 2 State of Art and Improvements

Traditional learning is experiencing a significant change in terms of lack of restrictions on location of traditional classrooms [Wang, 2007]. Current technology offers new devices and mobile possibilities. Learning environments, techniques and procedures can take advantage of these new opportunities. In this way, learning environments can be extended to places other than the classroom. For example, an entire University can be established as a technological environment where each student or teacher is connected to a specific system in order to develop their learning activities.

Regarding new technological opportunities, authors have studied how ubiquitous, context-aware and collaborative systems can be a useful tool when applied to learning environments. In spite of the number of proposals which have been made related to such fields, an adequate architecture has not been found, which is needed to support the system. In this way, the proposed architecture in Section 3 resolves that lack and improves learning environments in some aspects, as explained below: collaborative and cooperative learning, learning techniques and students' behaviour.

### 2.1 Collaborative and Cooperative Learning (CSCL and CL)

Collaboration and cooperation are two features which involve working together in order to achieve specific common objectives. Collaboration implies a way of interaction whereas cooperation is a structured interaction whose main objective is to facilitate the achievement of objectives [Fardoun, 2011] [Slavin, 1983].

Collaborative learning refers to any activity in which two or more people work together to define a meaning, explore a topic or improve skills. Teachers and students may consider their own capabilities and contributions to be applied in group work, where defining roles and responsibilities is a real need. In this way, current technology allows the creation of collaborative systems with ubiquity and context-awareness as main features. These create adequate conditions which improve collaboration in educational environments.

Context-awareness allows users to have information and functionality in their devices based on what tasks they are performing collaboratively: associated classmates, those who are active or inactive, information about pending tasks, planning, etc. Students and teachers are able to focus their efforts on the current activity, because the system helps by offering what they need at any time. They are able to create the most appropriate situation and atmosphere to work together because they know (through the system) who is in best conditions to work with collaboratively. Additionally, collaboration and cooperation between students is extended through ubiquity to any place of the learning centre. Work and study places can be undefined; users can work together wherever they want at any time. Therefore, students can work together out of class, where they want. This capability increases the possibility that students will perform the tasks to their best ability and in the best possible circumstances. Evidently, these work conditions imply a greater confidence in student responsibility. For this reason, the authors have designed the system with PhD students in mind, who generally know the importance of the task completion because of their own training and education. However, in other educational environments or in PhD courses where students present concentration problems out of class, the system may allow some control functionality in order to help them to improve the distraction problem.

Collaborative and cooperative learning has three key pillars [Fardoun, 2011]:

- Social interaction: according to the Russian psychologist Vygotsky, people learn in society, that is, from our families, our friend groups, classmates or workmates. Therefore, knowledge acquisition and the instruments used for learning are generated in the interaction within our social context.
- Personal process: cooperative learning is based on the idea that learning is a personal process that involves an effort from the student and that is linked to issues such as anxiety or self-esteem.
- Knowledge is more than information: students must perform tasks and solve problems by themselves in order to learn, experimenting with them than following rules or solutions delivered by the teachers.

A context-aware, ubiquitous and collaborative system improves each of those pillars. First, the social interaction is improved through allowing users to be connected to the system at any time and anywhere. Additionally, users have information about their classmates, so they can establish interaction when it is possible, for example by means of looking at the status of an account user. Location is no longer a problem, because they are connected to the system anywhere thanks to the ubiquity feature. Secondly, these types of systems help the process of each individual because users are able to work when they prefer and in their favourite location. Thus, they can personalize their work and make use of their efforts in the most appropriate conditions. Finally, the proposed system reinforces the idea that knowledge is more than information in the sense that users acquire experience through the ubiquitous and context-aware collaboration process. They have to search for workmates and adequate work conditions, and also they have to accommodate other needs.

### 2.2 Learning Techniques

The main objective of learning techniques is knowing more about how and what students are learning. Corresponding results offers feedback about how teachers teach. In this way, the most important goal is understanding how students understand contents and then improving the teaching [Angelo, 1993].

Classroom Assessment Technique (CAT) is an important technique which is simple, non-graded and mainly applied in-class. Teachers acquire knowledge about what the students are learning in the classroom by evaluating their knowledge with activities such as tests and exams. However, in some learning environments, there is a need for very valuable information on how students evolve and learn out of class. In PhD courses, many individual or collaborative activities may be done out of class. Not only are the results of activities important as well as information about how and what students learn; but in many cases the processes are just as important. Knowledge of the process can give information about responsibility or collaborative capability. The proposed architecture allows the creation of systems which allow students to obtain new learning techniques through context-aware, collaborative and ubiquitous features.

Regarding learning techniques and ubiquity, mobile learning (m-learning) has evolved thanks to the evolution of technology, currently an essential part of human life. M-learning can be defined [Tesoriero, 2009] as the application of mobile technologies to the learning process. This approach provides a new dimension from the educational perspective whose main features are as follows [Chen, 2002]: urgency of learning need, the initiative of knowledge acquisition, the mobility of learning setting, the interactivity of the learning process, the "Situatedness" of instructional activities and the integration of instructional context. Concretely, m-learning allows teachers and students to accelerate their educational process by using new technological devices and eliminating previously designated places where educational processes were carried out. Thus, mobile technologies become a powerful tool to support contextual life-long learning, by being highly portable, individual, unobtrusive, and adaptable to the context of learning, as well as the learner's evolving skills and knowledge.

The proposed architecture offers an appropriate support to offer m-learning in specific educational environments, which can be seen as an improvement of m-learning. Mobile technology and functionality are possibilities that are encouraged and facilitated thanks to the features of the architecture, specifically ubiquity. Additionally, m-learning is improved by adding context-awareness and collaboration. The former allows the student or the teacher to customize the learning tasks. The system adapts their functionality and offers information based on the current users' context. This feature means that users can find out at a specific time and location who can help them, what information is needed, the tasks which are being planned, etc. Consequently, personalization and mobility are improved in education and based on [Sharples, 2000], improved features we can mention are:

- High portability for people who want to learn.
- Availability of the learning process.
- Individual adaptation.
- Communication between teachers and students.
- Managing learning over time.

Furthermore, collaboration offers the possibility to interact and work together with classmates in order to complete tasks, which is an essential aspect of education. In this sense, the three main ways of collaboration [Galani, 2002] in these mobile educational scenarios are improved: real-life collaboration between learners, the presence of virtual students and the establishment of a 3D virtual reality environment.

Concurrently, through ubiquity and context-awareness our proposal offers the capability to carry out two additional learning techniques [Coombs, 1974][Watkins, 1990][Vavoula, 2004]: formal and informal. The first one is well known because teachers establish clear time parameters and guides to the educational process. Our proposal has features which improve formal learning because it creates processes to guide students and teacher who are following a defined schedule, for example, creating alerts. However, new technologies also encourage the development of new techniques in informal learning, mainly in university degree programs or post-degree studies. People can use current technology in their educational tasks, adapting it to their conditions and schedule. Therefore, students can continue with their education at any time, coincidentally, unexpectedly, or sporadically and also, depending on the requirements of practical situations.

| | **Active** | **Constructive** | **Interactive** |
|---|---|---|---|
| <u>Characteristics</u> | Doing something physically | Producing outputs that contain ideas that go beyond the presented information | Dialoguing substantively on the same topic, and not ignoring a partner's contributions |
| <u>Overt activities</u> | Engaging Activities<br>Look, gaze, or fixate<br>Underline or highlight<br>Gesture or point<br>Paraphrase<br>Manipulate objects or tapes<br>Select<br>Repeat | Self-construction Activities<br>Explain or elaborate<br>Justify or provide reasons<br>Connect or link<br>Construct a concept map<br>Reflect, or self-monitor<br>Plan and predict outcomes<br>Generate hypotheses | Guided-construction Activities in Instructional Dialogue:<br>Respond to scaffoldings<br>Revise errors<br>Sequential or Co-construction Activities in Joint Dialogue:<br>Build on partner's Argument, defend<br>Confront or challenge |
| <u>Cognitive processes</u> | Attending Processes<br>Activate existing knowledge<br>Assimilate, encode, or store new information<br>Search for existing knowledge | Creating Processes<br>Infer new knowledge<br>Integrate new information with existing knowledge<br>Organize own knowledge for coherence<br>Repair own faulty knowledge<br>Restructure own knowledge | Jointly Creating Processes<br>Creating processes that incorporate a partner's contributions |

*Table 1: Characteristics, overt activities, and cognitive processes, for active, constructive, and interactive activities, from the learner's perspective ([Chi, 2009])*

### 2.3 Improving Students' Behaviour through Activities

Learners can participate in three activities that are commonly studied in cognitive and learning sciences: *active*, *constructive* and *interactive*. These terms are not clearly differenciated, but [Chi, 2009] proposed a framework which helps to distinguish them in terms of observable activities and underlying learning processes.

The distinctions between these activities are specified in Table 1, but the most important differences between the three terms are as follows. First, being active is defined as doing something while learning. For example, while students are in a virtual environment, they can explore it by manipulating objects. Second, being constructive differs from being active in the obtained results, that is, learners produce some additional output. For example, in the previous virtual environments, learners are constructive if they manipulate objects in order to complete learning tasks, such as sorting artwork by categories. And third, being interactive is related to interaction with classmates, teachers or the system itself. For example, continuing with the same example as above, learners are interactive if they coordinate the sorting tasks in groups of five people.

Authors propose an architecture for learning environments which is collaborative, context-aware and ubiquitous, so each of the described learners activities are improved as explained below. Learners obtain an environment with the proposal in which the system can record activities they perform thanks to sensors that the architecture includes because of its ubiquity. Thanks to collaboration, learners can interact in the learning environment due to a complete connectivity through ubiquity and the collaborative functionality the system can offer. Context-awareness includes improvements in each interaction because it allows the system to offer needed information and functionality to learners based on their individual situation. Therefore, when learners want to collaborate, the system can offer information through the architecture about the most appropriate collaborators and about the current status of teachers and other students, specifically their current availability, an important fact in collaborative tasks. Finally, constructive activities are improved as a consequence of improving learning work conditions. Learners can access needed information and functionality anytime and anywhere, and also they can collaborate, cooperate and coordinate their actions, so that they can complete learning processes in a different and more comfortable way.

### 2.4 Frameworks and Architectures to Improve Learning Environments

The search for tools which allow the improvement of learning environments, such as frameworks and architectures, has been a key objective since mobile and ubiquitous technology were accessible to a greater or lesser extent. Additionally, collaboration between teachers and students has presented an essential need in order to generate a different way of work and alternative learning techniques. In this way, the authors have studied some frameworks and architectures proposed during the last two decades. Following, these proposals are described with the improvements that our architecture presents in comparision with them.

In 2002, an architecture to support collaboration of adaptive service and learning environments [Conlan, 2002] was presented. This proposal tries to offer a standardized mechanism for integrating learning services. Two years later, KnowledgeTree [Brusilovsky, 2004] was presented which is a distributed architecture for adaptative E-learning based on the reuse of intelligent educational activities. Both proposals try to offer users a centralized system with learning contents. However, collaboration, ubiquity and context-aware are concepts not considered. Nowadays, current technology allows us to create new architectures as a support for systems in order to adapt their functionality and offer information based on the user's status. Additionally, users can use mobile technologies to access required information or functionality anywhere and anytime. These features are important in order to create useful and adaptable systems, and they are missing from the previously mentioned architectures.

Parallel to previous architectures, in 2004 a remarkable architecture [Lonsdale, 2004] was presented under the MOBIlearn project applied to mobile learning environments. The main features of the proposal are to be object-oriented, feature-based and context-aware. The architecture allows the implementation of a generic mobile learning system based on sub-systems that interact through web protocols to provide relevant and timely learning content and services. Context-awareness is a key feature that is implemented as context-aware subsystems, selects content based on individual and specific requirements and then, presents a minimal user effort: it reduces the need to define search concepts and the system is usable while the person is engaged in another activity. These context-awareness subsystems provide context-based relevant content such as resources, services and options, apart from learning content. Additionally, the architecture is able to be used by several sources, from different locations to different devices.

A more recent related architecture was presented in 2011 [Yee, 2011]. It comprised of a base-oriented web-service infrastructure using semantic technologies to provide mobile users with a fresh learning experience. As the authors describe, the proposal consists of a knowledge aggregation subsystem and a querying subsystem that are loosely coupled, enabling rapid deployments. Therefore, the architecture offers context-aware learning systems oriented towards mobile users.

The last architecture that authors have studied has been presented in 2012, a hierarchical learning architecture [Liu, 2012]. This proposal includes multiple-goal representations based on approximate dynamic programming. The main objective is the integration of a new network, the reward network, in order to provide internal reinforcement to interact with the operation of the learning system.

Although the three previous described architectures imply important advances in learning infrastructures, they have some shortcomings that our proposal supplies. Concretely, collaboration and ubiquity are two features that are not clearly present in the aforementioned related proposals. Collaboration is an important capability to be considered in learning environments which the teacher can encourage students to apply, as described in section 2.1. Ubiquity offers the possibility of establishing a specific scenario where users can access needed information or functionality any time or anywhere. This feature can give an extra capability to learning environments, which ensures connection in specific environments such as schools. Additionally, ubiquitous feature allows the establishment of a greater range of tasks to be performed in that environment, without extending that range out of the learning environment. Therefore, ubiquity implies many configurations that are desirable in many cases. The previously described architectures centre their efforts mainly on mobile learning, but ubiquity is an additional feature that can establish a deeper connection to the infrastructure in the application of specific domains, which could be necessary if there isn´t enough mobile capability through Internet because of the signal. Figure 1 explains the difference between mobility and ubiquity, with a deeper established connection as the main one.

Due to the proximity between architecture and framework, some related frameworks applied to learning environments have been studied. Concretely, an architecture is a conceptual model to create a solution or system, and a framework is tools and good practices intended to adequately create an architecture model. Therefore, the studied frameworks can give another perspective to obtained ideas and solutions in order to create learning systems. In the following, three remarkable frameworks are described, including improvements that a framework based on the authors' architecture proposal would have.

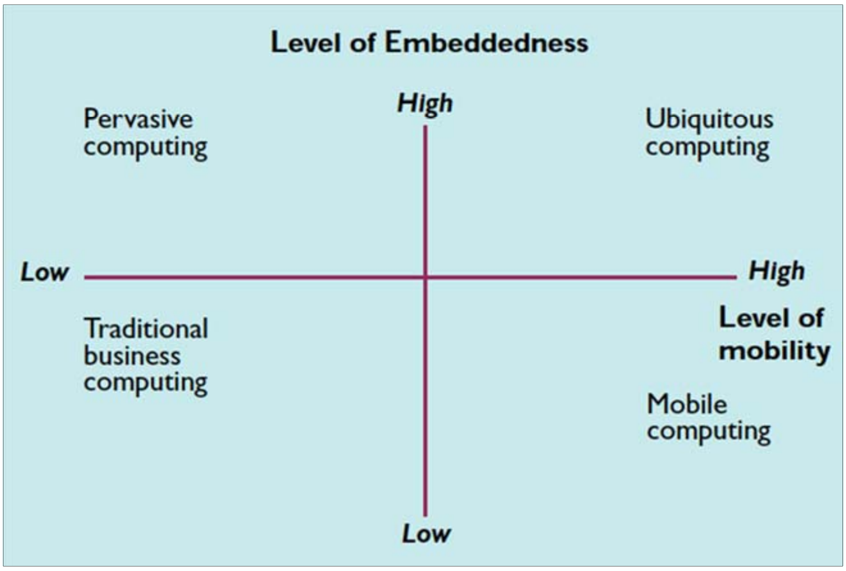


*Figure 1: Ubiquitous computing dimensions ([Lyytinen, 2002])*

In 2009, the first two studied frameworks were presented. On the one hand, the first framework is a generic learning framework design using a Web Service approach [Fang, 2009]. This proposal uses SOA (Service-Oriented Architecture) [Komoda, 2006] and some of its benefits: reusability, interoperability, accessibility and modularization. Using the web services approach, systems components and content can be distributed over the Web. On the other hand, the second framework [Kerawalla, 2009] is an empirically-grounded guide for educators who consider blogging to form an essential educational part of their courses. Therefore, the framework can guide the design of blogging activities in courses. Concretely, authors identified six factors of student blogging: perceptions of and need for an audience and community; utility of and for comments; presentational style of blog content;

overarching factors related to technological context; and the pedagogical context of the course.

The third remarkable related framework is based on educational control in game-based learning environments [Takaoka, 2011]. The game is named "Who becomes the king in the country of mathematics", with which students and teachers experiment in a junior high school. The related result is the possibility of creating relationships among students, that is, students and teachers can be motivated by the world of the game.

Studied frameworks offer advances in collaboration but continue without considering ubiquity in specific learning domains. As in the comparison of previous architectures, the importance and usefulness of ubiquity have been explained, so our proposal addresses this lack in studied previous frameworks.

## 3 Architecture Proposal

The general aim of this proposal is to set forth an architecture as a support of context-aware, collaborative and ubiquitous systems applied to real educational environments. More specifically, we have defined two base architectures: the hardware architecture and the software architecture. The former focuses on the way the different elements used for the implementation of the system are distributed in the educational environment. The latter defines how the different elements needed to handle the system are organized according to a set of layers defined on the basis of its functionality.

### 3.1 Hardware Architecture

The hardware architecture defines the hardware elements that make up the proposed system and their interconnections (see Figure 2). Thanks to the technological advances in recent years, the possibilities of hardware selection in the proposed system are very wide. This architecture is divided into different blocks to offer a distribution as clear as possible, in which each block contains a concrete functionality that distinguishes it from the rest of them. The functionality will depend basically on the capabilities of the elements of each block. The blocks composing the hardware architecture are described as following:

- *Server*. Its function is to analyse the information of the users´ environment stored in the database. The outcome of the analysis will allow the system to offer students and teachers the functionality and information they need at any moment. It is important to note that the information or functionality could be requested by the user or by the software application that s/he is using in his mobile device. In the first case, a student or teacher may request certain information or functionality through one of the different options the software application offers. Nevertheless, the second case could be when the software application offers certain information or functionality to the user in an automatic way, thus making the system context-aware. This feature implies that the system may offer the proper functionality and information according to the user context, with no previous explicit action by the user. As the system is ubiquitous and allows access to the information at any place and under any circumstances thanks to the technology available throughout the environment, the software application will be able to request the needed information and functionality from the server by itself.

The server will analyse, for both requests, all the appropriate information coming from the environment where the user is located at that moment, together with the significant information from the user involved. The information regarding the user´s environment is wide and diverse: user location, other users´ location that may be relevant, resources needed, state of the different resources needed, resources location, functionalities offered by the system which may help the user to perform his task, complete information on the task to be performed (steps to follow, restrictions) and so on.

A key point of any system of this nature is efficiency. The system requires a high level of efficiency, besides offering the required functionality. For this reason, the information analysed by the server in each case must be accurately defined. This definition consists of several fields and parameters that refer to the information of the educational environment. This is important because this way the server will localize the information in a rapid and concise way, based on the content and type of parameters. Also, the searches in the database, which is the main source of information, are improved. The entire process of reducing data processing is very important because the server will not only receive requests from a single user but instantly from any of the active users in the system and at any time. Therefore, a user must receive the needed information and the adequate functionality in the shortest possible time in such a way that it is useful and can be used according to his current status and not to a past status. Otherwise, it will useless or, even worse, totally inconvenient or disturbing for the performance of the tasks.

- *Database*. Basically this contains the information regarding the current state of the environment where the system is set up. Its structure must allow simple and rapid content searches. It must relate, by means of the proper fields, each user with the tasks s/he is involved in and in turn, the tasks with the context information and the required functionality in each case. Additionally, the database must offer stored procedures and functions that facilitate access and management with the aim of providing a data system as accessible as possible. We have to consider that the information stored is private in many cases. The data stored in the database does not only regard users' tasks but also includes their address, contact persons, marks, etc. Because of this, the database must include an access and security system as reliable as possible.
- *Mobile Devices*. They offer all the users of the system the mobility they need throughout the educational environment. They are essential for the system to be considered as ubiquitous. They allow users to have access to the system and enable the system to offer users the information and functionality they need in any place and at any time. Mobile devices included in this component may be a tablet, a smartphone and a laptop. These devices have to allow connectivity via Bluetooth, Wi-Fi and RFID (Radio Frequency

Identification) [Finkenzeller, 2003] in order to be able to use any functionality.

- *Static Devices*. Due to the fact that not all the users require mobility in their actions (for instance, teachers who are preparing an exam in their office) considering static devices in the architecture is a necessity. The most common static device is the Personal Computer. Nevertheless, we also consider wall screens, last generation televisions placed throughout the environment. The aim of these screens is to offer the users certain important information in certain areas, with important data for the performance of their tasks: exam marks, information about the following class, information regarding the state of other pending tasks, timetables, maps showing the user's current situation in the educational environment and the path or route to follow, if necessary. The most suitable places to place this type of devices are the users´ common areas and those areas where it is difficult to establish wireless connectivity, such as for instance a lift, corridors, dining hall, etc.

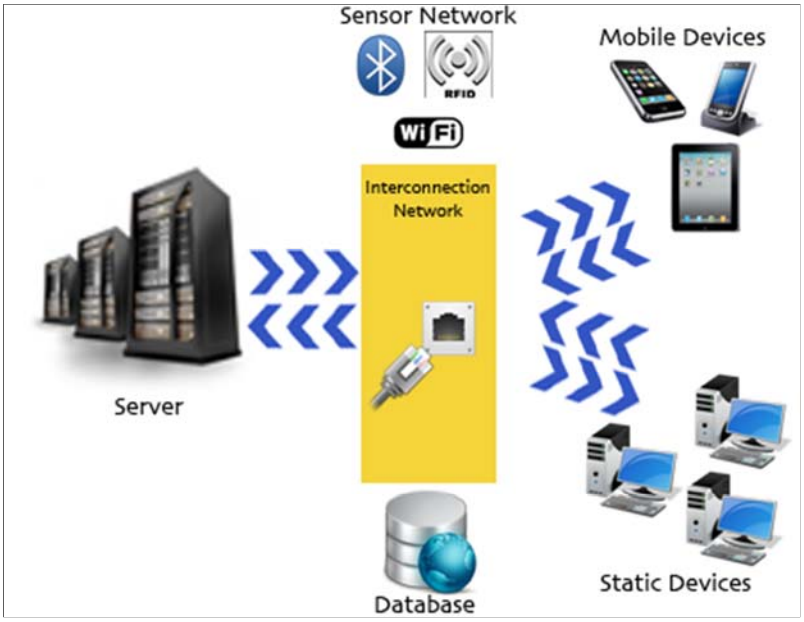


*Figure 2: Hardware architecture for a collaborative, ubiquitous and context-aware learning system*

- *The Sensors Network*. It is a set of sensors distributed throughout the environment which enables the user to obtain information on the state of the environment itself at any time, which is essential for any context aware system: users in the system and their location, resources location, etc. This information is stored in the database and will be analysed by the server with the aim of offering the adequate information and functionality to system users. The sensors network is made up of two types of sensors: (1) *static* *sensors* that are located in specific areas and control and collect information on events in that area; (2) *dynamic sensors* which are moving in the environment. Mobile devices are closely linked to them, as they may become sensors in specific moments. All mobile devices incorporated in the system use Bluetooth and Wi-Fi technology; therefore, the client application uses them to capture the information on the environment. Concerning RFID technology, a sensor can be a PDA with a RFID reader. Beside the RFID sensor, it requires RDIF cards (with RFID tabs) which allow them to obtain information on the user or element to which they belong simply by reading their tab.

- *Interconnection Network*. This is a necessary component so that all devices can be interconnected. It allows users to obtain the information offered by the system and also the possibility to communicate among themselves. The component is made up of a local network with the participation of all the physical elements of the system, from a PDA to the server itself. The local network is a cable network (for static devices) together with a WLAN network (for mobile devices).

### 3.2 Software Architecture

The software architecture allows the visualization of the system structure by means of a group of layers which are interconnected (see Figure 3). These layers show the way in which the information and the functionality offered by the system proposed is distributed in different levels, each offering specific treatment of the information. This structure is based on four concepts, which represent the functionality of each layer: (1) *interaction*, concerning the way the system is used by users and how the information on the environment is obtained by the system; (2) *management* of the information on the environment and the users´ requests; (3) *ubiquitous context aware collaborative application* that generates responses to users´ requests. It involves the study and analysis of the information on the environment aimed at offering users the necessary functionality and information; (4) *information* that is the representation of the current state of the environment in the system as a database.

Taking into account the previous basic concepts, the layers which make up the software architecture are hereby described with the corresponding components of the hardware architecture that are responsible for them:

- *Interactive Layer*. This represents the interaction of the educational centre's user with the system, as well as the interaction of the system with the users. It is offered by mobile devices and static devices. Thus, interaction is bidirectional in order to offer an ubiquitous and context aware system. Obviously, users must be able to interact with the system through a client application offering the functionality and information required. However, since the system must be ubiquitous and context aware, it plays an important role in the interactive layer. It must be capable of interacting on its own with the users and with the environment in general to be able to obtain relevant information (through the application and the sensors present in the environment). The information obtained will be the state of the environment, which, after being analysed, will allow users to be offered the information and functionality required at each specific moment. This is the essence of any context-aware environment: the system is able to automatically provide what is needed, depending on the user´ needs and their environment. In other words, the system allows users to attend their educational processes without having to be worry about the technology. The system tries to be as non-intrusive as possible, offering information and functionality only in the adequate situations.

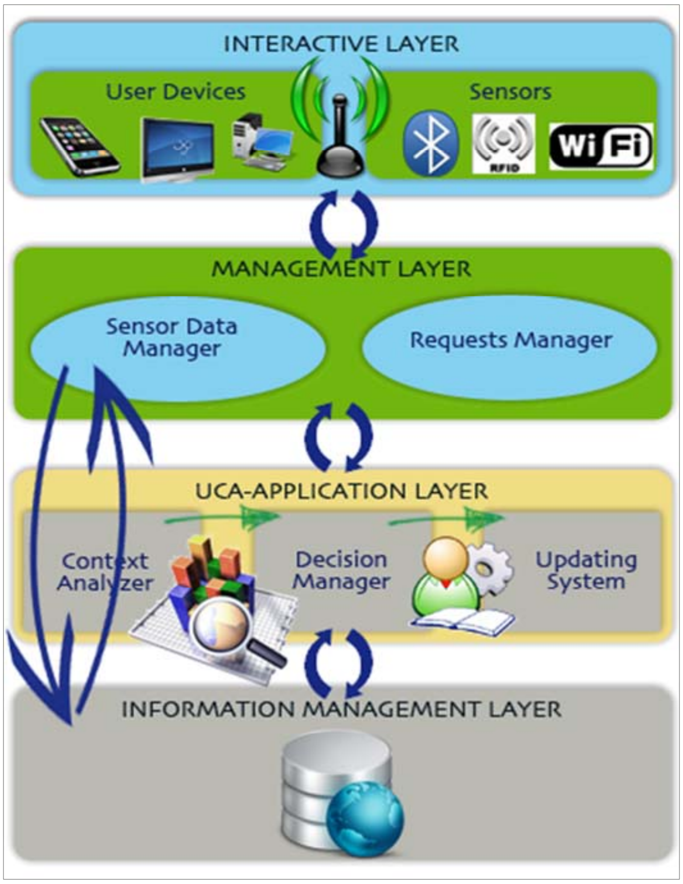


*Figure 3: Software architecture for a collaborative, ubiquitous and context-aware learning system*

- *Management Layer*. This element receives the users´ requests (*requests manager*). They are classified depending on the user and the parameters of the request. Those parameters mainly represent the objective of the request: functionality or information request, task start or end verification, timetable, etc. Once the request has been classified, it is sent to the management layer. This pre-processing facilitates the search for the information related in the next layer. Consequently, the achievement of request solution is improved and more rapid.

Another task of the management layer is receiving and transforming the incoming information from the sensors through the interactive layer (*sensors information manager*). This transformation is necessary before accomplishing data analysis and study. It involves eliminating useless or repeated information and giving it the appropriate format to be inserted in the database. The format will be related to the set of parameters which characterize each register in the database. These parameters make the search for information more dynamic, especially when working with large amounts of data.

The whole layer and the next one are supported by the Server, which contains the subsystems responsible for filtering the data and its processing.

- *CUCA (Collaborative Ubiquitous and Context Aware) Application Layer*. Its objective is to analyse requests and their environment to offer the functionality and information each user may require at each specific moment. The process is as follows: (1) the layer receives a request from an user or from the application automatically; (2) the system analyses the state of the context in relation to the request; (3) based on the analysis performed, the system makes a decision, which will be the functionality to be run or the information to be displayed; (4) finally, if the decision implies a change in the system, it is reflected in the database. Its implementation will be distributed between the server and a set of intelligent agents. The agents – distributed throughout the environment devices- allow the possibility to offer some functionality on the part of the system with no need to access the server. So that its functionality can be implemented, the CUCA application layer contains three elements: *context reader*, *decision manager* and *updating system*. The context reader is the tool responsible for reading the information which is relevant for the current environment context, based on the parameters received as input, sent by the decision manager. By selecting the information required by the manager from the database, the input enables the system to be able to make a decision on the request under consideration at that moment. The decision manager is the component that receives requests from the *requests manager* on specific information or functionality of the system from the users or from the applications they are using. In order to respond to the request, the information on the current context, which will help to make a decision about the request, is in turn referred to the *context reader*. When the information requested is received, the component studies the current context and collects the information to be displayed and/or the functionality to be used by the user. Finally, the updating system applies changes in the database. If the decision implies a change in the system, the fields associated in the database will have to be modified and should, subsequently, present an updated state which will be able to take decisions in accordance with the state of the system.
- *Information Management Layer.* This layer is made up of a database which stores the system information (concerning users, timetables, resources, tasks

and locations) and the tools required to access that information (whether writing or reading tools).

## 4 Conclusions and Future Work

Nowadays, current technology makes the creation of environments where users can collaborate easier and gives them access needed information and functionality based on their context. In this way, it is possible to mix collaboration, ubiquity and context-awareness in the same system in order to improve the management of educational environments. This improvement allows students and teachers to perform their tasks while avoiding oversights and, more specifically, to perform adequately the educational process. These kind of environments motivate students in their daily work because they can use their smartphones, tablets and laptops; these are things that can establish a user-friendly way of study.

In this paper we have presented an architecture proposal as a previous necessary and complementary step to the development of a collaborative, context-aware and ubiquitous system in an educational environment. The objective is to create an adequate support in those environments. The authors have studied several related works, architectures and frameworks, and they have found the need for an adequate support for learning, collaborative, ubiquitous and context-aware systems.

The proposed architecture is composed of two main parts: hardware architecture and software architecture. The former shows the distribution of the hardware devices as blocks offering different functionality: *server, database, mobile devices, fixed devices, the sensor network and the interconnection network*. On the other hand, the software architecture describes the layers in which the information and the functionality offered by the system proposed, is distributed in different levels. The layers are as follows: (1) *the interactive layer* that manages the interaction between the system and users, which is bidirectional; (2) *the management layer* which classifies each received request in order to facilitate the search of the answers; (3) *CUCA application layer* that is responsible for analysing each request and taking decisions; and finally, (4) *the data management layer* which works directly on the database.

We are currently working on the design of a system in a real case study considering the aforementioned architectures and concepts regarding awareness. Concretely, the real environment will be based on PhD courses where teachers and student use the proposal in order to evolve in their education and learning. The utilization will consider user tests and evaluations based on the knowledge and the use of the system by the students and the teachers. New technological proposals to be included will be studied in order to improve the management and the use of the system, as well as the user experience.

**Acknowledgements**

We would like to acknowledge the project CICYT TIN2011-27767-C02-01 from the Spanish Ministerio de Ciencia e Innovación and the Regional Government: Junta de Comunidades de Castilla-La Mancha PPII10-0300-4174 and PII2C09-0185-1030 projects for partially funding this work.

## References

[Ahn, 2010] Ahn, C., Nah, Y.: Design of Location-based Web Service Framework for COntext-Aware Applications in Ubiquitous Environments.In 2010 IEEE International Conference on Sensor Networks, Ubiquitous, and Trustworthy Computing, 2010, 426 – 433.

[Anagnostopoulos, 2006] Anagnostopoulos, C.B., Tsounis, A., Hadjiefthmiades, S.: Context Awareness in Mobile Computing Environments.Wireless Personal Communications, 42, 2006, 445-464.

[Angelo, 1993] Angelo, T., Cross, K.: A Handbook of Classroom Assessment Techniques for College Teachers.

[Bardram, 2010] Bardram, J. E., Hansen, T. R.: Context-Based Workplace Awareness. In Computer-Supported Cooperative Work 2010, 19, 2010, 105-138.

[Bick, 2008] Bick, M., Kummer, T.: Ambient Intelligence and Ubiquitous Computing. In Handbook on Information Technologies for Education and Training, ISBN: 978-3-540-74155-8, 2008.

[Brusilovsky, 2004] Brusilovsky, P.: KnowledgeTree: A Distributed Architecture for Adaptive E-Learning. In Proceedings of the 13th International World Wide Web conference on Alternate track papers & posters, 104-113.

[Chang, 2008] Chang, J. Hong, S.: Intelligent System Architecture for Context-Awareness in Ubiquitous Computing. In UIC'08 Proceedings of 5th International Conference on Ubiquitous Intelligence and Computing, 2008.

[Chen, 2002] Chen, Y.S., Kao, T.C., Sheu, J.P., Chiang, C.Y.: A Mobile Scaffolding-Aid-Based Bird -Watching Learning System. In IEEE International Workshop on Wireless and Mobile Technologies in Education, 2002, 15-22.

[Chi, 2009] Chi, M.: Active-Constructive-Interactive: A Conceptual Framework for Differentiating Learning Activities. Topics in Cognitive Science, (1), 2009, 73-105.

[Conlan, 2002] Conla, O., Wade, V., Gargan, M., Hockemeyer, C., Albert, D.: An Architecture for Integrating Adaptive Hypermedia Services with Open Learning Environments. In Proceedings of World Conference on Educational Multimedia, Hypermedia and Telecommunications 2002, 344-350.

[Coombs, 1974] Coombs, P., Ahmed, H.: Attacking rural poverty. How nonformal education can help. Baltimore, 1974.

[Endsley, 1995] Endsley, M.R.: Toward a Theory of Situation Awareness in Dynamic Systems. Human Factors, 37, 1995, 32-64.

[Fang, 2009] Gand, C., Chien, L.: Collaborative learning using service-oriented architecture: Aframework design. Knowledge-Based Systems, 22, 2009, 271-274.

[Fardoun, 2011] Fardoun, H.: ELearniXML: Towards a Model-Based Approach for the Development of E-Learning Systems. PhD Thesis. University of Castilla-La Mancha.

[Finkenzeller, 2003] Finkenzeller, K.: RFID Handbook, Fundamentals and Applications in Contactless Smart Cards, Radio Frequency Identification and Near-Field Communication. John Wiley & Sons, 2003, ISBN: 0470844027.

[Galani, 2002] Galani, A., Chalmers, M.: Can you see me? Exploring co-visiting between physical and virtual visitors. In Museums and the Web 2002, Archives & Museums Informatics, 2002.

[Greenberg, 1991] Greenberg, S.: Computer-supported co-operative work and groupware: an introduction to the special issue. In Jornadas Internacionales Man Machine Studies, 1991.

[Handte, 2010] Handte, M. et al.: The NARF Architecture for Generic Personal COntext Recognition. In 2010 IEEE International COnference on Sensor Networks, Ubiquitous, and Trustworthy Computing, 2010, 123-130.

[Kerawalla, 2009] Kerawalla, L., Minocha, S., Kirkup, G., Conole, G.: An empirically grounded framework to guide blogging in higher education. Journal of Computer Assisted Learning, 25, 2009, 31-42.

[Komoda, 2006] Komoda, N.: Service oriented architecture (SOA) in industrial systems. In IEEE International Conference on Industrial Informatics, 1-5.

[Langheinrich, 2010] Langheinrich, M.: Privacy in Ubiquitous Computing. International Chapter Book Ubiquitous Computing Fundamentals. Chapman and Hall.

[Liu, 2012] Liu, B., Li, S., Lou, Y., Chen, S., Liang, Y.: A hierarchical learning architecture with multiple-goal representations and multiple timescale based on approximate dynamic programming. Neural Computing & Applications, 1-17.

[Lonsdale, 2004] Lonsdale, P., Baber, C., Sharples, M., Arvanitis, T.: A context-awareness architecture for facilitating mobile learning. In Learning with Mobile Devices: Research and Development, 79-85.

[Lyytinen, 2002] Lyytinen, K., Yoo, T.: Issues and Challenges in Ubiquitous Computing. Communications of the ACM, 45 (12).

[Madeira, 2010] Maderia, R. N., Postolache, O., Correia, N., Silva, P.: Designing a Pervasive Healthcare Assistive Environment for the Elderly. In Ubicomp 2010, Copenhague, Denmark, 2010.

[Poltrock 2005] Poltrock, S. and Grudin, J.: Computer Supported Cooperative Work and Groupware (CSCW). In Interact 2005, Rome, Italy, 2005.

[Sharples, 2000] Sharples, M.: The design of personal mobile technologies for lifelong learning. Computers & Education 34, 177-193.

[Slavin, 1983] Slavin, R.: When does cooperative learning increase student achievement? Psychological Bulletin 94, 429-445.

[Takaoka, 2011] Takaoka, R., Shimokawa, M.: A Framework of Educational Control in Game-based Learning Environment. In 2011 11th IEEE International Conference on Advanced Learning Technologies.

[Tesoriero, 2009] Tesoriero, R., Fardoun, H., Gallud, J., Lozano, M., Penichet, V.: Interactive Learning Panels. Human Computer Interaction, 2009, 236-245.

[Vavoula, 2004] Vavoula, G.: KLeOS: A Knowledge and Learning Organization System in Support of Lifelong Learning. PhD Thesis, University of Birmingham, UK, 2004.

[Wang, 2007] Wang, Y.: Measuring e-learning systems success in an organizational context: Scale development and validation. Computers in Human Behavior, 23 (1), 1792-1808.

[Watkins, 1990] Watkins, K., Marsick, V.: Informal and Incidental Learning in the Workplace. 1990.

[Weiser, 1991] Weiser, M.: The computer for the 21st century. Scientific American, vol. 265(3), 1991, 94-104.

[Yee, 2011] Yee, K., Chia, Y., Tsai, C., Wee, A., Kanagasabai, R.: Cloud-based Semantic Service-Oriented Content Provisioning Architecture for Mobile Learning. Journal of Internet Services and Information Security, 1(1), 2011, 59-69.

[Zhou, 2010] Zhou, J., Gilman, E., Palola, J., Riekki, J., Ylianttila, M., Sun, J.: Context-aware pervasive service composition and its implementation. Personal Ubiquitous Computing, ISSN 1617-4909, 2010, 1–13.