THE PROJECT "LAB OF TOMORROW"

Designing and developing the school science laboratory of the future

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Abstract: The Lab of Tomorrow project introduces innovation both in pedagogy and technology. It aims at developing tools that allow for as many links as possible between teaching of natural sciences and every day life. Since science deals with the study of nature and the world around us, teaching science cannot be separated from daily experiences that result from student's interaction with the physical phenomena. In the Lab of Tomorrow project the re-engineering of the school lab of tomorrow is proposed along with the development of a new learning scheme based on the production of computational tools and project material that allow high-school students to use their every day life environment as the field where they conduct sophisticated experiments.

Key words: wearable devices; science education; sensors

1. INTRODUCTION

There is sufficient evidence to suggest that both the persistence and the quality of learning are highly enhanced when the student is actively participating in the learning process. This is the essential and widely accepted message of "constructivism"[1] (*S. Papert, 1994, M. Resnick, 1993*) Juxtaposing this ideal with the current reality of organized learning in school environments creates the impression that the school is not connected at the desirable degree with daily life experiences.

One particular and most striking example is science teaching. Throughout history science has advanced through observation, inspection, formulation of hypotheses, testing of the hypotheses by means of experiments and collection of data, rejection or acceptance of the hypotheses, formulation of topics for further research. It seems that in schools this process of acquisition of scientific knowledge gets reversed. Science is presented as a coherent body of knowledge, the experiment is the illustration of the phenomenon, and the questions are answered even before they are asked. The result is that the student acquires short-term knowledge targeted at standardized test questions, and in many instances this "forced and inefficient" learning lacks on long term sustainability.

As it turns out the main link missing in the learning process is that students do not learn sufficiently through experience but through a systematic model based approach, which should be the culmination of learning efforts and not the initiation. A particularly disturbing phenomenon that is common knowledge among educators is that students fail to see the interconnections between closely linked phenomena in e.g. biology and chemistry, or fail to understand the links of their knowledge to everyday applications. In most cases the physical quantities have become abstract for the students and the experimental set-ups alien or distant to every day experience. Students are early faced with two separate fields: "school science" and every day life's "rules and principles".

2. DESCRIPTION OF THE PROJECT

The **Lab of Tomorrow**[2] project is introducing innovation both in pedagogy and technology. It aims at developing tools that will allow for as many links of teaching of natural sciences as possible with every day life.

[1] Also referred to the literature as constructionism (*E.v. Glasersfeld, 1995, R. Duit, 1995*).

[2] Lab of Tomorrow project is co-financed by the European Commision under the School of Tomorrow action line of the IST 5th Framework Program (IST-2000-25076). The partnership

The Lab of Tomorrow project is developing a new learning scheme by introducing a technologically advanced approach for teaching science through every day activities. In the Lab of Tomorrow project the re-engineering of the school lab of tomorrow is proposed by developing a new learning scheme based on the production of computational tools and project materials that allow high-school students to use their every day life environment as the field where they will conduct sophisticated experiments experiencing the applicability of the theoretical background given at school. The connection of tangible phenomena and problems provides students with the ability to apply science everywhere and not only in specially designed experiments under the laboratory's controlled conditions (*D. Nachtigall, 1992*).

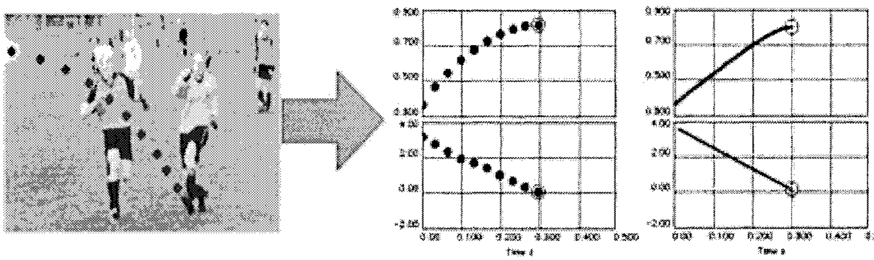

Figure 1. Lab of Tomorrow contributes to the connection of science teaching with every day life.

Within the framework of the project the partnership proceeds with the development of wearable technology, a series of "artefacts", called **axions**, which allow students to conduct sophisticated experiments and which, in many cases, involve data collection over extended periods of time. The axions embedded in toys or in clothes are used in order to collect data during students' activities. Important factors of their design are ergonomics and economy, so they will not stay on a test bench nor used by a small number of users. The data collected by the axions are presented with the use of advanced programming tools compatible with graphing and analysis software components so that students can easily investigate trends and patterns and correlate them with the theory taught at school.

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of the project consists of the following institutions: National Technical University of Athens, University of Dortmund, University of Birmingham, Ellinogermaniki Agogi, ANCO S.A and a network of 5 schools (Austria, Germany, Greece and Italy).

3. TECHNOLOGICAL INNOVATION

The trend of technology calls for smaller and smaller gadgets up to the point of the "disappearing computer", an ultimate goal of the proposed project that will build in ordinary items sensors and other measuring instruments and "disappear" them into clothes, toys and artefacts thus creating the "intelligent clothes" and "intelligent toys" all connected with a small wearable computer. By definition wearable computers will be used in environments, which differ dramatically from the normal domains of computer use. Wearable computers represent a new and exciting area for technology development, with a host of issues relating to display; power and processing design still to be resolved. Wearable computers also present a new challenge to the field of ergonomics; not only is the technology distinct, but with the manner in which the technology is to be used since the relationship between the user and computer has changed in a dramatic fashion.

Within the light of the above in Lab of Tomorrow, new wearable and embedded computer based technologies have been developed in order to foster the design of the new science laboratory of the school of tomorrow. Artefacts like a ball (Figure 2) that has a 3D accelerometer embedded represent innovative technological development of the project. A T-shirt (called sensvest) with several wearable sensors (Figure 2) is another state of the art educational toy.

The sensvest has embedded a heart pulse meter, a temperature sensor, a body accelerometer and an arm accelerometer some interconnected with embedded wiring and others wirelessly to a data local storage and communication board. All sensors can be used for the qualitative and quantitative study of several activities like walking, running, jumping or measuring the step rate for extended periods of time. In addition the senvest consists of a leg accelerometer module capable of measuring both the acceleration and the step rate of the leg for extended time periods. Leg acceleration data again transmitted wirelessly to the base station and the pc can be presented with information and data of the other toys in order to perform even more complicated experimental studies. As an example we can refer to the correlation of the acceleration data recorded by the axion ball and the leg accelerometer module aiming at comparing the forces exerted to the leg and the ball during a kick and thus used for studying the third Newton's law.

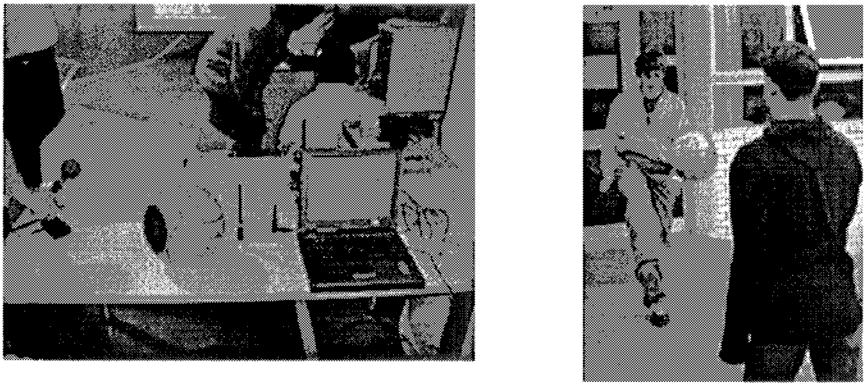

Figure 2. The axion ball shown on the table left transmits data wirelessly to the base station next to it. In the picture at the right the student wearing the sensvest kicks the ball.

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Finally a system called LPS (Local Positioning System) based on two CCD cameras is used for the location of 3D coordinates in space of selected objects with high accuracy. The two CCD cameras are situated in two orthogonal planes in space. The information deriving from the recorded images of the cameras combined with simple geometrical arguments (Figure 3) is used to calculate the position of the objects in space with a few centimetres accuracy. The LPS system can be used only inside the classroom as it is since the illumination conditions have to be controllable. Too much or too less sunlight might cause problems to the quality of the camera frame records.

A specialized software utilizes the information of the cameras and based on simple geometrical arguments allows for the determination of the three dimensional coordinates of selected objects. The data collected are synchronized, presented and analyzed with the use of a specially designed User Interface based on the concrete needs of the Lab of Tomorrow advanced teaching and learning "toys" and tools. Figure 3 illustrates two characteristic pictures that give a characteristic impression of the User Interface.

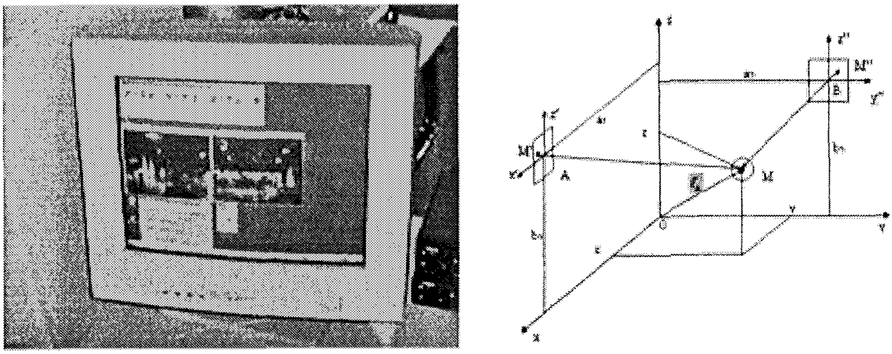

Figure 3. The LPS system is based on the combined use of the visual information of two CCD cameras that are situated in perpendicular planes.

The User Interface as the core node tool for an effective pedagogical use of the Lab of tomorrow systems is a very user friendly environment, easy to use even by novices and allows for many different ways of data representation and analysis. Students through a sequence of steps involving, data accessing, plotting data on a graph, creating a mathematical model to fit the data and relate the graph with the motions of the axions provided by the user-interface, gain deeper understanding of the phenomena. Moreover the user can easily export selected experimental data to other programmes like MS Excel or other specialized software for mathematical representation and analysis.

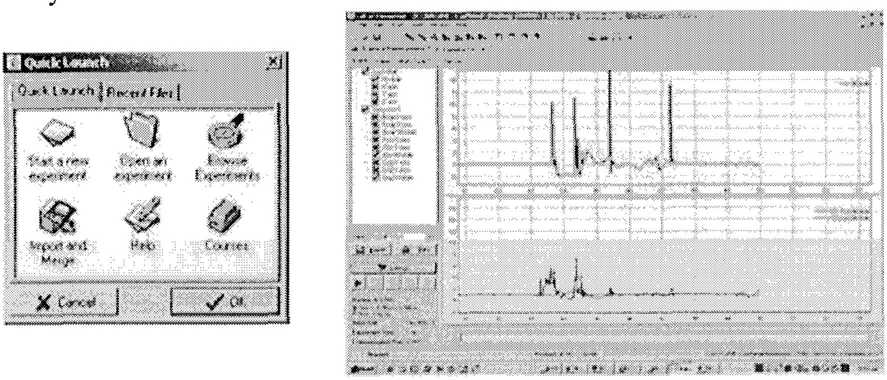

Figure 4. Aspects of the Lab of Tomorrow User Interface

4. IMPLEMENTATION

Within the framework of the project, a user scenario-based design methodology is used as a means of defining suitable applications of wearable technology. A series of lesson-plans (scenarios) has been developed. The lesson plans cover a wide spectrum of experimental activities and theoretical issues. Free fall, vertical throw, action and reaction or conservation of momentum experiments can be easily conducted with Lab of Tomorrow equipment. These lessons are implemented in the science curriculum of the participating schools[3] during the cycles of the school-centered work. The aim is to familiarize students and teachers with the new approach and toys as well as investigate possible qualitative upgrade of science teaching comparing with the conventional classroom lesson. The first school centered cycle was aiming at introducing students to the ideas and concepts of experimenting science lessons with Lab of Tomorrow. Moreover, during this cycle the developed toys were tested and evaluated in the different environments of the participating school and thus this cycle used to be called the test run phase. The conclusions derived by this phase formed the basis for the redesign of the axions and the determination of the implementation parameters for the successful application of the project's approach during the final run phases. The test run phase is followed by two other school centered working cycles, the final run phase A and the final run phase B. Currently the two final run phases of the project are in progress. In these two phases the new approach in science teaching is being systematically implemented and evaluated. To assure maximal usability of the new tools, optimal adaptation to the local environments and realistic evaluation of the pedagogical effects, the Lab of Tomorrow project utilizes a student-center approach that is expressed fully in final run phase B.

The final run phase A is based on the implementation of specially designed experimental lesson plans that are in accordance with schools' national educational curricula (Figure 5). The figures present aspects of the experimental and analysis activities during the "Horizontal Throw" experiment. The aim was to conduct experimental activities that were more or less included in the analytical programme of the schools but using the Lab of Tomorrow equipment instead. For instance students made the Free fall experiment with the use of both the axion ball and LPS system and analysed the data with the use of LOT User Interface. For the first time they had the chance, by viewing the data coming from the sensors embedded in the ball,

[3] The pilot implementation school sites that are included in the partnership of the Lab of Tomorrow project are 5 secondary schools from Germany (Phoenix Gymnasium and Helene Lange Gymnasium both in Dortmund, BG & BRG Schwechat in Austria, Technical School of Pininfarina and Ellinogermaniki Agogi in Athens)

to "feel" what the ball "feels" when free falling. For the first time the students had the chance to investigate, in the three dimensions, the motion of the ball by analysing frame by frame the camera recordings of the LPS system. In this way the students have the opportunity to perform in depth study of motion and verify experimentally the theoretical mathematical and physical predictions presented in the school book. The use of LOT systems provide opportunities for insight study of many theoretical issues in physics and expand the capabilities of the science school laboratory much beyond its conventional limits.

This implementation of both phases A and B, is systematically monitored for evaluation purposes so as for the teachers to be able to record possible qualitative upgrade of their teaching performance and effectiveness.

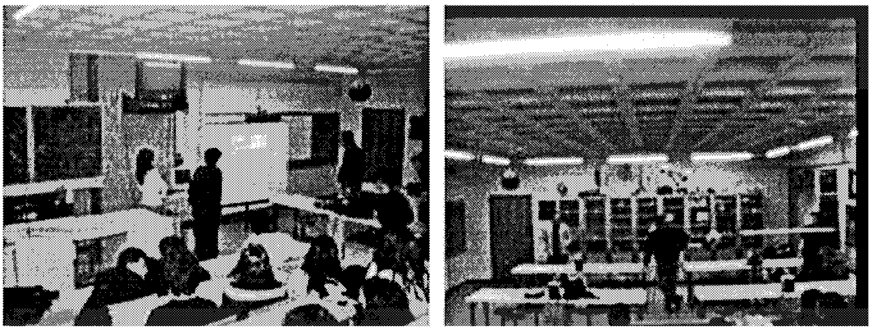

Figure 5. In final run phase A, students follow specific lesson plans based on the national curricula.

At the third school centered implementation cycle, the final run phase B, the students and teachers (having been used with the idea that scientific investigation is a process in which they can take part, day-to-day, creatively and pleasurably) have the opportunity to design their own scenarios for exploring phenomena of their everyday lives. The constructivist approach on Science teaching and learning becomes a reality and the students are taking an insight look of the connection of physics and science laws with their physical environment. These new experimentation ideas of the students will provide input for the development of new artifacts and the improvement of the Lab of Tomorrow prototypes.

5. EVALUATION

The evaluation of the proposed didactic was initiated at the two last cycles of school centered work, namely the final run phases A and B respectively. The evaluation of the project is evolving in parallel with the final run phases and it is performed on three aspects: evaluation of student's learning, evaluation of the underlying pedagogical framework and ethnographical evaluation.

- **Evaluation of the student's learning.** In assessing student's learning, student's engagement in science as inquiry will be primarily examined. It is believed that the activity of designing projects and experiments provides a powerful way for students to become meaningfully involved in scientific inquiry. In this way the dimension of self-expression will be introduced, something that is often missing in science education. Prompting students to see all sorts of daily activities, as possible subjects of both formal and informal scientific investigation will increase their motivation. Furthermore, this helps students on developing critical capacity and deeper understanding of the scientific concepts underlying the investigation. Finally students gain firsthand experience in the ways that technology can both serve and inspire scientific investigation.

- **Evaluation of the pedagogical framework.** The major theoretical issue underlying the Lab of Tomorrow project is whether the implementation of the emerging technologies (e.g. wearables) could offer a qualitative upgrade to the science teaching at the high school level. In such a case the introduction of technology would not act as a substitute of the conventional teaching but rather as an add-on that has to justify its introduction through the qualitative upgrade it offers to everyday school practice.

- **Ethnographic evaluation.** The project will take advantage of the different school environments across Europe and will study the attitudes of students and teachers with different cultures towards the implementation of IST in education as well as the attitudes between students themselves coming from different countries.

The evaluation design for the Lab of Tomorrow project's implementation in schools is organized as a semi-experimental. The main assessment tool is the "Third International Mathematics and Science Study" (TIMSS). For the Lab of Tomorrow project's evaluation scopes, performance and background tests in several grades are used. Both tests are suitable for the Lab of Tomorrow project's implementation, because their contents match with the content of the curricular of the participating countries and the content of the project. Secondly, Mathematics and Science items and test booklets are used for evaluation. These assessment tools have approved scales describing students' performance and they are available in different languages. The experimental group consists of the Lab of Tomorrow classes in the participating schools while the control group is build up by classes that are taught in traditional way, but on the same topics as the experimental group.

6. CONCLUSIONS AND FUTURE ACTIVITIES

Currently the project is about to complete its implementation phases (May 2004) and a six month evaluation and analysis period will follow. So far, the evidence of implementation in schools is very encouraging. Students are very positive with the new approach and Lab of Tomorrow project gives the opportunity for students to easily investigate a lot of new concepts experimentally with high accuracy and above all in a more experiential manner. New educational and technological aspects are investigated and put together in an open and exploratory fashion, encouraging educational innovations, within this project.

Within the framework of the project the educational and technological aspects are investigated and worked on together in an open and exploratory fashion, encouraging innovation. The new ideas, concepts and technologies are tested and evaluated in relation to real school environments. In Lab of Tomorrow project students and teachers will come together with researchers, psychologists, designers and technologists to re-engineer the lab of the school of tomorrow. The aim is to help both teachers and students reach beyond "cliches" to the areas in which they can make the most valuable contributions, and potentially increase their role on the world stage afterwards.

REFERENCES

Papert, S. (1994). *The Children's Machine.* New York: Basic Books

Resnick, M. (1993). *Behavior Construction Kits. Communications of the ACM,* 36 (7): 64-71.

Glasersfeld, E. v. (1995). *Radical Constructivism, A Way of Knowing and Learning,* Washington, Farmer Press.

Duit, R. (1995). *Zur Rolle der konstruktivistischen Sichtweise in der naturwissenschaftlichen Lehr-undLernforschung.* Zeitschrift für Pädagogik, 41(6), 905-923.

Nachtigall, D. (1992). *Was lernen die Schuler im Physikerunterricht?* Physikalische Batter. Vol.48, No.3, pp.169-173

Nachtigall, D. (1992). *Physikdidaktik im Aus-und Inland.* Vortrage Physikertagung 1992, Deutsche Physikalishe Gesellschaft, Fachverband Didaktik der Physik, Berlin, pp.8-33.