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THE LAB@FUTURE PROJECT

“Moving Towards the Future of E-Learning”

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Abstract: This paper presents Lab@Future¹, an advanced e-learning platform that uses novel Information and Communication Technologies to support and expand laboratory teaching practices. For this purpose, Lab@Future uses real and computer-generated objects that are interfaced using mechatronic systems, augmented reality, mobile technologies and 3D multi user environments. The main aim is to develop and demonstrate technological support for practical experiments in the following focused subjects namely: Fluid Dynamics - Science subject in Germany, Geometry - Mathematics subject in Austria, History and Environmental Awareness – Arts and Humanities subjects in Greece and Slovenia. In order to pedagogically enhance the design and functional aspects of this e-learning technology, we are investigating the dialogical operationalisation of learning theories so as to leverage our understanding of teaching and learning practices in the targeted context of deployment.

Key words: Activity theory, synchronous and asynchronous learning, mixed and augmented realities, e-learning laboratories.

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1. INTRODUCTION

The Lab@Future project (the project full name being - ‘School LABORatory anticipating FUTURE needs of European Youth’) is a research and development project, funded by the European Union (EU) as part of the Information Society Technologies (IST) program.

The project investigates the means by which pedagogical insight and state-of-the-art technologies can be harnessed in the development of e-learning technological tools so as to facilitate and enhance innovative approaches to teaching and learning in European high schools. In order to achieve this remit, pedagogical research in the Lab@Future project is underpinned by learning theories that highlight the significance of social and cultural aspects of teaching and learning practices in context whilst recognizing the dynamic nature of tool use behavior. Given this consideration, Lab@Future e-learning technological tools strive to support established ways of teaching and learning in focused contexts whilst nurturing emerging and innovative practices in teaching and learning methods. Lab@Future strives to achieve this by facilitating flexibility and exploration in tool use mechanisms when teaching and learning, therefore enabling the user to introduce new teaching methodologies and learning activities under a common communication and collaboration technological environment.

The main goal of the Lab@Future project is therefore, to research and develop a prototype system for supporting secondary school laboratory education. The overall rationale is that, both the pedagogical and technological effectiveness of the developed system will be evaluated at real educational sites i.e. school laboratories, educational venues e.g. museum and historical sites. In summary, key pedagogical and technological features integrated in the Lab@Future project include the following:

- E-learning and m-learning
- Open learning environments
- Human-computer interaction
- Constructivism, Activity Theory and Theory of Expansive Learning
- Communication and collaboration platforms for learning
- Mixed and augmented reality for learning
- Shared virtual learning environments
- Evaluation processes for learning

Teaching and learning experiments incorporated in the project’s systems development and evaluation processes includes both laboratory and non-laboratory based teaching and learning for the disciplines of science (fluid dynamics), mathematics (geometry: developing spatial skills) and arts &

humanities (environmental awareness and history, including educational walks, visits and seminars).

2. THEORETICAL FRAMEWORK AND PEDAGOGICAL CONTEXT

The three major pedagogical theories that Lab@Future supports are *activity theory*, *the theory of expansive learning*, and *social constructivism*. The Lab@Future platform is focused on supporting novel pedagogical concepts and learning practices based on constructivism, combined with action oriented learning such as real-problem solving, collaborative learning, exploratory learning and interdisciplinary learning. When working with the outlined pedagogical theories, we recognize the fact that there are diversities and variations in emphasis when applied to learning research. Therefore, in order to achieve a workable compromise with regards to the various facets of these three theories, research in the Lab@Future project in capitalizing on exploiting the dialogical aspects of these theories so as to facilitate positive debate in the perception of teaching and learning from the viewpoint of these three theories.

The core commitment of a *constructivist* position in relation to learning is that, knowledge is not transmitted directly from one knower to another but is actively constructed or built up by the learner. Therefore, constructivism considers learning to be an active process in which learners “construct” their own knowledge by testing ideas and approaches based on their prior knowledge and experience, applying these to a new situation, and integrating the new knowledge gained with pre-existing intellectual constructs. Therefore, the social constructivist pedagogical stance is supported and enhanced by enabling the learner to engage in relevant activities that involve problem-solving and critical thinking.

Activity theory and *the theory of expansive learning* go a step further [3] in that ‘subjects’ or participants (e.g. students and teachers) in a learning activity consciously and unconsciously are engaged in dynamic learning goal or object formation. This entails that the outcome from a learning experience or activity cannot always be predicted because it will be influenced by several factors operating within the contextual environment or community in which teaching and learning takes place. This pedagogical stance therefore, emphasizes the fact that knowledge emerges as a result of disturbances or conflicts in learning activity, which results in the construction of novel practical activity systems and artefacts for use in real life contexts. Therefore, participants in a learning activity are essentially involved in constructing new:

- Learning activities
- Methods for teaching and learning
- Tools for exploring and interacting with learning objects.

In practice, this pedagogical stance requires that schools initiate partnerships involving all stakeholders or interested parties in the community in which teaching and learning occurs in order to uncover challenging contradictions and explore hybrid forms of teaching and learning activities in which both students and teachers become co-producers of knowledge or what must be learnt.

In order to apply theoretical perspectives drawn from both activity theory and the theory of expansive learning in a more practical sense, research in the Lab@Future project [4] used the activity triangle model also known as the activity system (see Figure 1) as a representational model to portray key theoretical aspects incorporated in the various elements of an activity system (see also Mwanza and Engeström, 2003). Elements of the activity system incorporate the various components and mediational relationships that exist within and amongst stakeholders in an activity system. Figure 1 shows the various components and mediational relationships of an activity system:

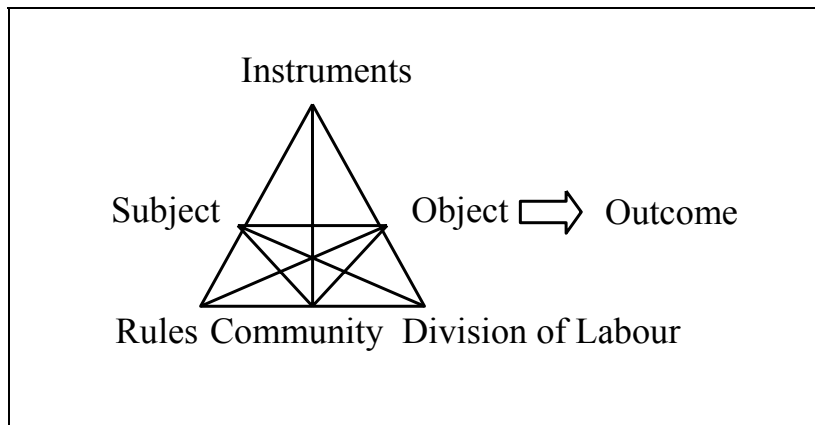


Figure 1. The activity system or activity triangle model (Engeström, 1987)

In order to map the theoretical perspectives described above onto systems design tasks, the activity system was used as a conceptual model for visualizing the various components and relationships in the targeted context of deployment during the requirements specification process. This was specifically associated with the abstraction of the division of labour through the conceptualization of existing roles within the teaching and learning

practices in the targeted schools and focused subject areas. During this design process, Lab@Future operationalised the activity triangle model in each focused subject area that was used as a test case for design purposes. Figure 2 shows an example of such operationalisation.

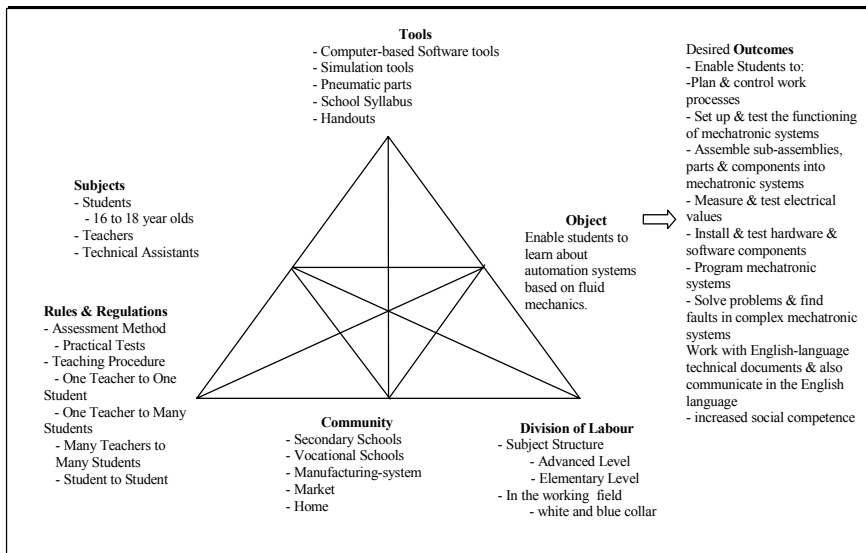


Figure 2. Activity System for Fluid Dynamics – a focused Science subject area in Germany

Figure 2 shows an activity triangular representation of components and mediational relationships that exist in the teaching and learning context of the Fluid Dynamics focused Science subject in Germany, which is one of the subjects and contexts being used as a test case during systems design. Fluid Dynamics as a science and practice subject proves to be especially suited for investigating consequences of the activity theoretical view on learning. The science of fluid dynamics with ever increasing theoretical models and refinements down to a quantum mechanical level, still have to be taught at a practical level for work in a factory. Many arising questions from production practice with pneumatic automation equipment (in a constructivist sense of disturbances or conflicts in learning and work activity resulting in the construction of novel mental models and practical activity systems and artefacts for use in real life contexts, see also Mwanza & Engeström, 2003) can be handled in a learning environment, where a bridge between school and factory, theory and practice is supported by adequate teaching methods and mixed reality tools.

3. LAB@FUTURE DISTRIBUTED PLATFORM

3.1 Session definitions

A collaborative e-learning session (referred to later as a session) is constituted by a group of persons working collaboratively, handling experiment specific data, performing experiment specific applications and using a set of groupware tools as support of their work. The groupware tools provide the basic communication and collaboration services to the users registered in the session.

Two phases are defined within a session, respectively an *asynchronous* phase and a *synchronous* phase. When a session is created, it enters an asynchronous phase that is continuously active until the session is deleted by the administrator. In the asynchronous phase, the registered users are authorized to access independently (i.e. without any synchronization among them) the e-learning content of an experiment (for instance, access to experiment specific Web pages, access to experiment-specific virtual scenes) and to perform independently experiment specific applications. During the asynchronous phase, only asynchronous communication tools, like E-mail or news groups, are available to the users.

When a synchronous phase is running, it is the responsibility of each user to explicitly join/leave this synchronous phase. As a consequence, all the users, who have joined a synchronous phase of a session, are aware of each other, and may use different synchronous collaboration and communication tools to work together and implement a pedagogic scenario. It is important to notice that the asynchronous and synchronous phases are not mutually exclusive and may coexist. That is, when a synchronous phase starts, the asynchronous phase keeps active. In this way, users are always allowed to work asynchronously while taking also part in a synchronous activity.

A session is created, configured and deleted by an administrator. The *administrator* is also responsible to start and end a synchronous phase, either manually or by configuring a specific time schedule.

3.2 Architecture topology

The general architecture of the Lab@Future platform is presented in Figure 3. Main components of this architecture are:

A set of distributed user workstations interconnected to a WAN network; mobile user workstations, like wireless (802.11 and possibly GPRS) laptops and PDAs, will also be considered;

A set of distributed servers. Four types of servers are considered: the Lab@Future server, generic collaboration and communication servers (GCCS), multi-user virtual reality servers (MUS) and experiment specific servers (ESS).

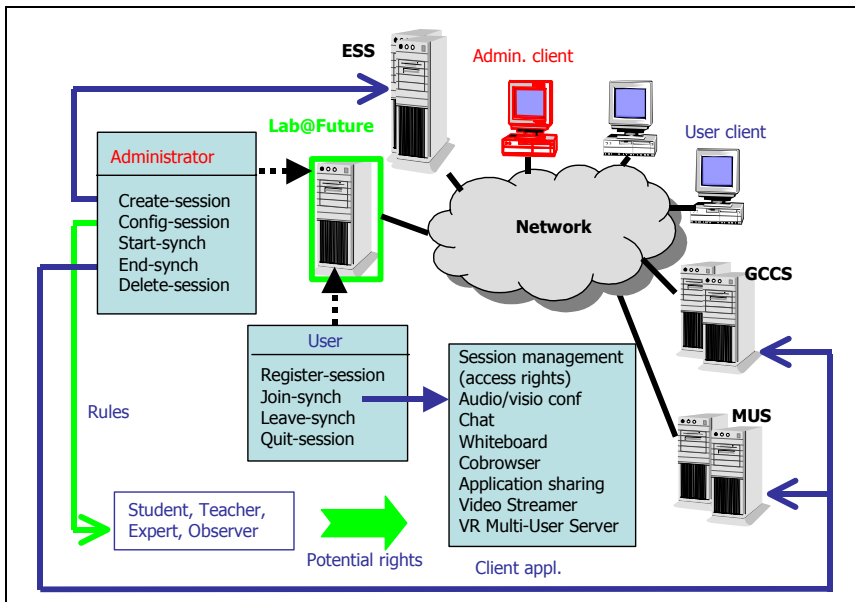


Figure 3. Lab@Future architecture topology

The set of client workstations for a collaborative session is made of, at most one administrator workstation, and one or more user workstations.

3.2.1 Lab@Future server

The Lab@Future server is a dedicated front end to access the platform. It provides a common Web interface for supporting the interactions of the administrator and the clients. Users may then access experiment specific data (e.g. Web pages, VRML scenes, Web applications), experiment specific applications and collaboration communication tools from a Web browser supporting the required plugins (like the Cortona VRML plugin of Parallel Graphics for interacting with a virtual scene), (<http://www.parallelgraphics.com>).

3.2.2 Generic collaboration and communication servers

The generic collaboration and communication servers (GCCS) contain and manage all the services required for informal communication among users during the synchronous phases of the sessions.

Three main collaboration and communication services are available during a session synchronous phase:

- Informal communication among users through audio video-conferencing (in a multicast setting) and chat;
- Document sharing through whiteboard and collaborative browsing;
- Video-based information sharing through application sharing and video streaming.

These services are implemented by a set of tools made available to the users during synchronous phases of the sessions. These tools belong to the PLATINE prototype environment developed by LAAS-CNRS.

3.2.3 Multi-user virtual reality servers

Some experiment-specific applications provide users with means to collaboratively interact on the same virtual scene. In order to allow the sharing of interactive virtual scenes, a multi-user virtual environment can be used [5].

Parallel Graphics Multi-user solution is a client-server based networking system that allows virtual worlds (described through VRML scenes) to be shared among different users, synchronizing movements and events from within the virtual environments over an IP network. It supports definition of 3D scenes with sophisticated shapes and animations. Then, users are able to move and explore by themselves the 3D scenes.

At the server side, the multi-user server (MUS) monitors user events in order to synchronize them. Accordingly, once a user changes something in a 3D world (like adding a new object), the MUS transmits the respective information to the rest of the clients.

Clients connect to the MUS with a Web-browser (including the Cortona VRML plug-in) or from a stand-alone application (often developed with the help of Parallel Graphics Cortona SDK). The Parallel Graphics Cortona engine allows users to interact with the 3D models in a one-sided way (local interactions) or synchronized with the other clients.

3.2.4 Experiment specific servers

Experiment specific servers (ESS) are dedicated data servers storing all the data and applications related to each particular experiment described in the next section. Through the ESS each experiment is integrated to the Lab@Future platform. In order to know how to start and stop an experiment and which experiments are available, the Lab@Future front-end queries the ESS by requesting a specific URL. The ESS returns an XML file that contains the needed information.

The XML based exchange file / protocol, used between the Lab@Future platform and experiment specific servers, is divided into two parts. The first one describes the ESS in general and the second describes the experiments that can run on this server. Information is provided in different languages. The Lab@Future front-end uses the best-suited version for display. By introducing the exchange protocol, extensibility and backward compatibility is guaranteed. The latter is fully supported by the Fluid Dynamics server.

3.3 Generic collaboration and communication tools

Collaboration and communication services are implemented by the PLATINE prototype (http://www.laas.fr/~vero/PLATINE_TEST/).

3.3.1 Informal communication among users

This service allows users to directly communicate the ones with the others through audio, video and text messages while the collaborative activity takes place.

The *multipoint video/audio conferencing tool* addresses the capture, compression, transmission, decompression and presentation of the multimedia streams. It is based on real or simulated *multicast* communication. The video and audio streams are based on the H.263 standard format to ensure compatibility with other current videoconference systems.

The *Chat* tool provides a textual communication service among the users. It can be used in parallel with the video/audio conferencing tool or as a backup informal communication service because it is more robust and less bandwidth consuming.

3.3.2 Document sharing

This service allows users to concurrently look at the same documents and possibly to edit them in a controlled way.

The *Shared whiteboard* tool provides a graphical document sharing service among the users. It reproduces the behavior of a classical whiteboard in a distributed way. The interface to the shared whiteboard is composed of a graphical window for each user. An authorized user loads images on the whiteboard (for example, JPEG, GIFF images) and writes annotations on them.

The *Collaborative browsing* tool allows several users to browse the Web synchronously, in such a way that a set of users follows the browsing activity of a privileged user [5]. It is an extension of traditional Web browsing activity where users are allowed to browse the Web together, in a synchronized way. This tool is a Java-based software environment where servers are responsible for tracking all browsing activity and dynamically defining user access rights. The collaborative browsing clients are synchronized Java applets.

3.3.3 Application sharing

The *Application sharing* tool provides users with a generic service for sharing any application. The application sharing tool periodically captures and samples the screen dumps of the shared application. They are displayed on a specific video window for each user. This window represents a remote view of the shared application. Through it, users can remote control the shared application.

3.4 Mobile clients

The Lab@Future platform is designed to take into account the new context created by the increased mobility of participants to e-learning sessions. Mobility opens new opportunities for e-learning but also adds constraints to the technical platform that supports the e-learning tools like for example limited bandwidth (in the case of low bandwidth wireless link, such as GPRS) and terminal limitations (smaller screen size of PDAs). Based on the rapid development of wireless technology, some of the central challenges of the Lab@Future project are to build useful systems that are well suited to small screens, require minimal or convenient user input, and adapt different data flow transfers to specific needs.

Anticipated benefits for the Lab@Future system from using a combination of wireless technology and PDA in e learning include:

Portability and mobility: Because of the small size and lightweight of wireless devices, students find them convenient to use and carry with them.

Flexibility: Students and educators can access information databases from almost anywhere. This includes while traveling or waiting in a queue.

Convenience: Whenever students need to contact teachers or urgently need information from the Internet, remote access is available to them. In particular, accessing the network using a PDA is very fast, compared with connecting the network using a modem.

Remote Accessibility: Students can add or update information remotely.

Ease of use: Using a PDA provides a larger screen than a mobile phone only. Also, it is convenient for user input.

Utility: A PDA provides some of the capabilities of a standard computer, such as processing and storing data.

The Lab@Future platform integrates a generic mechanism that allows dynamic adaptation of data and content to the constraints created by the mobility context. The Lab@Future adaptation framework consists of two main components: a basic middleware integrated in the platform as a content filtering proxy and a content presentation module (CPM), which is a set of specific modules that implement the specific adaptation functionality required by the application. The set of modules currently implemented is a set of custom tags, where each tag defines the way we want to display information. One tag per specific information object is created and for each tag a set of available actions (attributes of the tag) is defined. In this way, the CPM adapts html pages dynamically. The content adaptation is applied mainly to History mobile scenarios.

4. EXPERIMENTS

The following sections describe the main functionality of the Lab@Future e-Learning application experiments, namely the Fluid Dynamics, the Mathematics and the Arts & Humanities Experiment.

4.1 Fluid Dynamics

The main functionality of the Fluid Dynamics experiment is the use of a Mixed Reality environment as an assistant tool for teaching Mechatronics [1]. The Toolkit is implemented as a distributed and collaborative Mixed Reality Web Service that integrates real and virtual, local and remote media under one common interface. With a special kind of coupling between the computer and real hardware, it is possible to build hybrid systems that are a mixture of real and virtual parts by using bidirectional connections for physical phenomena (air pressure and electricity).

Users have the possibility to learn the topic of Fluid Dynamics not only by theory but also in practice. They cannot only create virtual experiments but can connect them to real hardware. The Web Service gives also access to supporting material for each experiment. This material can be used for self-education and/or homework composition.

The Fluid Dynamics experiment specific platform suite consists of several modules that together build the deriveSERVER system. Each component of the system has its own dedicated task, e.g. simulation. A central module, which controls the communication and data flow between the different subsystems, is the Mixed Reality (MR) Server. It maintains the resources of running experiments. The user sees only the HTML based Front End, the Virtual Construction Kit (VCK).

The virtual model is interfaced to the real hardware process, utilizing diverse innovative devices such as the Hyperbond [2], an image recognition system, etc. With the help of video-streaming changes to the real hardware it can be observed at distant places. All software components are realized as specialized software agents that communicate via standard Internet protocols (TCP/IP). The network of communicating clients forms the overall (software) system.

Lab@Future experiment scenarios relevant to course topics in the subject area of fluid dynamics are: industrial safety circuit, swivel driver and comparison of real and virtual behavior of double acting cylinder.

The integration of Fluid Dynamics experiment specific platform into the Lab@Future collaborative platform is based on the HTTP/1.1 protocol that controls the Mixed Reality Web Service. Users are accessing the platform front-end in order to manage the Fluid Dynamics experiments. The Lab@Future server starts and stops experiments using the HTTP/1.1 protocol, while the Mixed Reality Web Service automatically starts and stops the specific applications for the actual experiment.

The learning objectives specified in the framework of the scenario design method of Fluid Dynamics are to enable students to:

- Learn about automation systems based on fluid mechanics.
- Plan & control work processes.
- Set up & test the functioning of mechatronic systems.
- Assemble sub-assemblies, parts & components into mechatronic systems.
- Measure & test electrical values.
- Install & test hardware & software components.
- Program mechatronic systems.
- Solve problems & find faults in complex mechatronic systems.
- Work with English-language technical documents & also communicate in the English language.

- Have some insight in automation theory and practice.
- Have some knowledge of the application domain (e.g. conveyor belts).
- Develop increased social competence.
- Develop increased reflexive perspective.
- Acquire visions of change.

4.2 Geometry

Within the scope of the Geometry Experiment a system called Construct3D is developed, which is a novel tool for teaching descriptive geometry using collaborative augmented reality. The system incorporates the following laboratory equipments used during teaching and learning:

- Personal computers (PCs) (these include laptops and desktop)
- Head -Mounted Displays (HMD) used for presenting the output of our system i.e. the real world augmented by the virtual elements generated by the application
- Trackers used for obtaining head and hand position and orientation information:
 - USB and Firewire webcam based tracking
 - Electromagnetic tracking
 - Computer-vision tracking
 - Ultrasonic/inertial tracking
 - Inertial tracker used for measuring head movements
- BARCO projection table
- P5 virtual glove

Each student has his or her own head-mounted display and interaction hardware, so they don't share these devices. This approach enables students to actively participate in the learning process. Since these displays are optical see-through HMDs, they can see each other and are able to communicate simply by speech as well allowing for natural, familiar and therefore effective means of exchanging information. In addition to the HMDs, there is also a provision for students to watch the 3D construction procedure passively on a large projection screen or computer screens. The large projection screen or computer screens can be "shared" or viewed by several users thereby enabling several students to passively participate in the learning activity.

One or more tracking servers are needed to process the data coming from the input devices of the users i.e. the pen and the panel of the Personal Interaction Panel that provides an Augmented Reality GUI (3D menus and pointer). This data is then sent to the machines needing it through the Local Area Network using multicast. The output images for each user can be rendered either on a central machine that processes the data coming from the

tracking server(s) and renders the images for the HMD or the monitor of the user, or each user has his/her own machine for the same tasks. The machines associated with one or more users run the Studierstube collaborative Augmented Reality platform, which uses the tracking data and user interaction information to render the graphical elements representing the user and the current application status, while the Construct3D application is running on top of Studierstube.

Geometry experiment learning scenarios within Lab@Future framework include: hybrid AR classroom, projection screen classroom, distributed hybrid classroom and remote collaboration.

All the machines – the input and output components - connect to the ESS of the Mathematics Experiment, which serves as the interface for the Lab@Future platform. More specifically, on the ESS of the Geometry Experiment the Studierstube collaborative augmented reality application is running. The Construct3D application is using and being run in the Studierstube framework. There can be multiple machines running Studierstube, in this case the Construct3D application runs in a distributed manner, the scene graph of the virtual scene and the updates to the scene are synchronized over the network.

The desired outcomes from teaching and learning geometry in Lab@Future environment are focused on enabling students to:

- Acquire an improved comprehension of complex spatial problems and relationships.
- Recognize structures & properties of geometric objects.
- Recognize basic geometric shapes in a bigger context.
- Create & modify objects by modeling and transforming them.
- Apply fundamental geometric knowledge in scientific & technical problems.
- Recognize & apply geometry as a language.
- Interpret & develop geometric representations.
- Learn correct use of specific tools in accordance with the problem to be solved.
- Learn to use special 2D and 3D educational software.
- Learn a programming language & use communication tools to describe and explain geometric objects & procedures.
- Acquire preciseness in expressing ideas through the use of drawing as a means of intercultural understanding.
- Prepare for the professional world by learning to be precise & organized.
- Capture, understand, analyze and model natural and artificial objects and models.

- Develop creativity.
- Improve fine motor skills.

4.3 Arts & Humanities

4.3.1 History

The main functionality of the History experiment is the use of Mobile Technologies as assistant tools during the visit of a high school classroom at an archeological monument. The experiment is implemented in the following way: the class of the moderator school visits a remote environment (outside the school premises). The moderator class students are holding mobile devices such as PDAs or Cell Phones enabled with WLAN access. Through these devices the students can communicate with the students of remote classrooms who are sitting in front of networked desktop computers in their classroom. The PDAs and desktop computers also allow access to supporting material residing on web servers, over the Internet. Finally the mobile devices could also include a digital camera for taking pictures at the remote site to be shared with the remote students, or used later for homework composition.

Lab@Future experiment scenarios that are relevant to history are: comparing the real monument with its virtual representation on the PDA, looking for information in relevant websites through their PDA device and using this information in order to enrich the learning impact of the educational visit, communicating and exchanging information through the mobile devices and using PDAs and GRS Mobiles phones when studying classical art.

The ESS of the History Experiment serves as the interface for the Lab@Future platform. As mentioned earlier in the paper, History experiment also uses the Lab@Future adaptation framework to overtake the various constraints induced by mobile contexts.

4.3.2 Environmental awareness

The main functionality of the experiment is to enhance the learning effectiveness on the field and in the laboratory by making use of as much relevant and necessary information as needed concerning environment.

Learning experiments relevant to environmental awareness consist of scenarios involving the simulation of the environmental pollution in freshwater lakes, i.e. modeling a healthy lake and then studying what happens if pollution takes place. These are exploited in the following

scenarios: populating the lake with plants and animals, testing for animals and plants “survival” parameters, checking the degree of biological relevance and testing the impact of environmental factors.

The experiment specific tools, applications and data depend on the technology level of the school class performing work. The environmental awareness experiments are designed so that they can be performed with minimal equipment needed for Lab@Future platform. This experiment specific platform integrates with the Lab@Future collaborative platform with the use of Wireless LAN or GPRS.

The major learning objective of the environmental awareness experiment is to enable students to acquire awareness and practical skills for analyzing factual data about the purity of the environment.

5. CONCLUSIONS

Lab@Future defines a generic - universal “mixed and augmented reality” platform energizing 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. It provides a constructivist and expansive framework that introduces innovative features to e-learning, which can serve successfully as a common teaching environment in schools throughout Europe.

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