Towards Instructional Design of Ubiquitous Learning Environments

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Abstract— A remarkable shift of what technologies may offer particularly mobile, wireless and sensor-based ones, i. e. a SF like environment in which ubiquitous and pervasive technologies provide for opportunities only imagined before, e. g. Ubiquitous Computing and Ubiquitous Learning has taken place in the last decade. We introduce here the first version of our *generic u-learning scenario,* as an important step toward proper instructional design of ubiquitous learning processes that take place in ubiquitous learning environments.

Keywords— instructional design, ubiquitous learning, u-learning scenario, ubiquitous learning environments.

I. Introduction

More than 30 years have passed since Sir A. C. Clarke has proposed his 3rd law that states that *any sufficiently advanced technology is indistinguishable from magic* [1], along with more than 20 years since Weiser has pointed out that the *most profound technologies are those that disappear. They weave themselves into the fabric of everyday life until they are indistinguishable from it* [2]. During this time, and especially within the last decade, we have been witnessing a remarkable shift of what technologies may offer particularly mobile, wireless and sensor-based ones, i. e. a SF like environment in which ubiquitous and pervasive technologies provide for opportunities only imagined before, e. g. Ubiquitous Computing and Ubiquitous Learning (u-learning).

Thus, smart devices (mobile, wireless, service), working embedded in smart environments and interacting smartly, provide for a computing vision in which a larger variety of electronic devices may be used in a greater range of environments and activities [3]. Such environments are capable of awareness with respect to the presence of users, of perceiving their needs (particularly, their learning needs), and of responding appropriately to those needs, in a relaxed and unobtrusive manner [4]. Therefore, learning becomes ubiquitous, taking therefore place anywhere, anytime, anyhow, and being enriched with quick notifications, reminders and alerts, personal knowledge management, P2P communication, boosting of facilitator-learner interactions and in-class participation, increasing engagement and promoting active learning etc. [5].

Moreover, when context is brought into the picture, u-learning becomes context-aware, which allows better understanding of the user, as a person, and of the concrete situation around her [6], and provides for *multiple diverse learning contexts and automatically adapt to them* [7], making possible multiple learning activities and experiences that contribute to a immersive learning paradigm [8]-[9], in which learners interact actively with each other [6], [10] within interconnected ubiquitous dialogue frameworks that include learners and their capable peers, instructors, and digital resources [5]. Within such frameworks, knowledge is constructed as a result of the interaction, the communication, or the interplay between the environments, the individuals and the behavioral patterns corresponding to given situations [5]. Therefore, u-learning provide for and rely on constructivism as the pedagogical paradigm because it allows for both individual and social construction of knowledge, based on learners' interpretations of the experiences they have both in the real and the digital world [5], [11]. Consequently, as *knowledge cannot be transmitted, instruction should consist of experiences that facilitate knowledge construction* [11].

In our previous works we have approached the construction of learning scenarios that are viable in context-aware Ubiquitous Learning Environments (ULEs), based on our context-aware multiagent system for sharing public interest information and knowledge that is accessible through always-on, context-aware services (called ePH) [12-15]. We continue this work here and introduce the first version of our *generic u-learning scenario*, as an important step toward proper instructional design of ubiquitous learning processes that take place in ULEs.

The remaining of this paper is structured as follows: section two explain our motivation for this work, while in section three we describe our generic u-learning scenario, exemplifying it with a particular scenario for retrieving information and knowledge. In section 4 we present the related works, and the final section include the conclusion and some future work ideas.

II. Motivation for Research

While contextualized, ubiquitous learning is promising and more and more present within our lives, it does not come without challenges, such as the need for a context-aware infrastructure [16]-[17], along with methods for development of specific tools that are tailored to a particular situation [18], and the necessity to research, from a human computer interaction perspective, new paradigms of interaction with ubiquitous and contextualised media and learning experiences [19]. Furthermore, complementary measures that concern integration of contextualized media in already existing learning scenarios have to be found [16]. Moreover, the biggest challenge of all is to specify better the pedagogical models that support contextualized, ubiquitous learning, together with best practice of putting these models to work. Thus, there is concern that, for example, without proper support, the emerging u-learning scenarios may be too complex for learners, and that the learning achievements could be disappointing [10]. In this context, technologies are expected not to instruct learners, but rather as creating opportunities for knowledge construction that are used for learning with, and not from [10, 20]. Therefore, ubiquitous learning should be considered in the first place within the framework of learning theories, not just as a supporting technology [5].

However, despite existing numerous u-learning environments, experiences and projects around the world, they generally focus on one specific sub-problem [12], [21], u-learning is still to be defined and researched, especially with regard to offering strategies for facilitating effective learning activities within such environments, and providing for integrated solutions for lifelong and life-wide learning. Instructional design, educational process, authentic reflective learning, instructional paradigm, learning outcomes, and so on, are not considered yet with the needed emphasis in the today u-learning research [6], [7], [16], [21].

Critical tasks of instructional design for u-learning have been approached in the literature such as (1) the provision of the necessary means that allow learners operating within the complex context of the real-world, (2) the availability of support that enables instructors to interact knowledgeably and collaboratively with each individual learner or with cooperating groups of learners, and (3) the provision of facilities for developing u-learning activities to allow learners to improve their skills and the ability of using knowledge [10].

So, in our opinion, in order to benefit fully from the potential of ubiquitous learning within ubiquitous learning environments, there is a stringent need to approach it under the umbrella of instructional design theories and models, and within the larger context of instructional strategies and educational theories.

III. GENERIC U-LEARNING SCENARIO

Our work is rooted in the lessons we have learned during the process of development and use of our context-aware multiagent system, which allows free sharing of information and knowledge [12-15]. The system provides for context-aware u-learning, i. e. *learning with mobile devices, wireless communications and sensor technologies* [6], which is u-learning in the sense that it may happen anywhere and anytime, and it involves sensors, mobile and wireless technology.

The literature in the field shows that ubiquitous learning is expected to provide for: *permanency* (the learners will under no circumstances lose their work unless it is voluntarily deleted, and what is more important, all the learning processes are recorded each and every day, which allows for learning that is reflective), *accessibility* of the learning content from anywhere via active personalized services, *immediacy* (the content may be accessed instantaneously, and the learners may store it and retrieve it at anytime), *interactivity* between learners and facilitators or peers, which takes place both synchronously or asynchronously, *situated-ness* of the instructional activities (learning occurs naturally in everyday life in a context-aware manner), *adaptability* to learners' current situation, both in the virtual world and in the real world, which makes possible personalized active learning experiences), and, of course, *non-intrusiveness* (the ubiquitous technology should be as invisible as possible, resulting in natural interactions with users and, consequently, in seamless learning; moreover, the learning scenarios must not be interrupted by this technology or by her movement within the environment) [2], [6], [12], [16], [21-24].

Basically, a *generic u-learning scenario* is triggered by the *user* (*who* she is and what is her *context*) and starts with user's *learning needs*, her *learning goal*, and her *learning objectives*. Her learning need may consist of acquiring new knowledge, acquiring new practical skills, change attitudes, viewpoints or feelings, or acquiring transferable abilities [25]. In the first case, the desired end results include the *acquired knowledge* and the *reached achievements* (objectives, outcomes, and results). The problem to be solved is *retrieving information and knowledge*, i.e. finding the matching learning resource, artefact, case, etc. or place (and the set of tasks to be executed to reach that generic "point of interest"), and adapting their internal structure to the learner (see Fig. 1). In a traditional learning environment, the user looks for, and, eventually, finds and retrieves contents, while, in a ubiquitous one, the agents are responsible for bringing content to user's attention [26]. Appropriate *learning activities* are performed to complete a viable learning scenario that ensures the success of the learning process. The u-learning scenario may take place either in a formal environment or in an informal one [16].

Who the user *„is"*, as a person, is extremely relevant for any learning scenario, in any kind of learning environment.. The ePH's context model encompasses the specificity of learning experiences and education within u-learning environments. Thus, we use a multidimensional context model that subscribes to a meronomy that articulates various works from the literature [see cited works in 12, 15, 21] [25] [27-29]. Thus, he *user's personal context* incorporates *user's personality* traits (*openness* - inventive/curious vs. consistent/cautious, *conscientiousness* - efficient/organized vs. easy-going/careless, *extraversion* - outgoing/energetic vs. solitary/reserved, *agreeableness* - friendly/compassionate vs. cold/unkind, and *neuroticism* - sensitive/nervous vs. secure/confident), *user's interests and intentions* (both general and current), his *state of mind, feeling and emotions* - e.g focused, distracted, bored, tired, etc.), *knowledgeability* (education, profession, expertise etc.), *limitations* (health

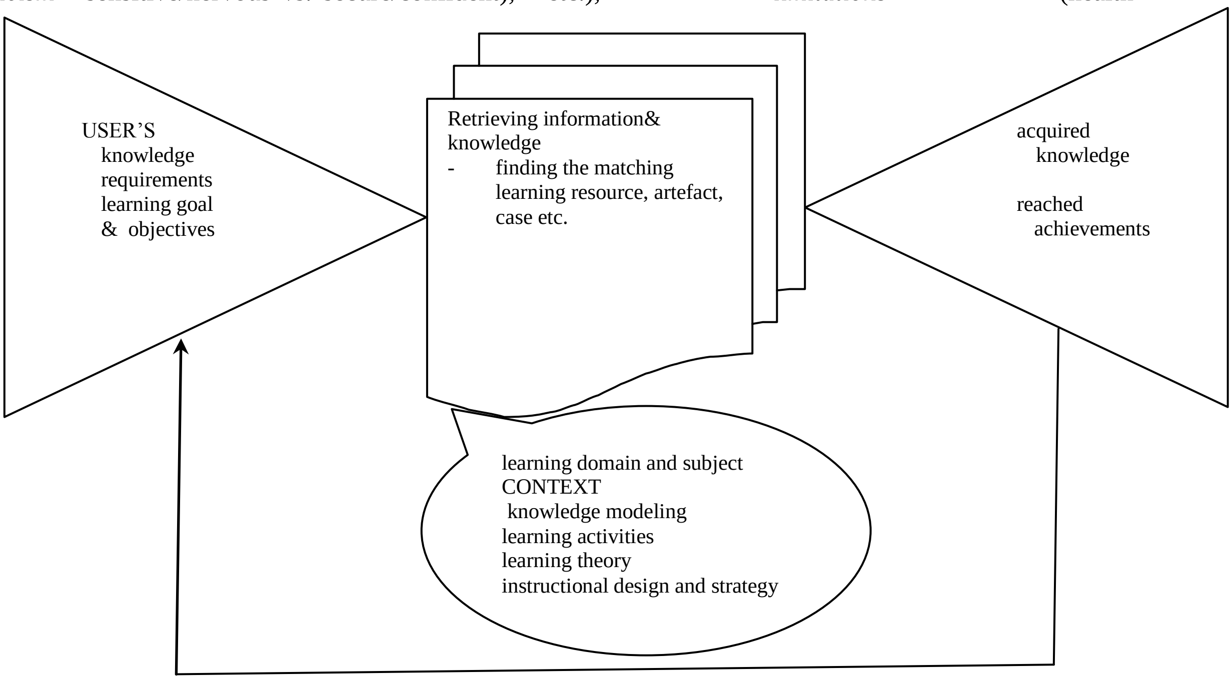

Fig. 1. U-learning scenario in ubiquitous learning environments

issues, disabilities etc.) and *preferences* (e. g. the preferred stimuli: visual, auditory, kinaestethic; preferable learning activities, preferable communication paradigm, i.e. self-learning, face-to-face, asynchronous, synchronous, blended etc.), *social customs and cultural habits* (punctuality, getting up late in the morning or having a siesta, community or individualism etc.), *motivation and conation* (self-consciousness or self-ignorance, interest or disinterest, self-esteem or self-doubt, motivation or discouragement, goal oriented or disoriented etc.), *social abilities* (leadership, teamwork, communication, empathy etc.), *cognitive abilities and disabilities* (alternating, divided, focused, or selective attention, memory-wise, algorithmic, mathematical, conceptual reasoning, visual tracking, logical, inductive reasoning, associative learning, reflective thinking, ; dyslexia, attention deficit disorder, intellectual or memory impairments, etc.), *learning style* (diverger, converger, accomodator, or assimilator), *learning portfolio* and *learning profile* (predefined schedule, constraints of a learning activity - expected starting time, acceptable duration, learning place, learning paths etc.), *feedback* (observed or sensed data of the target items – temperature, air pollution, shape, color, machine status etc., acquired photos, and interactions with the learning system, if any), and so on.

Other relevant facets of our context mode include: *task context* (operations, goals, operating mode – static or dynamic, etc.), *device context* (mobile phone, gipix, PDA, laptop, desktop etc.), *social context* (friends, family, colleagues, acquaintances etc.), *spatio-temporal context* (date, time, user's location, orientation and movement, space – e.g. public, private, limitations – e. g. time interval, location area, etc.), *environmental context* (things, persons, services, sensors, devices, weather, indoor/outdoor, terrain, urban/rural, civilization/wilderness, illumination, temperature, humidity, noise, crowded etc. from user's surroundings; data about the learning site: schedule of learning activities if any, management constraints, notes for using the site, available equipments, persons in charge etc.), *user interface* (textual, graphical, 3D, web-based, resolution, dimensions, versatility, etc.), *infrastructure* (network related - availability, bandwidth, stability, price, performance, connectivity, security, QoS, and so on, or other resources related - availability, coverage, battery, aesthetics, charger, performance, connectivity, security, QoS, etc., software related – operating systems, browsers, database management systems, information systems, multimedia, and so on), *strategic context* (something important for a planned effect), and *historical context* (for keeping trace of the past experience).

The *learning activities* used in any modern learning scenario are expected to facilitate learners to construct *knowledge* and develop skills and abilities, instead of solely the traditional information transfer followed by simple memorisation. Of course that information transfer will still be present in this new learning paradigm, but just as a part of it. What is even more interesting is that the expression of the learners' needs has to be seen as the result of interactions during the learning process, and not as only its starting point [7], [16].

Each *learning activity* is defined by its *topic* (learning domain – well or ill structured, relevant subjects, super-subjects and sub-subjects, follow-on subjects), *educational level*, *prerequisites* (wrt age, knowledge, time, abilities etc.), technical requirements, *type* (presentation, tutorial, summary, introduction, case study, review, comparison, hands-on, debate, simulation, experiment, group learning, game, role playing, assessment, exam etc.), *participants* (real – learners, instructors, coordinator, facilitators, teams, and virtual), *purpose* (knowledge oriented – acquirement, activation, revision, enrichment, etc., abilities-oriented – cognitive, social, affective, etc., or skills-oriented – physical and intellectual, etc.), *expected educational outcomes in various domains* (cognitive, affective, psychomotor, physical, social, and conational), *learning theory* (behaviorist, cognitivist, constructivist, humanist and motivational etc.), *instructional design model* (ADDIE, ARCS, ASSURE etc.), *instructional strategy* (directed instruction or self-study, experiential learning, interactive instruction, learning by doing etc.), *content and content's scope, sequencing, organization, and navigation*, *appropriate design and presentation*, *participatory culture and collaborative aspects* (contribute to the resources or to collaborate with fellow teachers/learners/developers), *assessment* (self- or peer- evaluation, formal or informal; means: project, exam note, report, essay etc.), *necessary instructional resources* (references, software applications, how-to manuals, online resources, etc.), *current status* (time elapsed and remaining, progress monitoring, resources used and still necessary), *feedback* (instructor or peer, real or virtual, informational, motivational, alert etc.), and *management and financial aspects* (time requirements and time schedule, variants of cost, classroom-based, online learning, blended learning etc.) (some of these aspects have been adapted from [6], [25], [27], and [29]). Knowledge modelling with explicit semantic and didactical relationships between (contextualized and adaptable) learning objects plays a key role in retrieving a specific piece of knowledge that matches learner's needs.
The learning scenario includes also a feedback from its final stage to the first one if the learner is not fully satisfied with the accomplishment of his needs, or if he wants to continue and refine the learning process.

IV. RELATED WORK

The pedagogical aspects of ubiquitous learning in ULEs have been approached in the literature, and we present in this section the works that are concerned with aspects that are similar with our work.

A concept map approach for developing collaborative Mindtools for context-aware ubiquitous learning activities for butterfly ecology observation is presented in [10]. This collaborative tool enables learners to *construct, share and revise concept maps while learning in an authentic learning environment.* The authors have also evaluated the effectiveness of this approach and have obtained better results with respect with the learning achievements of students using this approach than the ones adopting traditional and conventional u-learning approaches. The authors point out also that learners have showed greater interest in science learning and in group learning, along with increased computer skills, in accordance with [30], which shows *that awareness and reflection can help develop students' meta-cognition to enhance their learning and creativity abilities*, being important to enable students to construct knowledge and to experience reflective thinking and learning through interaction with peers.

The role of continuous and ubiquitous support for learning activities is crucial when embedding learning into day to day life, work, and other activities [16]. The authors have identified a couple of challenges of current solutions for context-based learning support, and have proposed a generalized technical framework as a possible solution. This framework consists of four layers: (1) sensor layer, sensor proxy and data capture, (2) semantic layer, data aggregation and entity definition, (3) control layer, application logic, and process definition, and (4) indicator/actuator layer, interaction logic and dynamic multimodal output. This framework provides for modeling of various instructional applications based on content, context and information flow, and implementation of these applications with minimal effort and in a standard manner. The framework has been tested in a application concerned with blogging in context.

Construction of a theoretical framework for learners' development ecosystem based on a knowledge spiral is presented in [5]. First, the authors introduce a ubiquitous educational information infrastructure, which has the learner at its centre, surrounded by tools (learning instruments, media tools), a micro-system (fields in which the learner gains experience by direct involvement), mesosystem (interrelations between settings in which the learner is active), exosystem (settings which do not influence the learner directly, but in which events affect or are affected by settings in the mesosystem), macrosystem (nationwide shared cultural values, beliefs, customs and laws), and chronosystem (framework to analysing learner's development during a long time). Secondly, a theoretical framework of knowledge spiral-based ecosystem for learner development, which considers the learning space divided in four quadrants, is presented. One axis represents ill- and well-structured knowledge, while the other holds personal and, respectively, social learning. This model supports five learning activities: presentation, communication, construction, production, and contribution.

An interesting work that outlooks at the criteria, the strategies and the research issues of context-aware ubiquitous learning may be found in [6]. Twelve possible generic u-learning scenarios are proposed: learning in the real world with online guidance or with online support, online test-based on observations of real world objects, real object observations, collecting data in the real world via observations or via sensors, identification of a real world object, observations of the learning environment, problem-solving via experiments, real world observations with online data searching, cooperative data collecting, and cooperative problem solving. Concrete examples of some of these scenarios are also provided. New pedagogical theories, tutoring and assessment strategies for context-aware u-learning environments, innovative and practical use of ubiquitous technologies for education, learning, and training, and psychological analysis for context aware u-learning and training are to be researched further in authors' opinion.

A promising learning infrastructure is proposed in [7]. Thus, the *Semantic Grid for Human Learning*: is envisaged as being able to provide for collaboration, socio-constructivism, personalization, learner-centricity, context-awareness, realism, experiential and active learning, personal learning profiles, personal special needs, ubiquity, accessibility and availability. This infrastructure makes possible learning scenarios that include the pedagogical model, the learning goals, the resources and activities, and so on, and constitutes a building block for construction of more complex and interactive learning experiences. Moreover, what is even more interesting, once produced and virtualized as a *human learning service*, a learning scenario can be indexed and stored in a knowledge base, becoming this way a shared unit of knowledge that may be reused in other contexts. They demonstrate their ideas by articulating some scenarios that combine traditional learning contexts and novel ubiquitous opportunities, in activities like immersive virtual reality, virtual laboratory, and field trip.

In [31], a Learning Activity Model (LAM) based on activity theory, along with procedures for designing ubiquitous learning scenarios based on this model have been introduced. LAM is a framework that describes what is to be analyzed when scenarios are prepared, namely goals, sub-goals, subject, basic activities (unit activity that learners think of and speak of intuitively), variants of basic activities, activity steps, and so on. These elements vary depending on the goal, the target learner, the time, place and other situational factors of the activity, and even on the objects and instruments that will be used while the activity is being done. Further on, the data collected and analyzed by this model can be a good starting point for developing learning scenarios. An example of such a scenario that used a ubiquitous handheld device to help family members to improve communication among them is also described.

A general framework for adaptive context-aware pervasive and ubiquitous learning is presented in [27], in which a learner performs educational activities within a ULE using various resources and infrastructures as he moves in this environment. In order to have her having a highly positive learning experience, which unfolds seamlessly, an adaptation engine is seen as necessary. This engine takes as input the learner's state, the educational activity's state, the infrastructure's state, and the environment's state, and outputs the adapted educational activity and/or infrastructure. For instance, this adaptation engine may present to the mobile learner adapted content and media according to his current situation, and it could locate other learners in his vicinity to perform a collaborative activity.

V. CONCLUSIONS AND FUTURE WORK

In this paper we have introduced a generic u-learning scenario that have been built as a result of our work with ePH system, a context-aware system that provide for sharing information and knowledge via always-on, context-aware services. We consider this only the first step toward developing proper models for instructional design, strategies and pedagogical theory for ubiquitous learning within ubiquitous learning environments. Moreover, knowledge modelling in such environments is of our concern. Our future work will be focused on these issues.

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