Συνέδρια της Ελληνικής Επιστημονικής Ένωσης Τεχνολογιών Πληροφορίας & Επικοινωνιών στην Εκπαίδευση

Τόμ. 1 (2002)

3ο Συνέδριο ΕΤΠΕ «Οι ΤΠΕ στην Εκπαίδευση»

School Laboratory Anticipating Future Needs of European Youth

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SUMMARY
The work presented in this paper is based on the development of the LAB@FUTURE Learning Platform. LAB@FUTURE's theoretical base convolves social constructivism with expansive learning, a special focus of activity theory. Within a mixed and augmented realities set-up, enabling mobile eLearning, experiments that will involve laboratory teaching for the disciplines of Science, Mathematics, and Arts & Humanities, will be conducted. LAB@FUTURE uses both real and virtualised objects for educational purposes. Virtualized objects are interfaced to the user, using mechatronic systems, mobile technologies and 3D multi user environments. In addition, there will be real objects that the teacher or student will be able to interact with, using special interface devices, in order to specify or carry out an experiment.

KEYWORDS: *Laboratory Education, Mixed Realities, Augmented Realities, Mobile Learning*

INTRODUCTION

Laboratory education at schools and higher-level educational institutions is a significant part of the curricula and teaching methods worldwide. Today advances in technology and dissemination of learning methods through electronic instruction books and computer based training courses have already made an impact on supplementing current laboratory teaching methods. However, these are only partial solutions in that they require discipline and understanding on behalf of the student and perhaps they only take additional consideration in progress and understanding achieved. Most of the existing e-learning tools do not allow for enhanced participation, versatility, collaboration and large experiments realisation. The key to a significant contribution to the student's personal growth lies in the ability to make the best use of laboratory education as an indispensable section of school activities. We herewith regard laboratory education as an opportunity to transcend from traditional classroom based teaching, to a "feel and interact" student experience.

LAB@FUTURE Learning Platform defines a generic - universal "mixed and augmented reality" platform energising mobile and wireless information interaction and addressing issues of the constructivist theory of learning, in combination and dialogue with activity theory, especially the theory of *expansive learning* (Engeström,1987). These pedagogical concepts and learning practices are addressed implementing a set of mixed reality scenarios (experiments), employing shared virtual spaces and mobile e-Learning in order to enhance the effectiveness and quality of the teaching/learning process.

Through the LAB@FUTURE Learning Platform development life cycle, project experiments will investigate social life parameters that are not embodied in traditional school conditions. These social life parameters are expected to find their way in the mixed realities laboratories. For example social aspects that can only be seen in real life (e.g. aggressiveness, environmental awareness, social rights), or conditions and physical phenomena that may not be easily reconstructed (e.g. water pollution, fire, earthquake, thermodynamics, hydraulics, mechanics, mathematics, biological and chemical experiments), may be implemented partly in real life conditions, and partly in virtual environments (Wellner et al, 1993).

This paper will begin with the presentation of the specified educational methodology framework and the needs that this framework infuses in the e-learning process. Based on these, the learning scenarios that the LAB@FUTURE Learning Platform is aiming at are discussed so that to outline the functional and operational features of the platform. The work continues with a presentation of the information and communication technologies that are essential to the development of the LAB@FUTURE Learning Platform and concludes with a presentation of the LAB@FUTURE evaluation framework.

THEORETICAL FRAMEWORK

The core commitment of the *constructivist theory* of learning is that knowledge is not transmitted directly from one knower to another but is actively built up by the learner. Learning is considered to be an active process in which learners "construct" their own knowledge (Duffy & Cunningham, 1996). This is supported through relevant, engaging learning activities, which involve problem-solving and critical thinking. In addition, a factor that plays a fundamental role in the development of cognition is social interaction. As a result, both teachers and older or more experienced children play very important roles in learning. This constructivist approach is often called *social constructivism* because it emphasizes the critical importance of culture and the importance of the social context for cognitive development (Resnick et al, 1991).

According to the theory of social constructivism, students learn through interaction with others. The theory of social constructivism addresses two basic aspects of collaboration. The first involves the relationships among students. Students work together as peers, applying their combined knowledge to the solution of a problem. The dialogue that results from this combined effort provides students with the opportunity to test and refine their understanding in an ongoing process. The second aspect of collaboration involves the role of the teacher. Teachers should serve as models and guides, showing students how to reflect on their evolving knowledge and providing direction when students are having difficulty. Learning is shared and responsibility for the instruction is shared (Salomon, 1993).

Expansive learning differs from traditional types of learning, including most forms of constructivism, in that: (a) the contents and outcomes of learning are not merely knowledge in texts and in the heads of the students but new forms of practical activity and material artefacts constructed by students and teachers in the process of tackling a real-life project or problem - it is 'learning what is not yet there'; (b) learning is driven by genuine developmental needs in human practices and institutions, manifested in disturbances, dilemmas, double binds, and episodes of questioning the existing practice; (c) learning proceeds through complex cycles of learning actions in which a new object and motive for the activity are created and implemented, opening up a radically wider perspective of possibilities for the participants. This typically also calls for new tools, rules, and ways of crossing organizational boundaries (Engeström, 1991).

Students operating within the framework of LAB@FUTURE will be situated in a relevant or "authentic" context. This is known as *situated learning*, whose advocates argue that knowledge is to a great degree a product of the activity, context, and culture in which it is used (Lave & Wenger, 1991). It cannot be taught in the abstract; it must be taught in context. Situated learning proponents, for example, support that learners can often master complex and difficult material through cognitive apprenticeships. They also support *problem solving* (Boud & Feletti,1992) as a crucial instructional strategy.

In a problem solving approach learners must use previously mastered skills to resolve a challenging problem. Problem solving is based on the scientific method of *inquiry*. The usual steps are: (1) define the problem and all major components (2) formulate hypotheses (3) collect and analyse data (4) derive conclusions and/ or solutions and (5) verify conclusions and/ or solutions. Through this process learners can be expected to arrive at a higher level of understanding of the phenomenon under study.

LAB@FUTURE initiates problem solving activities in the form of carefully designed experiments related to real-life conditions. These activities are expected to help students develop the ability to think critically, analyse problems, and find and use appropriate learning resources. Problems also situate or provide a context for learning basic skills. The LAB@FUTURE Learning Platform provide essential tools to accomplish these goals via:

- connecting remote participants by telecommunication
- allowing tele-cooperation in a distributed virtual reality
- providing a close coupling between real and virtual worlds
- augmenting reality and virtuality by multi-perspective views

APPLICATION FRAMEWORK

Technology-enhanced Education in Europe defines a clear vision to enhance the learning process by interleaving learning and knowledge acquisition between individuals and organisations. To achieve this goal complementary innovative technologies determine the framework of "ambient intelligence", therefore improving the learning process is being pursued by adopting this challenge. This work focuses on enabling "ambient intelligence" in education laboratories.

Leading research organizations have recognized that literacy in basic sciences (i.e. physics, chemistry and biology) amongst the average citizen in Europe is insufficient (Knowledge and Skills for Life: First Results from PISA 2000, OECD, 2001) and the same observations can be drawn for cultural context knowledge (King, 2000). As the European economical and cultural strength has been and will be greatly dependent on its technical and scientific basis, such recognitions must lead to action. These actions should motivate students and also empower teachers so that sustainable European development is guaranteed. Perhaps the greatest challenge in these efforts is the identification and formation of new ways to convey the excitement and wonder of science to young people, while allowing for building of culture consciousness.

Functional requirements of LAB@FUTURE will define a shared virtual space, students will be encouraged to communicate not only with classmates but also with learners from other school environments. Interacting with others and sharing views and experiences are expected to result in cognitive development. This form of social interaction and collaboration plays a fundamental role in the development of cognition (Resnick et al, 1991). Based on the theory of social constructivism, emphasis will be given to the development of virtual and real learning heterogeneous communities, where competition, knowledge delivery, teacher-centred approaches and independent, individual work will be substituted by collaboration, knowledge construction, student centered instruction and interdependent teamwork.

The aforementioned framework will be experimented in laboratory trials focused on the fields of: Science Fluid Dynamics, Mathematics and Geometry and Arts and Humanities. Work related to Science Fluid Dynamics stems from the development and the results obtained from previous projects BREVIE (Schmudlach, 2000) and DERIVE (Bruns, 1999). LAB@FUTURE will integrate these achievements and evaluate the impact in the school laboratory. Mathematics and Geometry is due to existing experience on the successful use of Augmented Reality experimenting to a critical mass of end-users/learners in Austria. Arts and Humanities includes mobile learning (m-learning) and is organising the didactic methodology of Virtual Educational Visits. In the remaining section we proceed with the scope and description of the planned activities in these three fields:

I. Science- Fluid Dynamics

Certain physical properties of fluids will be considered during these trials: density, specific (or unit) weight, viscosity, elasticity, critical pressures, and surface tension. The understanding of the interaction of these properties in fluid dynamics will be demonstrated in this type of experiments.

In order to provide arbitrary boundary conditions, a mechanism to generate one phenomenon and sense the other, has been developed. All necessary components are available in a standard mechatronics construction kit, and a prototype will be build and applied within the shared virtual space (Bruns, 1999). This kind of Future-Laboratory will allow to have certain critical phenomena on the laboratory desk to compare reality with a simulation model, while having the laboratory desk integrated in a broader application context; being represented in the virtual world or at other reality places.

II. Mathematics- Geometry: Improving spatial abilities

Spatial abilities present an important component of human intelligence that is a prerequisite for many design and construction tasks in medicine, architecture, engineering, visualisation etc. The term “spatial abilities” covers five components, i.e: spatial perception, spatial visualization, mental rotations, spatial relations and spatial orientation. Generally, the main goal of geometry education is to improve these spatial skills. As shown in various studies spatial abilities can be improved by virtual reality (VR) technology (Bell & Fogler, 1995). Though spatial skills are a requirement in many areas, in the beginning the main focus will be on construction. Experiments in Mathematics and Geometry will be based on Augmented Reality (AR) technology, and a special AR subsystem will be integrated within the LAB@FUTURE Platform for this purpose.

Using (AR) systems, users are able to immerse in a Geometry world and attend an educational session (Fuhrmann, 1999). Learners immersed in the LAB@FUTURE AR subsystem will be able to interact with the models and gain access to background information. Sessions will be organised where the on-line participation of mentors will enable the proactive investigation of Mathematical problems. The LAB@FUTURE AR subsystem will allow for an integration of the virtual world into the real world, where users can partly see the real world and also interact with virtual projections. The LAB@FUTURE AR subsystem will contain the following learning units:

Studying surface intersections of cone, cylinder and sphere

The pedagogic aim of this unit is to learn about Boolean operations, which are used in all CAD packages nowadays, to learn about intersection curves of surfaces of 2nd order and to experiment with intersections in order to understand how a) Boolean operations work, b) how to construct surface intersections and how they may look like and c) to learn the mathematical theory behind intersections of 2nd order surfaces.

Conic Sections

A tutorial presented as an interactive animation will introduce elliptic, hyperbolic and parabolic intersections of the cone. Information about conic intersections, their properties and (parametric) equations will be available and accessible all the time. Dynamic modifications of the cone and the intersection plane allow visualisation of all cases of conic sections.

Vector algebra

One or more examples (tutorials) will introduce students into vector algebra. Various examples using points, lines, planes, spheres, cones and cylinders will be available for exercising.

III. Arts & Humanities

These trial experiments will consist of three main sections, i.e. visits, educational walks and seminars and will also explore certain cross-thematic aspects. During these experiments, wireless technologies and mobile devices in so-called 4G environments will be used and evaluated, both outdoors and indoors (Abowd et al, 1997).

TECHNOLOGY PROFILE

The technology profile underlining LAB@FUTURE development is based on advances in the following technological domains.

Ubiquitous Environments

Participants to the LAB@FUTURE multi-user 3D space, will be using an appropriate Content Presentation module enabling their accessing over internet via mobile technologies, while effecting position tracking feeding the respectful location awareness server. This will be implemented via the appropriate architecture to be defined in such a way that the software will be easily portable on top of mobile environments and equipment (accounting for transparency and emerging standards, e.g. UMTS over ipv4, and investigating compatibility with ipv6), (Lobley, 2001). During recent years users took a first taste of wireless freedom, for example by accessing text-only web-pages with a Palm Pilot connected via infrared to a GSM Phone. PDAs may provide new operational features but the bandwidth is too narrow for even reasonably large-capacity data transmission.

Radio link-based broadband technologies were introduced in the late 90's, of which the most important ones turned out to be Bluetooth and WLAN (Wireless Local Area Network). Bluetooth has a quite short range (usually a radius of 10 m), and therefore is suitable for applications where wire or infrared ports typically have been used (Haartsen et al, 1998). A more established alternative is WLAN, which is suitable for wireless local area networks. WLAN is a good technology for mass data transmission over short distances, even though it still faces some challenges, such as bandwidth expansion, security and Quality of Service (QoS) as well as coupling with other access technologies.

Currently much interest is focused on 3G UMTS technology. An important role of WLAN in the future will be to complement UMTS coverage. The so-called 4G is considered, as an interface between different media, such as GPRS, UMTS and WLAN (EURESCOM, 2000). The objective is obviously the seamless routing of connection from one medium to another. After this convergence the user will be free to move from one place to another without losing the connection. Mobile user localization in addition, offers many opportunities for service developers, typically the user receiving information relevant to his current location.

Mixed realities and mechatronics systems

LAB@FUTURE is aiming at an environment where students can experiment in a tight mixture of real physical, social and personal phenomena and also their virtual computer generated representations or even complements. This environment will be built on top of existing technology offerings with respect to mechatronic systems. With appropriate editors, abstract languages or specification by concrete demonstration, students will be enabled to build models of their understanding of real world phenomena in a constructivist way, connect these models with real surroundings or with their virtual duplicates and run simulators to verify and validate the correct and adequate modelling. Therefore, a system distributed between reality and virtuality is utilised, allowing for well-known aspects to be represented algorithmically in a formal way in the computer, while other aspects to be represented in reality, but also coupled to a dynamic surrounding. This is expected to empower completely new forms of experimental work and learning.

Hyper-Bonds (Bruns, 1999) presents a new type of mechatronic interface, which offers a new concept and prototype to realize the above-mentioned functionality. Hyper-Bonds provides a sensing and generating mechanism for various relevant physical phenomena. Theoretically, these are based on Bond graphs, a unifying approach to describe dynamic behaviours of different physical domains with a uniform formalism (Paynter, 1961). The feature of effort and flow, determining a systems behaviour can be used fruitfully, to implement arbitrary cuts in an overall system, realizing one part in reality, the other one in virtuality and provide a mechanism to sense and generate arbitrary efforts and flows. In practice, they are based on a mechatronic construction kit, having actors and sensors for the desired phenomena. With this interface it is possible e.g., to push a virtual button and a real hydraulic cylinder is moving or to close a real switch and the virtual circuit is reacting.

This principle can be applied to many physical laboratory scenarios. For example, a group of learners from different places and cultures meet in one distributed virtual environment as avatars and build one common laboratory experimental system on one table or construct various preferred solutions of the problem on different tables in a communicative co-operation. These tables may stay completely in virtuality and serve for experimentation by simulation, but it could be very fruitful for the construction of action relevant mental models, if the learners can experience real parts and phenomena on a local real table but still be connected to the rest of the system.

Different virtual and real behaviours then can be compared. Aspects of formalization and abstraction, reduction and enrichment, very important for ITC competence, can be discussed. The application can be extended towards urban design, co-operative buildings, ambient rooms, laboratory desks, single devices and whole factories.

Augmented reality and Haptics

In order to provide mathematics and geometry education with an applicable tool, an AR module called Construct3D is going to be used for the LAB@FUTURE AR subsystem. Construct3D, is a collaborative augmented reality system and uses immersive devices such as the Personal Interaction Panel (PIP), a two-handed 3D interaction tool composed of instrumented hand-help props – a pen and a pad equipped with position and orientation trackers (Kaufmann et al, 2001). This user interface is only possible in AR and allows multiple users at different locations to work and interact in the same environment under various system platforms. This feature will be used for teacher-student and student-student interaction. In addition, a mobile system will be developed, using 3G mobile devices for networking and communication means. This mobile system will offer ultimate flexibility and can be used in classrooms, outdoors and whenever mobility is needed.

The main advantage of Construct3D to student learning in mathematics and geometry education, is that students actually see and feel three-dimensional objects, which they until now had to calculate and construct with traditional methods. Complemented by integrating haptic devices, (e.g. Cybergrasp), a tangible picture of complex three-dimensional objects and scenes is also provided.

Construct3D, is based on the collaborative augmented reality system “Studierstube” (Szalavári et al, 1998) that uses AR to allow multiple users to share a virtual space. See-through HMDs are used, which are capable of overlaying computer-generated images onto the real world, thereby achieving a combination of virtual and real world allowing natural communication among users. The latest version of Studierstube allows the mix and match of heterogeneous output devices such as personal HMD, virtual workbench, conventional monitors, and input through a variety of tracking devices. All these devices appear to act as interfaces to a single distributed system.

Multi user environments, web collaboration

Using interactive mixed realities access points, and interactive terminals, to integrate a distributed environment aiming at real world observation and virtual world interaction, users are supported in constructing knowledge taking into account views, experiences and opinions from a larger group of users/attendees (Leigh, 1996). Every user, in taking part in the social constructivist educational context, gives his/her own profile (physical, navigation style, habits etc.), and is represented by the respective avatar. In the shared virtual space profiling and personalisation will affect the space content, context and access methods. Within a common virtual space, fitting to the context and matching the user’s profile, the user participates either as a mentor (expert) or as a student. Possible conversations and discussions could also be launched with the assistance of a knowledge management system and software agents.

Users will be able to put themselves in the shoes of different space and time characters, thereby taking up the profiles of other cultures, eras, civilizations, so as to determine social and cultural evolution. Some of the participants may be actually situated in real life places of particular interest to the social subject. The real places for the social constructivist education may vary, according to the subject matter (e.g. parliament, police station, archaeological site). In addition, combined Mixed Realities will nurture aspects relating to cross-cultural education and civilizations’ comparison based on the transfer of real life experience within the virtual space (situated learning in a virtual space).

Technological advances presented in this section will be integrated in the LAB@FUTURE Platform and will be evaluated and assessed with respect to the benefits that they can offer to learning activities in the school laboratories.

EVALUATION FRAMEWORK

Evaluation procedures will be based on the Concept for Interdisciplinary Evaluation of Learning Technologies (CIELT) (Grund, 2002) that defines the framework for all evaluation activities and involves teachers, students, technicians and industry representatives. Evaluation will be an iterative process that will affect all phases of LAB@FUTURE lifecycle, from the system definition, to the implementation of prototypes up to the evaluation and assessment of the final system. Evaluation outcomes from each phase will provide feedback to previous phases, in order to conform to the evaluation objectives and update successful LAB@FUTURE prototype versions accordingly. Within the CIELT evaluation framework the following aims are identified:

- Step I: Development of evaluation methodology and adjustment to LAB@FUTURE objectives

- Step II: Evaluation of LAB@FUTURE user centred system design, based on the specifications of LAB@FUTURE system requirements.
- Step III: Usability testing of rapid prototype. Usability testing will be performed with respect to: (i) Suitability of user interface design to the tasks that the users need to accomplish, and (ii) Suitability of user interface design with respect to the cognitive ergonomics of the LAB@FUTURE functionalities evaluated.
- Step IV: Testing of the “LAB@FUTURE Evaluation Prototype” with respect to: (i) User behaviour (ii) Learning outcomes, i.e. factual knowledge, practical abilities, mental models and problem-solving styles (iii) Assessment of teaching and learning aspects by teachers and students
- Step V: Evaluation of the final system is composed of: (i) Usability testing (ii) Identification of all advantages, disadvantages, constraints and problems (iii) Continuous evaluation with respect to organisational aspects i.e. system implementation, system use, integration of pedagogical, didactical, curricular and technical aspects (iv) Teacher’s reactions, learning and behaviour (v) Student’s reactions, learning and behaviour.

The evaluation framework for the LAB@FUTURE system arranges a number of horizontal, complementary strategies in order to get a survey of all evaluation sessions and to monitor progress in the user’s impressions. These strategies include a general online questionnaire, log-file analysis of end-user sessions linked with online questionnaires, video observation/analysis including haptic and auditory aspects and online observation for all kinds of tele-settings.

CONCLUTIONS – NEXT STEPS

A community of interest consisting of 100-120 secondary education schools throughout Europe, is being built up so that to evaluate and exploit the results of the LAB@FUTURE. Furthermore a number of 4-10 remote sites (Museums, Research Institutes etc) will also be incorporated. Deep evaluation will be performed in a group of LAB@FUTURE partner schools that consists of 2 to 3 schools from each participating country.

Moreover, a Network of Experts is currently being developed and has already organised respective workshops in the field of advanced e-learning technologies. This human network will span across Europe and will consist of key persons and institutions in the fields of Mixed Realities, Augmented Realities, Shared Virtual Environments and Mobile Computing among others, with a special focus in the particular needs of Expansive Learning.

The network of schools participating in the evaluation of LAB@FUTURE is really large and this fact itself imposes the most challenging difficulty in this project. Putting into operation the evaluation procedures that LAB@FUTURE is planning is a real difficult and time-consuming task that needs commitment both by the project team of evaluators but also by participating teachers and students. LAB@FUTURE is a three-year project and from the beginning it has built the nodes of evaluating partner schools in all participating European countries. In Greece twenty-five schools countrywide are involved and are supported for their evaluation activities through extensive use of the EDUNet schools’ network.

ACKNOWLEDGEMENTS

The LAB@FUTURE platform development is partly funded by the IST Fifth Framework Programme of the European Commission (IST-2001-34204).

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