Designing the Science Laboratory for the School of Tomorrow
Artwork:

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Preface

The move away from the traditional classroom is influenced by a number of recent developments outside the call for education reform such as new developments in telecommunications, increased use of the Internet, proliferation of affordable hardware and software, and growing acknowledgement among policy makers that proper use of technology has the potential to improve teaching and learning. A variety of excellent programs are in operation, which demonstrate that technology-rich schools result in richer classroom content, higher student achievement, lower dropout rates and improved attitude and enthusiasm for learning. However, sustained support and long-term investment make it difficult to point to one model as the classroom of tomorrow. Nor should we, since each model serves its local needs and individual student requirements.

How, then, do we define the “classroom of tomorrow?” Is it measured by the variety and availability of technological tools? Is it dependent on the learning opportunities outside the school environment?

Powerful new technologies promise to transform education and training in ways previously unimaginable. Rapid advancements in educational technologies in the years ahead could enable new learning environments using simulations, visualizations, immersive environments, game playing, intelligent tutors and avatars, reusable building blocks of content, address distributed communities of learners, and many more.

There are many challenges in the process of educational innovation that must be addressed in order to take advantage of these technologies to improve learning. Advanced technologies developed to meet other purposes must be translated into affordable tools for learners to use. Technical standards must be deployed to help guide the development of educational content that will be drawn from countless sources throughout the world. The technology community has to form stronger partnerships with the educational community. The educational institutions need to prepare for rapid technological change.

In the not so distant past, content filled our books and TV screens and echoed from vinyl discs and radios. Today we can get much of the same from the Internet. The advances in technology which have brought about this change have had wide-ranging impact. Technological advance has enabled perfect, inexpensive and unlimited replication of content. It allows the instant delivery of any form
of content to individual users, and seamlessly across borders. It has led to a proliferation of new media and has fuelled the development of new content products such as electronic games, learning applications, search engines and filters for unwanted content.

With this continued innovation have come not just opportunities, but also technical, organisational and regulatory challenges. They touch our content industry and content-holding public sector, individual citizens and businesses alike.

In this framework, the conference aims to bring together individuals and teams from a wide range of technology and education fields to look into the future and to share their visions as to what the learning experiences and educational technologies could be like. A rich collection of examples of futuristic scenarios and visions will be presented and discussed in detail. These will offer a glimpse of a future in which learners could explore worlds and cultures beyond their own, both in distance and time, as if they were there. And they will serve to remind us that we must strive to apply the power of technology in ways that empower people, enlighten the mind and enrich our lives.

The Editors
Research and development in science communication: the source for renewing our science centres

Asger Høeg
Executive Director of Experimentarium
President of ECSITE

The vehicle for renewing museums is research into their collections

A museum has five obligations: to collect, register, preserve, research and communicate. Normally science museums have very large collections and these collections give inspiration to research. This research gives insight into new knowledge that in turn inspires new exhibitions. This is the renewal process in a museum. A new artefact implies new research, which gives new stories to tell to the visitors. In this way, museums have an unlimited source of new exhibitions for their visitors.

What is the vehicle for renewing science centres?

I have often claimed that it is much easier to be Director of a science centre than to be a museum Director, since science centres must ‘only’ communicate science and technology. We do not have the ‘problems’ of collections. But with no collection, where is the source for renewing our science centres? Since the opening in 1991, now (as I write in November 2004) Experimentarium has welcomed 4.8 million visitors. In 2003 we received 338,000 visitors of which 72% had visited Experimentarium at least once before. The need for innovation is obvious.

Two reasons for running a science centre

As I see it, there are two reasons for running a science centre. One is that the centre is a useful resource for the educational sector in the country. In our science centres we offer informal and formal learning to school children. And we inspire the
teachers to improve their teaching. The other reason for running a science centre is to support the lifelong learning of the adults visitors. In both cases you need to innovate - you need to develop new exhibits, new exhibitions, new educational material, new programmes and new methods of interaction between the visitor and the exhibition.

*Asger Høeg in the role of science demonstrator, at the 2004 Directors’ Forum*

**Research and development in new ways of communicating science**

What we need in the world of science centres is a coordinated international research and development programme, for innovating new science communication tools and methods. This research and development programme will be the mechanism for renewing our science centres.

**In what areas could research and development in science communication be conducted?**

First of all, we need much more research into: what is the reaction of visitors interacting with an exhibit? Which exhibits appeal to visitors in general? Which exhibits appeal to younger visitors and which to older visitors? Which exhibits achieve the communication intended? And which do not? Secondly, we need to develop new educational material that can support the teacher and the pupil when experimenting with the exhibits. How do we introduce the Internet as a helpful tool in the communication between the visitor and the exhibition? How do we combine exhibits, written educational material, a website closely connected to the exhibition and some tasks to challenge the visitors? And what is the optimal role of the pilots (‘explainers’, ‘guides’, ‘hosts’, whatever)? Thirdly, we need to develop new types of interactivity. I introduced the concept of The Intelligent Exhibition
some years ago in the ECSITE Newsletter, Food for Thought. How do we develop a growing interactivity between the interested visitor and the exhibition? The mode of conversation would be the web page on the Internet and the cell phone. Another kind of interactivity that will gradually grow during the next five years, I think, is the use of Virtual Reality when you want to let the visitor experience science and technology.

A joint EU and ECSITE research and development programme?

Science communication is today more important than ever. The Lisbon Declaration in 2000, stated that Europe should be the most innovative region in the World. The need for attracting the younger generation towards science and technology is more crucial today than 10 years ago and a must if the Lisbon Declaration is to be fulfilled. Therefore, Europe needs better tools for science communication. The younger generation is sitting on the top of the Pyramid of Maslow and their primary task in life is to realise themselves. We must develop tools of science communication that meet the younger generation in their self-realisation process. This is only feasible if the EU and ECSITE join together in a research and development programme concerning best practices in exhibits, exhibitions, educational materials, new types of interactivity, etc.

250 science centres, each with their own research and development department

I have a dream of a science centre for every 2.5 million people in Europe. This will give us approx 250 science centres. Each science centre should have its own research and development department. Research and development in science communication deals with hands-on exhibits, educational material (on paper and the net), e-learning programs, learning-by-teaching activities, virtual reality, videos, video games, competitions, etc. etc. The 250 science centres innovate - they develop new methods of best practice in science communication all over Europe. Although European diversity is a bit problematic in daily life (how many languages do our 25 countries speak?!), this very diversity will be the guarantee of a very fertile research and development climate. The goal is that the 250 European science centres should exchange ideas, information, and expertise concerning their newly developed temporary exhibitions, programmes, educational material, etc. In this way, science communication in Europe will prosper to the benefit of science and technology and - finally - to the benefit of Europe’s future wealth!
Fostering Tomorrow’s Learning Society

Lynn D. Dierking, Ph.D.
Institute for Learning Innovation
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“Whether in school, at work or engaged in free-choice learning, the purpose of education is to connect personally with the learner in order to meet and facilitate his/her lifelong learning needs.”

J.H. Falk & L.D. Dierking
Lessons without Limit
AltaMira Press, 2002

There is a quiet revolution going on in education worldwide. Societies are rapidly becoming nations of life-long learners supported by a vast infrastructure of learning organizations. The Learning Society in which we live now offers learning opportunities 24 – 7 – 52 – 80+. Learning is rapidly becoming a number one industry and leisure activity globally. As evidence one can look at tourism, the largest industry worldwide. The fastest areas of growth within this industry include eco- and cultural tourism. People are seeking value-added learning experiences even on holiday!

In fact, the centers of this learning revolution are not the traditional educational establishment of schools and universities, but are two emerging learning sectors not typically recognized and appreciated. One is the workplace sector, increasingly engaged in education and training and the other is a vast network of organizations and media (museums, libraries, television, film, books, and increasingly the Internet) which support the public’s ever-growing demand for free-choice learning, learning guided by a person’s needs and interests (Dierking & Falk, 1998; Dierking & Falk, 2001; Falk & Dierking, in production). Depending on a person’s age, interests and abilities, he/she accesses the resources of these three learning sectors at different points in his/her life.

Science and technology learning is an important part of this educational shift. People engage in such learning every day, across their life spans—at home, at work and out in the world. For example, in the U.S. less than 1% of a person’s entire life is spent participating in formal instruction and even children spend 91% of
their waking hours outside of school. In Europe the numbers may be different, but I would venture that formal schooling still represents a significantly smaller proportion of learning time than typically thought.

In the 21st Century, free-choice learning institutions such as museums, the Internet and broadcast media, and the workplace are assuming an ever more prominent role in providing the public with science learning opportunities. All of these represent important, in fact I would suggest, essential ways that we learn and most importantly, contextualize our science knowledge and understanding throughout our lifetimes. If as science educators in the 21st Century we truly want to move beyond the rhetoric of supporting lifelong science learning, it is critical that we recognize, understand and learn how to facilitate workplace learning and free-choice learning as powerful vehicles for lifelong learning. Not as a nicety, or a supplement to the science learning engaged in at school and the university, but as equally essential components of lifelong science learning. To not understand and embrace these institutions as valuable players in the science education infrastructure of a community is to seriously impede our ability to enhance science learning worldwide.

My colleagues and I at the Institute for Learning Innovation, a research institute based in Annapolis, MD, USA, with a mission of understanding, facilitating and advocating for a broader notion of learning that includes workplace and free-choice learning, believe there is a unique opportunity to be leaders in expanding notions of learning, as well as agents of change for future generations, introducing innovative models of science learning to individuals, groups and society across people’s lifetimes. How can the field of science education play a leadership role in 21st Century lifelong science and technology learning? This paper will focus on the three following objectives:

1) Describe the roles that the three learning sectors can play in supporting lifelong science and technology learning;

2) Discuss two free-choice learning efforts in more detail which provide evidence and support for the role (and potential roles) that free-choice learning plays in supporting lifelong science and technology learning;

3) Describe a new effort within the Science & Mathematics Education Department of Oregon State University to create a new vision for preparing the next generation of science and mathematics learning leaders, whether they are classroom teachers, college professors, free-choice learning or workplace educators; and,

4) Encourage you to play an advocacy role within the science and technology education community with fellow educators and researchers, and most importantly, with administrators and politicians, by more clearly identifying and describing the vast number of ways and places in which people of all ages learn science.
The Three Learning Sectors

Lifelong learning, long a utopian educational goal of societies globally, is increasingly becoming not just a necessity, but a way of life. As societies become increasingly inundated with information, each individual is finding it necessary to develop better strategies with which to analyze increasing quantities of information in order to select that of high quality and broad utility. The new knowledge economy is being constructed with ideas, and creating these new ideas, let alone keeping up with all of them, is a challenging task. It takes information and experience to generate a new and innovative idea. The best route to new information, more refined knowledge, and relevant cutting edge experience is learning. Creating an innovative idea, above all, requires openness to new information and a commitment to learning all the time. Let’s look at the contribution of each of the learning sectors.

School & University Learning Sector

This broader notion of learning does not suggest that schooling is bad or unnecessary. In fact if anything it points to its importance. The School & University Learning Sector has always been and will remain the centerpiece of most societies’ educational efforts. Schooling provides a foundation for the development of basic skills and introduces students to new knowledge. Higher education (universities, trade schools, etc.) offers opportunities for specialization in a field of the student’s choosing. However, schooling though important, is not sufficient to meet today’s needs for lifelong learning. We have developed a bad habit of assuming that learning is only that thing we do in school. Now, as well as historically, most people acquire much of the knowledge, understanding and information they require for their daily lives outside of school.

Workplace Learning Sector

The Workplace Learning Sector is a neglected sector within the lifelong learning landscape, yet increasingly it is a major educator, investing large sums in training, remediation and re-training. In this sector we learn skills necessary to do productive work and earn income to sustain our lives. As workplaces automate and embrace new technologies, the ability to learn and adapt to new situations is crucial. In fact, employers no longer can predict the skill sets they will need in their work force even 3-5 years from now so consequently they seek staffs who are adaptable and able to learn new skills.

Free-Choice Learning Sector

As previously defined, the Free-Choice Learning Sector supports learning that is guided by the needs and interests of the learner(s), a type of learning we engage in throughout our lives. Children and adults are spending more and more of their time learning, not just in classrooms or on the job, but through free-choice learning at home, after work and on weekends. We engage in free-choice learning to explore what is useful, compelling or just plain interesting to us. All around the world, societies are witnessing a virtual explosion in opportunities for free-choice learning. From the birth of the Internet to the proliferation of educational
programming offered by IMAX, educational television, and museums, there are more opportunities for self-directed learning than ever before, much of this is science, technology and health-related. In a typical day, a person might surf the Internet in a local library to track down information about arthritis, attend an amateur astronomy club meeting, watch a nature documentary on television or interact with exhibitions on robotics at the local science center. All of these events are free-choice learning experiences, the most common type of learning in which we engage throughout our lives.

As we have suggested, as world societies transition from being industrial to knowledge-based, learning across the lifespan becomes ever more important. There is no single right way to learn things, and no single place or even moment in which we learn. All of our learning happens continuously, from many different sources, and in many different ways. Despite this fact though, currently there is unequal recognition, use and support of these three learning sectors by citizens of all ages. This is not intended as a condemnation of school-based learning. The point is merely to emphasize the fundamental role played by non-school-based learning. Each of the three learning sectors significantly contributes to the science and technology learning of the public. The science and technology learning journey of 21st Century citizens requires many way stations, each helping to fulfill part of the citizen’s learning needs. What science and technology educators in all three sectors need to appreciate and tap into is this rich, broadly supported educational infrastructure, a system of support that enables millions of unique individuals to meet their widely varying science and technology learning needs any time of the day, at any point in their life. This basic learning infrastructure (St. John & Perry, 1994) already exists, composed of schools and universities, the Internet, print and broadcast media, libraries, community-based organizations, the workplace, and friends and family. Ideally all of these educational entities work together to support and sustain science learning across the life span (Johnston, 1999).

![Diagram of Educational Infrastructure](image-url)
The science and technology learning infrastructure serves as a web of influence that shapes people’s understanding, attitudes, aesthetic beliefs, etc., for although schools and universities are important, so is the workplace and museums and science-technology centers, electronic media, increasingly the Internet, as well as community-based organizations, libraries and a whole host of others. The entire science and technology educational infrastructure provides value and support to any nation, and the entire infrastructure needs to be valued and supported.

The implication of this idea is that we look for science and technology teaching and learning in novel places. For example, we are currently working with the Astronomical Society of the Pacific, based in San Francisco, CA. With our assistance, over the last 13 years they have been exploring and experimenting with ways to tap into the vast resource of amateur astronomers. With funding from the National Science Foundation, they have involved these astronomers in supporting elementary and middle school teaching in classrooms through Project ASTRO, then through Family ASTRO, they provided fun and engaging astronomy experiences to families through a network of museums, science-technology organizations and community-based organizations such as scouts. They are now disseminating this model nationally and training staffs of small museums and science-technology centers to facilitate it. This effort represents a creative way of brokering connections within the science & technology education infrastructure.

Evidence Supporting the Importance of Free-Choice Learning

Sources of Information Some of you reading this paper may not believe this is true, but take a moment to do a thought experiment. Think of five topics that you know something about, any five topics. How did you come to know something about those topics? Where did you first begin to learn about them? Why did you learn about them? How do you stay current in that topic? If you are like most people, at least one of the topics you picked was related to your work. Hence, much of what you know about the topic you learned as part of “on-the-job” training. But, what about the others?

Institute research would suggest that the majority of the topics you listed represent a range of subjects relating to personal and avocation interests. Some of these may be topics traditionally taught in school, but many are not. Your interest in these various topics was likely developed early in life, maybe initially from friends or perhaps your family. Although you may have even gained some basic information about some of these topics in school, over time, because of your interest in the topics, you maintained and extended your knowledge by reading articles in magazines and newspapers. You also probably watched television shows on these topics, continued to talk to friends and family, perhaps even checked out a book or two from the library or visited a museum somewhere along the way. Of course you may be saying that I learned about my hobbies such as cooking or vintage movies outside of school. But the real substantive knowledge I possess, knowledge of
history, literature and science, I most certainly acquired in school. But is that really the case? In the United States, ever since Sputnik, billions of dollars have been poured into schools to enhance the quantity and quality of science and technology education. These are subjects taught in every school in America, not once, but repeatedly from elementary through high school and college. However, on national tests of science and technology knowledge most adult Americans fare poorly (Miller & Pifer, 1996). Only those with college level courses in science do well on these tests. Of course what should we expect, the questions asked on these tests are typically college level multiple choice questions; many drawn straight from university textbooks. Does every American really need to know how a laser works or be able to define radiation in order to be a productive, informed and competent citizen? I do not think so. However, given the importance of science and technology in modern life, should every American know something about these topics? Of course, the answer is yes.

John Falk and colleagues at the Institute launched an investigation to help determine how, when, where and why people learn science (Falk & Coulson, 2000; Falk, 2001). To do this they conducted two large scale strategically sampled telephone surveys. In each study, they randomly called hundreds of Los Angeles, California residents (close to two thousand in all) in five representative communities in the Los Angeles area and asked them questions about their science and technology knowledge. These were average folks--some were poor, some were affluent, some had graduate degrees, some had not completed high school. Represented were young and old individuals of virtually every imaginable race, ethnicity and background. They asked these people if they were interested in science and technology--overwhelmingly they said they were. Interest in science and technology seemed to be universal, true of virtually all individuals, regardless of education, race, ethnicity or gender. They asked them if they felt they were knowledgeable in science and technology--by and large they thought they were “sort of knowledgeable.” Then they asked each person to describe some area of science and/or technology in which they felt they knew more than the average person, in other words an area of working science/technology knowledge. They also asked people to tell them why they had that greater than average knowledge in this area of science and technology and from what source they acquired the knowledge.

Virtually everyone in the sample felt that there was at least one area of science and technology they had some reasonable knowledge of, a knowledge that exceeded the norm. The areas described ranged from astronomy to zoology. Some people described very specific areas of scientific knowledge such as the physics of the internal combustion engine or the physiological basis of depression; others gave more general categories of knowledge such as health or the environment. Most people claimed that the motivation behind their knowledge was simply interest and curiosity, although occasionally the motivation to learn about a topic was a personal crisis such as the need to learn about the disease of an ill relative. Professional and work-related reasons were also commonly given. Across the board, though, at some point in each individual’s life, something about the science and/or technology topic they claimed a special knowledge of had piqued their curiosity. And it was this curiosity for the subject, which had primarily prompted
them to continue pursuing greater knowledge and understanding of the subject. Most fascinating of all were the sources of working science and technology knowledge that the public identified. Table 1 presents these results. As one can see, roughly a third of the people surveyed claimed to have primarily learned their favored science topic in school. Just under a quarter of the sample said they learned their science on the job, as part of their work. However the majority of people, approximately half of those surveyed, claimed to have learned about the science and/or technology topic through some kind of free-choice learning experience during their leisure time.

<table>
<thead>
<tr>
<th>Source</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Free-Choice Learning</td>
<td>43%</td>
</tr>
<tr>
<td>School (or other formal institution)</td>
<td>34%</td>
</tr>
<tr>
<td>Workplace</td>
<td>23%</td>
</tr>
</tbody>
</table>

*Table 1. General Sources of Information: Working Science Knowledge*

Table 2 shows specific sources of working science knowledge. People described learning science and technology from the Internet, reading magazines and books, going to museums, zoos and aquariums, and participating in special-interest clubs and groups. Although schooling was an important source of scientific learning for some, it was not the primary source for most.

<table>
<thead>
<tr>
<th>Source</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Books, magazines, not for school</td>
<td>76%</td>
</tr>
<tr>
<td>Life experiences</td>
<td>74%</td>
</tr>
<tr>
<td>Television</td>
<td>74%</td>
</tr>
<tr>
<td>School courses</td>
<td>68%</td>
</tr>
<tr>
<td>Museums, zoos &amp; aquariums</td>
<td>65%</td>
</tr>
<tr>
<td>On the job</td>
<td>57%</td>
</tr>
<tr>
<td>Family and friends</td>
<td>55%</td>
</tr>
<tr>
<td>Radio</td>
<td>31%</td>
</tr>
<tr>
<td>Internet</td>
<td>10%*</td>
</tr>
</tbody>
</table>

*Table 2. Specific Sources of Information: Working Science Knowledge*

* 3% in 1997; 10% in 2000; 17% in 2004*
A study by the National Science Board supports these findings (Miller, 2001). Researchers found that 50% of American adults read a daily newspaper including articles on science and technology, 15% read one or more science magazines each month and a majority of Americans watched one or more science television shows each month. Approximately two-thirds of adults visited a science center or natural history museum at least once a year and a third of Americans reported that they had purchased one or more books on science and/or technology topics during the preceding year. These studies lend tremendous support to the important role non-school sources play in sustaining lifelong learning in general and science and technology learning in particular. The data would suggest that even a traditional school subject such as science, is not exclusively, or even primarily, learned in school. Similar investigations have been conducted to determine where the public learns history. And similar to these studies of science learning, it was found that the majority of Americans attributed their knowledge and understanding of history to free-choice learning sources such as family members and television, not to school or university.

Long-Term Impact
Identifying the sources of science information is one way of demonstrating the importance of free-choice learning, but ultimately it is critical to understand the impact such experiences have on learners and the ways in which these experiences connect to other experiences: in school, on the job and to other free-choice learning experiences. One of the challenges in the area of free-choice learning is meaningfully documenting the impacts of such efforts, both short term outcomes and particularly long-term impact. For example, over the last 11 years, the U.S. National Science Foundation, primarily but not exclusively through its Directorate for Education and Human Resources, has funded more than 250 projects focused on enhancing girls’ interest, engagement and understanding of science, for a total investment of $90 million. Despite this significant investment, the field knows very little about the strategic impact of these efforts; in part because the outcomes and impacts were conceptualized and measured differently, and often in ways not generalizable across projects (Darke, Clewell, & Sevo, 2002). Further, most of the projects were evaluated for program effectiveness during the grant period alone, and focused on short-term rather than long-term impacts on participants (i.e., 5-20 years after participation). Darke et al. (2002) reviewed efforts supported through NSF’s Program for Girls and Women across ten years and concluded that the collection of longitudinal data would make a significant contribution to understanding this arena of learning.

Currently I am collaborating on a 4-year NSF-funded study with a colleague, Dr. Dale McCreedy, Director, Gender & Family Learning Programs, Franklin Institute Science Museum (TFI) to do just that. The retrospective study is exploring the
role that informal science learning (e.g. museums, Girl Scouting, after school and outreach programs) plays in supporting girls’ long-term interest, engagement, and participation in science communities, hobbies, and careers. Project goals include:

1) Document long-term impacts and perceptions of ways such experiences influence future choices in education, careers, hobbies and habits of mind;
2) Determine ways free-choice contexts contribute to girls’ science learning and achievement; and,
3) Develop a model for understanding the impact of free-choice girl-focused science learning initiatives with broad application across informal programs.

The theoretical framework guiding the research is the Community of Practice (CoP) framework (Lave & Enger, 1991), which focuses on a domain of knowledge (in this case, science learning); the community of people engaged in its practice (i.e., girl and adult participants, as well as professional and amateur scientists and other facilitators of girls’ informal science learning); and the shared activities in which they are involved (e.g., hands-on science activities, kits, museum experiences, and other program components). This framework shows promise as a useful paradigm when trying to document the broad, strategic impact of a particular field of practice on participants and because it is an approach that respects the ideas and perspectives of the subjects themselves. Research findings will be disseminated through informal science and gender-based research and practice fields.

**Research Design**

The retrospective study includes four linked investigations:

- **Investigation #1 – Me & Science in my Own Words**
  - Identify past active and highly engaged participants from among alumni of five longstanding girl-focused programs
  - Conduct in-depth qualitative interviews \((n=10-15)\) & use findings to develop a web-based questionnaire to identify girls as passive, active and highly engaged participants

- **Investigation #2 – Expanding the Universe**
  - Administer web-based questionnaire to alumni of five longstanding girl-focused programs \((60-75\) young women/program) \n  - Utilize these data to identify girls as passive, active and highly engaged participants \((n=300-375)\)

- **Investigation #3 - Study of Active & Highly Engaged Participants**
  - Conduct life-history interviews, observations & interviews with adults significant to these young women’s lives \((10\) young women/program; \(n=50)\)
• Investigation #4 - Telling Their Stories & Validating Findings
  - Identify past active and highly engaged participants from among alumni of five longstanding girl-focused programs
  - Share findings with them via a questionnaire, focus groups & interviews to validate findings
  - Share findings with young women currently actively engaged/interested in science through education, career, hobby or habits of mind to validate findings

We are currently completing Investigation #1 and already are discovering the challenges of talking to young women about the role of science in their lives, even with extremely unobtrusive measures. However, we are also discovering indications that these experiences are important ones even for women who do not identify themselves as science-interested or engaged. One young woman talked about how early free-choice geology experiences helped her in an undergraduate course because she could “see” and contextualize the material she was reading. Another young woman said that early girl scouting experiences outdoors had helped her to enjoy camping and hiking, activities that she did not participate in with her family but now participates in as a 22-year old. We hope that the findings emerging from the full study will greatly enhance the free-choice learning field’s ability to discuss and advocate for its role in lifelong science and technology learning.

Creating a Vision for Preparing the Next Generation of Science & Technology Learning Leaders

Leadership in Reforming Science & Technology Teaching & Learning It is not enough to recognize a diverse learning infrastructure and to tinker around the edges; fundamental changes in how, when and where we think about science and technology learning requires bold leadership to change the current status quo. This is critically important to do and an essential place to begin is in the area of “teacher” preparation in science and technology education, the source of the next generation of science and technology learning leaders. Currently Dr. John Falk and I are sharing a full-time Full Professor position in the Science & Mathematics Education Department at Oregon State University, Corvallis, Oregon. Hired as faculty to develop a graduate area of concentration in free-choice science and mathematics learning, we are playing a larger role in helping to redefine the entire Science & Mathematics Department. The department has crafted a vision statement about their approach to the preparation of science and mathematics learning leaders that focuses on contribute to knowledge about science and mathematics learning across the lifespan, particularly the integration of schooling, workplace and free-choice learning practices. This program is just beginning this re-visioning exercise but it is exciting and overwhelming all at the same time. We are dealing with the myriad questions that plague any start-up programmatic effort at a university: 1) What should the curriculum for this program look like?
2) How will students be recruited into the program? 3) What should the criteria for Master’s and Ph.D.’s be? Despite these challenges, there is great excitement about the possibilities for innovation, both within the structure of these programs themselves, but also by the collaborative way this program is being conceived and conceptualized—the program itself represents an innovative collaboration between entities within the science and technology education infrastructure. However, unique times require unique solutions!

Advocating within the Science & Technology Education Community

As we begin a new millennium and live through the dawning of a new economic order based primarily on ideas rather than things, re-thinking and re-energizing our educational system seems only appropriate. Our future depends upon having a system that can be responsive to the needs of today and anticipate the demands of tomorrow. However, the new educational system of the 21st Century must be based upon a whole new concept of education, one that says: Learning is an essential part of every facet of society and individual citizen’s learning needs are supported every moment of the day, every day of their life.

The current educational infrastructure can be used as a starting point for this new system, but our fundamental approach to education needs to change; all parts of the current educational system must be fully used and integrated. Although our current formal education sector—pre-K through graduate school—is vital to any nation’s education, it is not, in and of itself sufficient. A successful American education system cannot be based solely upon schooling; it must include free-choice learning and workplace learning also.

So what can you do to participate in this exciting movement? First I would encourage those of you involved in the international science and technology education community to play an advocacy role for this important type of science learning. If you are involved internationally make sure that all parts of the science and technology education infrastructure are at the table as well. Invite fellow educators and researchers exploring work place and free-choice learning to participate in your international efforts. They have much to share and much to learn from you.

There is also much to do back in your own local communities. If you do not already know what is going on in the area of science and technology learning in other parts of the educational infrastructure, in your local community, find out. As you develop new efforts and sustain existing ones, ensure that all the science and technology education partners are involved.

Most importantly, we need to work together to educate administrators and politicians about this broader perspective of lifelong science learning. By more clearly identifying and describing the vast number of ways and places in which
people of all ages learn science and technology, we stand a much greater chance of transforming education and subsequent learning to meet the demands of a changing world.

References


The CONNECT Project: bridging science education activities at schools and science centers with the support of advanced technologies

S. Sotiriou, Ellinogermaniki Agogi

Abstract

The main objective of the CONNECT project is to develop an innovative pedagogical framework that attempts to blend formal and informal learning, proposing an educational reform to science teaching. The project creates a network of museums, science centers and schools across Europe to develop, apply and evaluate learning schemes by pointing to a future hybrid classroom that builds on the strengths of formal and informal strategies. The proposed approach explores the integration of physical and computational media for the design of interactive learning environments to support learning about scientific phenomena. The project implements an advanced learning environment, the Virtual Science Thematic Park, developed upon emerging technology that will allow for ubiquitous access to educational and scientific resources. The CONNECT project evolves through a systematic, multi-step assessment process involving the collection and

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1 The CONNECT project is co-financed by the European Community, within the framework of IST priority, 6th Framework Programme and the National Science Foundation (NSF), USA. The CONNECT consortium is composed by the following partners: Institute of Communication and Computer Systems (Greece), Fraunhofer Institute of Technology (Germany), INTRASOFT (Belgium), University of Duisburg Essen (Germany), Vaxjo University (Sweden), University of Bayreuth (Germany), University of Birmingham (UK), Ellinogermaniki Agogi (Greece), HEUREKA (Finland), @BRISTOL (UK), Eugenides Foundation (Greece), ECSITE (Belgium), Institute for Learning Innovation (USA), Weizman Institute of Science (Israel), Q-Plan S.A. (Greece), Ministerio da Educacao (Portugal), Universidade do Minho (Portugal).
The current paper presents the project’s focus and learning environment, reports the Swedish trials as well as a few wearability results from the Greek trials with the CONNECT technology.

**Introduction**

The CONNECT project proposes to create a learning environment that will link effective informal learning strategies with exemplary formal curricular activities in an attractive learning environment that utilizes cutting edge information and communication technologies in science education. It provides a framework for a closer and more effective collaboration between museums and schools. It has the real classroom as the point of reference. It is not pointing though to bring the museum at school but to connect the different educational environments, keeping alive their strengths. By describing and analysing the functionalities of the virtual thematic park and by creating operational terminology, the partnership aims to guide the design of future museum-school collaborations and to document efforts that seek to bring the worlds of formal and informal learning closer together.

The CONNECT project follows the contextual model of learning, which emphasises the importance of the learners’ contexts (i.e. personal, physical, and socio-cultural) when learning (Falk, 1999) and explicitly points out the role of free choice learning (Falk and Storksdieck, 2001; Dierking et al, 2003a,b). Within this approach, the design of specific pedagogical scenarios needs to be flexible enough to allow the integration of free choice learning. As such a certain degree of freedom is required when selecting the pedagogical question to focus on, within a science centre setting.

Of particular relevance are the pedagogical approaches employed to project- and problem-based learning, which focuses on a driving question or problem that the students focus on (Jonassen, 1999). Within this context, students should be able to perform scientific experiments and thus construct their own knowledge. To achieve such learning skills as self-regulation, the system has to be designed in a way that provides the appropriate level of flexibility to the learner.

Additionally, informal (free-choice) science learning environments (e.g., science museums, zoos and outdoor settings; science youth programs; science media) could be utilized to provide (1) a wide repertoire of instructional strategies for teachers to instruct learners in schools, as well as (2) a wide range of out of school environments which foster science learning. Opportunities of informal learning in science centres often give the students the possibility to explore a variety of interactive exhibits fostering their curiosity. Boards next to the exhibits, sometimes audio systems and computer monitors, show additional information that can foster students’ learning. Evidence from current research literature suggests that informal science experiences in school based field trips, casual visits to informal learning settings, etc. can be effectively used to advance science learning (Hofstein
The project brings together schools and science centres, and produces novel computer-based technologies such as augmented reality (AR) and web-based technology. Such interactive learning environments can better contextualize and support learning in school and in other settings where people learn (i.e. science centres and home). These environments allow students to visit science centres and perform experiments that are not possible in school. They can also build on these experiences back at school and at home through visual augmentations. Through these “connecting” partnerships, the learning benefits are maximized in ways difficult to afford by either schools or science centres alone, and they boost the potential of making significant contributions to the field of science education.

**The CONNECT technology**

An advanced learning environment has been developed, the CONNECT Virtual Science Thematic Park (VSTP), that incorporates all resources available in the CONNECT network of science parks, science museums and research centres. The VSTP is the entrypoint of information for interested teachers, educators and/or organizations. The system provides a fruitful environment for innovative use of educational technology and also interconnects the members of the network. In addition, the VSTP organizes the procedure of students’ both virtual and conventional visits to the science museums and thematic parks. These visits fulfill (through an informal but yet structured way) not only main pedagogical aims of the official curriculum but also estimate costs and efforts for museum staff and teachers as well as provide information regarding usability and wearability issues of the technology.

The VSTP includes two major components:

1. the CONNECT platform (CP) which facilitates pre-visit and post visit activities as well as the remote visits to the museums and science parks, and
2. the mobile AR system which the student will wear during his/her visit.

*Fig. 1 A version of the Virtual Science Thematic Park. It contains representations of the augmented exhibits that students could virtually visit from school. They could also ‘visit’ exhibits from other science centres and museums around Europe.*
The CP is a web-based application whose aim is twofold. It serves as a central hub distributing the resources available through the project, thus creating a network of science parks, science museums and research centers. It also distributes information and organizes educational activities; it coordinates teachers, students and museum staff in the use of the innovative technology. The CP supports the mobile’s AR system specifications and functionalities as well as materializes the VSTP’s requirements and procedures. It supports the management of educational pathways, the authoring tool (CONNECT Visual Designer, CVD), allows science museum and classroom communication and provides collaborative tools for teachers and students.

Fig. 2 In the preparatory phase teachers could use the CVD to create the visual augmentations (left). These augmentations can be presented in the AR view of the students when visiting the specific exhibit of the science centre (right).

Technological Approach and Technologies utilized
The CONNECT web-based applications (CP and CVD) utilize MS Internet Browser. Backend technologies include ASP (Active Server Page), PHP (Pre-hypertext Processor), XML (eXtended Markup Language), CSS (Cascading Style Sheets), MS FSO (File System Object) and Javascript. Repositories and Database utilize the Opensource MySQL Relational Database. Communication within the platform, and in specific between CVD (Authoring Interface) and the Mobile AR system are handled with a newly developed XML based language, MRIML (Mixed Reality Interface Markup Language).

Educational Pathways for CONNECT
An educational pathway refers to specific series of activities, undertaken by teachers and students, which illustrates what they could do to teach/learn a specific science topic in the CONNECT project. Educational pathways connect schools and science centres to promote quality learning for all students. In addition, they are valuable tools for lesson planning. Creating pathways to connect schools and science centres means identifying methods by which to embed a visit of a school class to a science centre. The pathway activities have been grouped in phases, each of which
supports the integration of the informal learning experience in the science centre into the formal learning situation of the classroom.

Within the school environment, students learning normally is organized on the basis of a more or less strict curriculum, separated into different subjects, taking place in a fixed time schedule. The teacher has to assess to what extent learning aims have been reached by his/her students. Student’s motivation is often influenced by this assessment extrinsically. Learning within a science center is often based on visitor’s curiosity and thus they are intrinsically motivated. Inspiring visualizations of phenomena can be discovered within a more authentic learning environment. A variety of interdisciplinary exhibits can be explored. Still, learning within a science center often remains shallow, only triggering curiosity often without supporting deeper experimentation.

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**Fig. 3 A graphical representation of the CONNECT educational pathways for supporting the link of schools with science centers through the use of AR and broadband technology.**

Within the CONNECT project, the strengths of both learning environments are combined by integrating field trips to science centers with school learning procedures. The CONNECT technology supports an optimal learning flow from the pre-visit activities in school to those when in the science center and those when back in school, by providing students with information, i.e. video and the data collected during their visit.

**Adjusting an educational pathway to specific learning needs**

Before an educational pathway can be initiated in a school class, a series of preparations are necessary by the educator. Therefore, in a preparatory phase, the teacher and the science centre staff have to perform specific tasks, i.e. administrate the visit, configure the platform, configure the visual AR augmentations according the school class’s needs.
Configuring the AR augmentations according to the school class’s needs is a crucial task from the teacher since it provides the opportunity to personalize the augmentations of the AR technology. During the students’ visit to the science centre, the AR system will blend virtual elements into the real students view and show them “at the right time”. The decision of when to show what virtual elements is made by the teacher or the museum educator. The virtual elements could be data about current exhibit state (e.g. displays, graphs), impulse for guidance (e.g. ‘Try to push this handle’), questions about phenomenon (e.g. ‘Why do the..’), related images, videos, audio.

The educators decide how to use this new possibility to enhance their students learning according to their age, pre knowledge etc. A teachers’ authoring tool has been built especially for this reason: The CONNECT Visual Designer (CVD). It enables the teacher to decide, when the system should show what content to the student at which position. To decide about when to show additional elements, the teacher can build conditions taking into account the students distance to the exhibit, his view position and orientation (what is the current view focus: E.g. he is looking exactly at the center of the aerofoil wing?), and specific variables describing the state of the exhibit (e.g. temperature measured in a balloon is higher than 120 degrees centigrade). Also the teacher can enable the student to decide by himself during the visit to observe additional elements by switching them on and off through the AR system. For example, the teacher can integrate a school book image used in the pre visit phase to the AR visualizations and provide an additional explanation on a phenomenon discovered while exploring an exhibit. The teacher can also define the image to be shown due to a specific state the exhibit (e.g. a wing turned around to a certain angle), and the place where it should be shown within the AR view.

**Educational Pathway phases**

A typical educational pathway has three phases: the pre-visit, the visit and the post-visit phase. The pre-visit phase is realized in the classroom. The students are preparing for their science centre visit, and inform themselves about the domain, the possible research areas and the according exhibits, and have to develop a research plan/questions.

The visit phase is taking place at the science centre (for the standard pathway) or the classroom (for the remote school visit pathway). The students are performing their experiments according to the research plan they developed in the pre-visit phase. The technology used during the visit (AR technology) will enhance their views by adding virtual objects, like 3D models of invisible phenomena, data displays and other.

The employment of interactive visualizations through the AR technology introduces flexibility into science learning. Each student-visitor can, through the fusion of synthetic and real-world artefacts, see new perspectives and views of physical phenomena and concepts. In this manner, students can better articulate their understanding and mental models about physical phenomena and concepts in science, while reflecting more effectively on these in the context of
experimental investigation. Furthermore, students can undergo such experiences in a collaborative fashion, a catalyst for an informal and interactive learning through enjoyment and entertainment.

Such interactive content helps the student to explain the phenomenon and perform the activities with the exhibit. The students can compare their experiences with the predictions made in the pre-visit phase. During the visit phase the students will produce data that can be used in the post-visit phase for working on their research plans. Data collected are videos recorded and tables of variable values can be stored on students demand. If allowed, the students can communicate with remote visitors and share their findings.

The post-visit phase is again located back in the classroom, where the students have to complete their research reports and possibly use additional simulation and visualization tools. In addition to the computational support by the platform they had in the pre-visit phase, now they have access to the experimental data produced during the visit phase. If they are unsure about a detail they can review the video recording that was automatically produced. Finally they will upload a research report to the platform.

The first trials in CONNECT

The project includes 3 extended phases of work: (a) the Test Runs, (b) the Final Run (Phase A), and (c) the Final Run (Phase B). During the Test Run, the technological tools will be initiated to different educational environments. During the Final Run (Phase A), the actors involved will be using the technology and learning content in science centers and museums. With the experience gained from the two first pilots and after the appropriate modifications on both the educational tools and on the educational pathways, the final and most important cycle of the user-centered work, will be implemented. The Final Run (Phase B) is where the implementation of the open educational pathways. In this phase teachers and museum staff will collaborate in order to create their own pathways and motivate their students. These phases are not only meant for evaluation purposes (technological and pedagogical) but involve teachers, students and museum educators to give direction to the project and its technological and pedagogical results.

The first trials of the CONNECT applications, the Test Run, had a three-month duration and students’, teachers’ and museum staff’s reactions to the proposed pedagogical approach and technology was monitored and is currently analyzed. The Educational Pathway included pre-visit activities in school, visit activities in the science centre or museum following the conventional field trips procedures and a few post-visit activities in the school environment.

Four exhibits in four different countries were augmented, each focusing on a different question. In particular, The Aerofoil from Explore-At-Bristol, Bristol, United Kindom focuses on the question “Why do planes fly?”, the Airtrack,
Eugenides Foundation, Athens, Greece focuses on the question “What stop things from moving?”, the Hot Air Balloon from Heureka, Vantaa, Finland focuses on the question “What keeps a balloon moving up and down?” and the Biotube, Xperiment Huset, Växjö, Sweden focuses on the question “Why do plans grow?”

There were pedagogical evaluating activities taking place at every stage of CONNECT intervention as well as usability and wearability assessment of the CONNECT mobile AR system at the end of the visit phase. The pedagogical evaluation activities were based on quantitative questionnaires based on knowledge acquisition, attitudes and motivation and qualitative data based on interviews, video analysis and our insights from conducting the trials.

The first attempt to use the CONNECT technology was fruitful and useful for gaining insights regarding enhancements of the educational pathway and the technology. Regarding the educational pathway, the preparatory phase was implemented by the CONNECT team instead the teachers. This means that teachers were not involved in designing the augmentations that students saw in the AR view. During the visit phase, each augmented exhibit was presented to a group of students while the rest of the class was occupied in visiting other exhibits. The post-visit phase at school was based on discussions held between the teachers and the students for their impressions and reflections of the visit. The focus of this test run was mainly the assessment of the CONNECT technology and the students responses to this innovative experience. The first results of the students’ thoughts of the Greek trials have been reported in Sotiriou et al. (2006).

The CONNECT trials in Sweden

This section describes the initial results of the CONNECT test run activities with the BioTube and the mobile AR system at Xperimenthuset (XH), a science center in Sweden. The Biotube is a freestanding vertically oriented plant growth system in which plants are encased in a Perspex tube (see middle panel of figure 4). The plants are cultivated hydroponically, which means they have no soil and all their nutrients are delivered dissolved within the water supply. The water is delivered via a pump and the BioTube has fans to control the temperature. A programmable device is in charge of controlling these processes (Jansen et al., 2004). Within this controlled environment, the conditions of light, humidity and temperature can be altered by the participants. The aim of this exhibit is to allow learners to explore and learn those aspects related to the photosynthesis process with specific respect to sustaining plant growth in outer space. In particular we are interested in letting students to investigate the effects of light on photosynthesis by measuring the change of CO₂ in the air. Thus, some of the important questions under investigation are: What are the parameters that influence plant growth? Why does the level of CO₂ change, when increasing or decreasing light intensity? How do the CO₂ gas particles change, when reducing the light intensity?
We are using CONNECT technology in order to allow students to get new insights while trying to understand the underlying phenomenon related to the photosynthesis process. Augmented Reality is a particular technological solution that allows mapping virtual objects onto real world objects. While seeing the Biotube through the AR system, students can for example see CO2 molecules moving around the tube while they are wearing AR glasses (see figure 4). When students look through these AR glasses the real plants of the BioTube exhibit become augmented through virtual menus, pictures and molecules, which the students can see on top of the Biotube (see figure 5). In the coming section we described the initial results of our trials with young learners using the Biotube and the mobile AR system.

![Fig. 4 Young learners interacting with the BioTube using the mobile AR system.](image)

The visits to the Xperimenthuset
Two 9th grade classes from Växjö local schools participated in the test runs that took place in November 2005. Totally, 44 students attended the test runs. From a total of 22 students that participated in the first day, 3 of them did not manage to use the AR (due to technical problems with the different components of the system). In the second day of the test run, all 22 students from the second class were able to try and successfully use the mobile AR system.

Implementing the CONNECT educational pathway
All classes conducted a pre-visit phase and also prepared the visit to the science center, according to the CONNECT educational pathway described earlier in the paper. During these activities, students were introduced to several concepts related to photosynthesis and relevant knowledge needed to get an understanding of the BioTube exhibit. Among those issues that were discussed in the pre-visit phase students learned about, photosynthesis, biomass and advanced life support in space.

During the CONNECT test runs at Xperiment Huset students worked in groups to conduct scientific experiments related to photosynthesis following a scientific inquiry learning approach (Milrad et al., 2003). Groups planned and conducted experiments to test hypotheses and to draw conclusions. In order to carry out an experiment, students could use the virtual menu in the AR view. They could make predictions, capture data and observe how the level of CO2 and temperature change.
Reflections on the Swedish trials

All activities including the pre, on site and post visits were conducted smoothly, thanks to the fact that the teachers have already an on-going collaboration with the museum staff and they worked together before. However, during the first day of the test runs we experienced many technical difficulties that had an impact on the educational flow and how the activities were conducted. The post visit activities were conducted on site in order to summarize the experiences with the BioTube. During these activities, we were able to use streaming video directly from the AR system to one of the rooms where students were discussing, so they could talk about what other peers were doing while using the AR system.

Regarding the role of the teachers during the pre and pro activities, we can mention that they had a more passive role as these activities were conducted by museum staff and a researcher. During the actual visit to the science center, the teachers’ role changed a bit, as they were in charge of activating those students that were not at that time using the AR. Teachers served also as translators during the test runs as most of the mobile AR activities were in English. They also help with the data collection activities for usability purposes.

When it comes to the actual visual augmentation and its impact on students understanding, it is quite premature to assess whether or not students learned better, since technology needs improving and there were no comparison data. However, students were quite enthusiastic about the idea of seeing the invisible. At the beginning of the test runs, some of the students thought that if the light will be increased it will result in a higher concentration of CO2, however when looking at the information panel used to visualize data they could correct their misconceptions. One important aspect we can mention is that the actual way in which the visual augmentation for the Biotube exhibit has been implemented needs to be improved. In one of the cases, the molecules and their representation...
did not fit the actual settings in which the experiment took place. Students felt confused and they have difficulties to understand what was going wrong.

What did we learn from these activities and what can it be improved in future trials? The activity flow and the educational activities during the visit to the museum need further planning and elaboration, as only few of the students can use the mobile AR system at the same time. In these trials, we let students watch a NASA movie regarding food in space and the ISS in order to understand the rationale of the Biotube. Much time of the visit to the exhibit and the post activities was dedicated to data collection techniques related to usability aspects. Teachers and museum staff thought that these activities should be less intrusive.

From our experience in these test runs, we learned that in future activities we should concentrate more on those content related activities to photosynthesis in the pre-visit, so the main efforts while in the museum are put in using and exploiting the mobile AR system. In this way, students will be able to formulate more elaborated questions and hypothesis that they will try during the visit to the Biotube augmented exhibit.

**Assessing the wearability of the CONNECT mobile AR system**

A starting point for the evaluation of a wearable system is the self-evident assertion that to be usable it must be wearable. As such, an assessment of usability should include an aspect of wearability (see Gemperle et al., 1998). At an extreme level, this will involve ensuring that the systems are safe to wear. But will also include issues that relate to perceptions of satisfaction (ISO9241), which may in turn relate to user acceptance of the systems. In addition, while rating the wearability of the device can address key ergonomic concerns, they may provide useful input to the design process (Knight et al., 2005a).

The wearability evaluation of the CONNECT system assesses the effect of the wearable on three aspects. The physiological aspect assesses the energy expended due to the load attached to the body. Assessment of the biomechanical aspect focuses on musculoskeletal loading as the device is attached to the body. This may manifest itself in sensations of pain and discomfort, which may be localised to a specific region of the body (Knight & Baber, 2004, Knight & Baber, in press). Additionally, an overall sense of well-being is determined with an assessment of comfort.

Immersion in virtual reality environments using Head Mounted Displays (HMDs) has often been found to result in visual fatigue and eye complaints (Kern & Reidel, 1996) and induce symptoms of motion sickness, including nausea, drowsiness, general discomfort, apathy, headache, disorientation and fatigue (Kennedy et al., 1992). As such, any evaluation of a HMD based system should include an
assessments of these symptoms. Here this is achieved through an assessment of visual comfort.

Table 1: Levels of Effect for Wearability

<table>
<thead>
<tr>
<th>Metric</th>
<th>Units</th>
<th>WL1</th>
<th>WL2</th>
<th>WL3</th>
<th>WL4</th>
<th>WL5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Energy cost</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Heart rate</td>
<td>beats per minute</td>
<td>Upto 90</td>
<td>91-110</td>
<td>111-130</td>
<td>131-150</td>
<td>&gt;151</td>
</tr>
<tr>
<td>Relative perceived exertion</td>
<td>Borg RPE score</td>
<td>6-9</td>
<td>10-11</td>
<td>12-13</td>
<td>14-15</td>
<td>16-20</td>
</tr>
<tr>
<td>Biomechanical</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Localised pain and discomfort</td>
<td>Borg-CR10 score</td>
<td>0-1</td>
<td>2-3</td>
<td>4-5</td>
<td>6-7</td>
<td>8-10</td>
</tr>
<tr>
<td>Comfort</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>General wearable</td>
<td>CRS score</td>
<td>0-4</td>
<td>5-8</td>
<td>9-12</td>
<td>13-16</td>
<td>17-20</td>
</tr>
<tr>
<td>Vision</td>
<td>VES score</td>
<td>0-2</td>
<td>3-4</td>
<td>5-6</td>
<td>7-8</td>
<td>9-10</td>
</tr>
</tbody>
</table>

Using physiological, biomechanical and comfort assessments, the wearability of a device can be determined, based on a “level of effect” rating. Table 1 gives five levels of effect from which five Wearability Levels (WL) can be suggested:

1. **WL1** – System is wearable.
2. **WL2** – System is wearable, but changes may be necessary, further investigation needed.
3. **WL3** – System is wearable, but changes are advised, uncomfortable.
4. **WL4** – System is not wearable, fatiguing, very uncomfortable.
5. **WL5** – System is not wearable, extremely stressful, and potentially harmful.

For a discussion of the metrics used to measure the level of effect see Knight et al., 2005b. Suffice it to say that the tools used rely on subjective rating on a scale and were employed, as they are non-invasive, quick, and simple to implement without interfering with the users while interacting with the exhibit.

**Method used**

Trial runs with the CONNECT wearable system took place in Athens in November 2005 and January 2006. During the trials 26 (15 male, 11 female) school students aged 15 years (height 1.71±0.09m; weight 66.38±13.74kg) participated in rating the wearability of the system. On first putting on the wearable the students gave an initial rating of their energy cost before interacting with the Airtrack exhibit. After finishing the Airtrack exercise the students gave a post-test evaluation of energy cost, comfort, visual effects, and pain and discomfort.

**Results**

The duration of each trial and the time that the participant wore the wearable system was 7.81-4.54 minutes.
The results for the wearability evaluations are shown in table 2. For all dimensions the modal level of response rated the system at a Low level of effect. However, for a number of metrics a considerable number of participants rated the system as having a Large effect, suggesting that changes are advised. Indeed, V. Large levels of effect were recorded for a few participants, specifically for the General comfort and Visual effects variables, where the main areas of concern were associated with the attachment of the wearable onto the body, a sense of being embarrassed when wearing it, and difficulty in focusing when viewing the head mounted display. Figure 1 shows the results of the Visual Comfort Assessment.

Table 2a: Wearability results for the CONNECT wearable system during the Athens Trials

<table>
<thead>
<tr>
<th>Level of Effect</th>
<th>Low (WL1)</th>
<th>Moderate (WL2)</th>
<th>Large (WL3)</th>
<th>V. Large (WL4)</th>
<th>Extreme (WL5)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Percentage Rate (N=26)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Energy cost</td>
<td>84.6</td>
<td>7.7</td>
<td>7.7</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td></td>
<td>76.9</td>
<td>15.4</td>
<td>3.8</td>
<td>0.0</td>
<td>3.8</td>
</tr>
<tr>
<td>General comfort</td>
<td>57.7</td>
<td>7.7</td>
<td>3.8</td>
<td>19.2</td>
<td>11.5</td>
</tr>
<tr>
<td>Emotion</td>
<td>42.3</td>
<td>11.5</td>
<td>15.4</td>
<td>23.1</td>
<td>7.7</td>
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<td>Attachment</td>
<td>76.0</td>
<td>12.0</td>
<td>4.0</td>
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</tr>
<tr>
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<td>7.7</td>
<td>23.1</td>
<td>15.4</td>
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<td>11.5</td>
<td>15.4</td>
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<td>15.4</td>
<td>7.7</td>
<td>3.8</td>
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<tr>
<td>Anxiety</td>
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<td>7.7</td>
<td>11.5</td>
<td>3.8</td>
<td>3.8</td>
</tr>
<tr>
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<td>0.0</td>
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<tr>
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<td>7.7</td>
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<td>Irritation in eyes</td>
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<td>11.5</td>
<td>11.5</td>
<td>3.8</td>
</tr>
<tr>
<td>Difficulty Focussing</td>
<td>69.2</td>
<td>11.5</td>
<td>11.5</td>
<td>3.8</td>
<td>3.8</td>
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<tr>
<td>Visual Fatigue</td>
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<td>19.2</td>
<td>3.8</td>
<td>0.0</td>
<td>0.0</td>
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<tr>
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<td>7.7</td>
<td>3.8</td>
<td>0.0</td>
</tr>
<tr>
<td>Dizziness</td>
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<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
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<td>76.9</td>
<td>15.4</td>
<td>3.8</td>
<td>0.0</td>
<td>3.8</td>
</tr>
</tbody>
</table>

There were few reports of sensations of pain and discomfort. What reports there were, were localised around the head, shoulders and back, which were the areas supporting the weight of the HMD (0.65kg) and the backpack (5.35kg). Four participants experienced sensations of discomfort in the hands, where they associated this with having the hold the HMD, to maintain its stability in front of the eyes.
Future work

Extended trials will follow in the coming months with the use of the updated CONNECT technology but also with more educational scenarios. The currently realized 3-dimensional complex phenomenon representations only adjust themselves to the current state of the exhibit. Within this state they remain static. For the final test runs these representations will become dynamic within a state (e.g. showing moving air molecules floating around a wing with different speed). More demanding Pathway patterns – requiring broadband Connection to remote classrooms – will also be implemented and tested.

![Visual Discomfort](image-url)

**Table 2b:** Wearability results for the CONNECT wearable system during the Athens Trials

<table>
<thead>
<tr>
<th>Number of Reports (N=26)</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Head</td>
<td>4</td>
</tr>
<tr>
<td>Face</td>
<td>2</td>
</tr>
<tr>
<td>Neck</td>
<td>3</td>
</tr>
<tr>
<td>Collar</td>
<td>1</td>
</tr>
<tr>
<td>Left shoulder</td>
<td>2</td>
</tr>
<tr>
<td>Right shoulder</td>
<td>2</td>
</tr>
<tr>
<td>Left upper arm</td>
<td>1</td>
</tr>
<tr>
<td>Right upper arm</td>
<td>1</td>
</tr>
<tr>
<td>Left lower arm</td>
<td>2</td>
</tr>
<tr>
<td>Right lower arm</td>
<td>1</td>
</tr>
<tr>
<td>Left hand</td>
<td>3</td>
</tr>
<tr>
<td>Right hand</td>
<td>1</td>
</tr>
<tr>
<td>Chest</td>
<td>2</td>
</tr>
<tr>
<td>Upper back</td>
<td>2</td>
</tr>
<tr>
<td>Mid Torso</td>
<td>1</td>
</tr>
<tr>
<td>Mid back</td>
<td>2</td>
</tr>
<tr>
<td>Waist</td>
<td>1</td>
</tr>
<tr>
<td>Lower back</td>
<td>2</td>
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</tbody>
</table>

**Fig. 6** The effects of visual discomfort
Acknowledgments

The consortium would like to thank all the teachers participated in the Test Run and facilitated the procedure of the CONNECT approach. Their efforts and input are much appreciated.

References


Empowering teachers to Adopt Active Learning Methods for school of tomorrow

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Abstract

There is a growing consensus that traditional teaching in basic science in schools, do not lead to the desired results. Most of the students who complete these programs do not gain deep knowledge about the basic concepts and develop a negative approach to the sciences. In order to deal with this problem, a variety of methods have been proposed and implemented, during the last decade, which focus on the “active learning” of the participating students. We found that the methods developed in leading educations colleges and universities are fruitful for the future schools. Despite research-based evidence of the success of these methods, they are often met by the resistance of the teachers. This article describes how schools could achieve significant changes in science lessons, as well as the stages teachers undergo, as they adopt innovative teaching methods. In the article, we adopt the Rogers model of the innovative-decision process, which we used to evaluate the degree of innovation adoption by teachers. An analysis of interview and observation data showed that four factors were identified which influence the degree innovation adoption: (1) teacher readiness to seriously learn the theoretical background of “active learning”; (2) the development of an appropriate local model, customized to the beliefs of the staff; (3) teacher expertise in information technologies, and (4) the teachers’ design of creative solutions to problems that arose during their teaching.
Introduction

During the past decades, a consensus has formed that traditional teaching of basic science courses (e.g., physics, math, and chemistry) does not result in desired outcomes. Research universities in America, with their large classes, have a poor reputation for teaching science (Meltzer & Manivannan, 2002; Powell, 2003). Students complete these courses with a shallow understanding of basic concepts, poor abilities in problem-solving, a shaky understanding of scientific processes and a negative approach to learning science (Pundak & Rozner, 2002; Pundak & Maharshak, 2003). Experts in science education have dealt with this phenomenon by developing teaching methods which try to address significant student difficulties that occur during the learning process (Heller et. al. 1992, Laws 1991, Mazur 1997, Sokoloff & Thornton 1997, Barak & Dori 2005). In spite of evidence that these methods are successful in institutions of higher learning, many academic staff members in teaching colleges prefer to use traditional teaching methods.

Resistance to Innovative Teaching Methods

The on-going practice of many experienced teachers continues to be based on traditional teaching methods, year after year, despite disappointing achievement and despite the negative reactions of students to these methods (Henkel, 2005). Changing these methods demands that these teachers invest effort to develop new learning materials, integrate modern technologies and confront unexpected conditions (Zellweger, F. 2004). When weighing the future advantage with the anticipated investment of effort, the common tendency is for many teachers to reject the desired change.

There are several reasons why an academic staff resists innovative educational change. Geoghean (1994) suggested that there is the unwillingness to take risks. For example, teachers may suspect that their adoption of an innovative teaching method may involve situations where they might lose control and thus fail to achieve the desired results. A teacher who is confronted with the necessity of changing his role in the classroom – even if he has evidence that the innovative teaching method is effective – often experiences a threatening feeling of uncertainty (Bonk, 2001). For this reason, teachers often are not eager to invest the necessary energy needed to master an innovative teaching method which demands on-the-job experience to develop this mastery. In this case, the resistance to change is used to reduce one’s feeling of inadequacy and to minimize the resulting conflict, as much as possible.

A second reason for resistance to change in teachers might be termed “justification of previous decisions.” (Braskamp, et. al. 1984) This phenomenon goes well beyond the field of teaching and is present in decision-making processes, in many fields. People tend to continue to invest their energies in a failing activity due to the desire to prove to others (and to themselves) that their original decisions were correct. For example, even if teachers are aware that their teaching methods are
ineffective and do not lead to the desired outcomes, these teachers experience a sense of conflict. Should they continue to teach with methods which have been developed with so much effort? Or should they change these methods and “start from scratch” to learn a new teaching method whose success is not guaranteed?

A third reason for resistance to change is the tendency of teachers to imitate the traditional teaching methods of leading universities. These teaching methods are based on “the final exam” as the main component of a student’s evaluation in a given class (Donald et. al. 1996); however, processes that occur during the semester – such as carrying out specific learning assignments, facing the challenges of problem solving and creativity (Heller et. al. 1992), and committing oneself to working in a team – are a much less important component of the student’s performance. Therefore, in addition to the above-mentioned reasons to resist change, this conventional approach to student evaluation, as practiced in leading universities, represents a serious problem to the academic staff in a teaching college. Moreover, many of these college staff members teach in the other institutions which are characterized by these traditional methods, so that they often need to teach with two different teaching methods for the same course.

The Center for Active Learning

With the goal of improving its teaching practices in science education, the ORT-Braude Academic College for Engineering established the Center for Active Learning (Pundak & Rozner 2006), which aims to encourage teaching practices with demonstrated effectiveness, such as the use of demonstrations, posing conceptual questions, as well as providing brief lectures, peer teaching and structured problem-solving. We adopted these methods from learning environments which were developed in MIT (Dori & Belcher 2005a) and NCSU (Beichner et. al. 2000). In these approaches, the lecture is replaced with a classroom workshop (Meltzer & Manivannan, 2002), in which the students sit near several roundtables. The lecturer is situated in the center of the classroom. For most of the class session, the students work on specific learning tasks which deal with problem solving and laboratory investigations. The class functions as a research group, in which different teams give reports about their work and results. The role of the lecturer focuses on planning the learning environment, activating the students and giving effective real-time feedback. The classroom learning activity is supported by a computer network between the lecturer and the students as well as between the students themselves. This network allows for retrieving tasks, presenting computerized models, presenting problems, giving feedback, establishing discussion groups, and the like. These changes in the culture of teaching often give rise to difficulties and reluctance of academic staff members, even those who are interested in improving their classroom teaching.
Fig. 1 Design of the Center for Active Learning in the Ort Braude College. Notice that the instructor is positioned in the middle of the room, surrounded by 5 sets of round tables and chairs, for the participating students.

Fig. 2 Collaborative Learning with Groups. Many innovative teaching methods involve student problem-solving, with the sharing of different points of view.
A Model for “The Adoption of Innovative Teaching Methods”

In many cases, the need to change teaching methods and to adapt them to new technologies is a result of external pressure, which results from processes which take place outside the activities of the academic teaching staff. Such processes include the development of new technologies, competition with other colleges or partnerships with them, awareness of the need to improve client services or the requirement of improving student achievement. In order to assist the teaching staff in the process of adopting innovative teaching methods, and to help them identify in what stages of this process they are presently located, we have used the model of Rogers (Rogers 1995), which deals with the processes of decision-making during the diffusion of innovations. Rogers developed his model over 40 years ago, based on innovation research in agriculture; the model was later applied to other fields, such as medicine and advanced technologies. The model presents various steps that lead to the successful diffusion of innovations, as well as expected difficulties that occur during this process. We thought that this model could be fruitful in guiding us to support our faculty to adopt innovations in their teaching methods.

Fig. 3 The Rogers 5-Stage Model of the Innovation-Decision Process.

As can be seen in Fig. 1, the Rogers model of the innovative-decision process relates to prior conditions and several stages:

**Prior Conditions.** The teacher must feel dissatisfied with the way he teaches. In addition, a teacher’s decision-making will be influenced by his beliefs and values about teaching and learning, by his prior teaching practice and by the common assumptions and norms of the institution and/or department in which he teaches.

**Stage 1: Knowledge.** In this stage, the instructor expands his knowledge about innovative teaching methods. There are three levels of knowledge. “Awareness-knowledge” relates to information that a particular innovation exists. “How-to knowledge” relates to the practical information needed to implement the innovation. “Principles-knowledge” deals with the functioning principles which underlie...
how the innovation works and how to deal with problems that arise during its implementation.

**Stage 2:** Persuasion. As a result of the acquired knowledge, the instructor develops a tendency to either adopt or reject the new teaching method. According to this model, five perceived characteristics of an innovation influence this tendency and account for between 49%-87% of the variance for adopting it (Ellsworth 2000). These variables can be defined as questions asked by the teacher about the new teaching method:

- **Relative advantage.** Is the new teaching method better than the one I’m using now?
- **Compatibility.** Does it conflict with my beliefs about learning and teaching or with my teaching experience?
- **Complexity.** Is it too hard to understand or implement in the learning environment where I teach?
- **Trialability.** Is it possible to try it and then return to the way I teach now?
- **Observability.** Can I watch an instructor use it before I decide to adopt it?

**Stage 3:** Decision. According to his understanding, the instructor decides whether to adopt or reject the new teaching method. In some cases, the decision to reject the method derives from the fact that the instructor never considered it seriously. The decision to adopt or reject an innovation is not final and can change with time, depending on the level of success during implementation, or on new information that may cause the instructor to reconsider his position.

**Stage 4:** Implementation. The instructor usually implements only part of the new teaching method and does not implement it exactly as designed by its developer. Instead, he usually modifies it to fit into his teaching practice, gained over years of experience.

**Stage 5:** Confirmation. The instructor’s decision to continue teaching according to this new method is the result of his or her satisfaction with its successful implementation. However, it usually takes time for a instructor to learn how to successfully implement a new teaching method. Therefore, one of the dangers involved in the implementation of such a method is that, during its initial stages, the instructor will decide to give up and return to his or her old teaching practice, despite its limitations.

**Confronting the Challenges**

To address the difficulties faced by the academic staff— the College undertook a number of steps in order to minimize instructor resistance to the new teaching methods. These steps were taken at the beginning of the prior conditions and the
stages of knowledge, persuasion, decision, implementation and confirmation, in accordance with the Rogers’ model.

Prior Conditions.

The factors which led to changing teaching methods were:

(a) Dissatisfaction by the academic staff. Low students scores on the final exams created dissatisfaction with the academic staff as well as by the college administration.

(b) Student dissatisfaction. Many students who completed their studies claimed that the basic science courses did not contribute to their education as engineers, but rather used by the College as a “selective filter”

(c) Academic commitment. Some academic staff members were motivated to change because of need to improve student achievement, their belief in the importance of the basic science courses and the successful experience of other colleagues, in Israel and abroad, to integrate new teaching methods into their courses.

Stage 1: Knowledge.

Knowledge acquisition was initiated in several ways: in some cases the initiative came from some academic staff members, sometimes it came from the Center for the Development and Advancement of Teaching at the College, and in other cases it came from informal meetings between members of the academic staff. Below are four methods that were used in this stage.

(a) Integrating academic staff in planning the change. During the past 5 years, the academic staff in the College has been engaged in a process of extending the student learning environments beyond traditional science courses. The research base for these changes rests on the benefits of active learning (Hake 1998). During the past two years, some academic staff members have presented proposals to the instructors in the Center for Active Learning, based on two active learning programs, one from the North Carolina State University (Beichner et. al. 2000), and another from MIT (Dori & Belcher 2005a, Dori & Belcher 2005b) The process of presenting proposals allowed instructors to become familiar with innovative teaching methods and to decide which components of these methods they wanted to adopt for themselves.

(b) Involving the academic staff in implementing the change. Fourteen teams of academic staff presented proposals to integrate Internet-based technologies and develop active learning methods, within the framework of the second CFP (Call for Proposals) of the country’s Council of Higher Education; six of these proposals were awarded grants. In addition, two of the teams that were not awarded grants decided to develop active learning methods. Each staff worked in cooperation
with an expert in science teaching, with the goal of deciding which active learning method to adopt, e.g., working in small groups (Heller et al. 1992), peer teaching (Mazur 1997), active demonstrations (Sokoloff & Thornton 1997), working with computer simulations (Eylon et al. 1996), alternative assessment, and the like. At this stage, the academic staff had to learn innovative teaching methods and to weigh their willingness to adopt parts of these methods.

(c) Engaging in long-term R&D of active learning methods. The process in the College of changing to active learning started when Internet-based technologies were introduced, in the year 2000. The College administration initiated another change, with the establishment of the Center for Active Learning (Pundak & Rozner 2006). The Center’s process of research and development was undertaken with participation of the academic staff, taking into account the courses they taught.

(d) Making connections with research centers with successful track records. The College’s change to active learning methods, such as those successfully developed, implemented and researched by other research centers, was accompanied by making connections with these institutions, e.g., the North Carolina State University, which developed the SCALE-UP program, and MIT, which developed the TEAL program. The goal of making contact with these research centers was to learn the philosophy of the respective active learning method, as well as the drawbacks and difficulties of the method, as experienced by the staff and students. Consulting with these centers occurred as a result of discussions we had with Prof. Beichner of the North Carolina State University and with Prof. Dori, who evaluated the TEAL program at MIT. These discussions made it possible for us to deepen our professional knowledge and gave us the opportunity to meet with experts who had the experience of successfully implementing these innovative teaching methods.

Stage 2: Persuasion.
The stage of persuasion was based on the knowledge that the academic staff developed in the first stage. Along with getting to know the new teaching methods, the academic staff started to plan how they would adopt these methods. In spite of accumulated knowledge, some staff members still were not convinced of their ability to bring about the desired change. In order to deepen their knowledge and to allow them to express their doubts and worries, three methods were used:

(a) Creating support groups to deal with the change. In order to allow the academic staff to discuss the changes they are planning, two supportive working groups were set up: a small working group and a larger one. The small working group consists of 2-4 members of the academic staff who developed the work plan and associated learning materials associated with the specific teaching method; they met once a week. The larger working group, consisting of all the academic staff involved in the change to active learning, met every 2-3 months. In this way, the professional knowledge relating to each new teaching method was expanded and ways to implement each method were presented. This dual process made it
possible for the teachers to express their legitimate worries and doubts regarding the adoption of each teaching method.

(b) Dealing with uncertainty through knowledge. Milliken (1987) describes three types of uncertainty which are created by the resistance to change: understanding the change, effects of the change and behaviors which might arise because of the change. The College attempted to lower this uncertainty and to increase the staff's feeling of control through collective participation in the learning process and identification of difficulties of the students and staff. For each teaching method, the following topics were discussed: (1) What are the anticipated changes which are likely to accompany this method? (2) How might this method affect the academic staff as well as its working conditions? (3) What types of resistance might negatively effect the successful adoption of this method? These discussions were accompanied by reading research articles that dealt with these topics, encouraging the expression of staff resistance and the presentation of the difficulties which were raised.

(c) Taking account of the extra staff effort needed. Staff members who involved in the project presented their work plan and schedule which included hours for developing the method and implementing it in the Center for Active Learning. This commitment by the College, which lasted 18 months, was appreciated by the participating staff. Although the monetary compensation did not cover all of the hours spent by the staff to adopt the new teaching methods, it expressed the College's appreciation for the extra staff effort.

Stage 3: Decision.

Making the decision to adopt a new teaching method was taken after the stage of persuasion. This process took about 10 months, during the period between November 2004 and October 2005. The process of implementing the kinds of new teaching methods that have been described above involved a process of planning, to be followed by a process of implementing an innovative learning environment. Despite the many doubts and worries of the staff, it appears that they were willing to “jump into the water.” This decision was accompanied with the development of learning materials, which was an effort to critically investigate the advantages and disadvantages of the particular innovative teaching method (Dori et. al. 2003). The closer the staff approached the date for the new semester, the faster their work pace on these materials became and the greater were their doubts about the new learning environment.

Stage 4: Implementation.

During the winter semester of 2005, seven academic staff members taught four introductory science courses at the Center for Active Learning that was established at the college. The instructors had previously taught these courses, for at least eight times, using traditional teaching methods. Four of the instructors
taught introductory courses in physics and three taught introductory courses in mathematics. Details relating to these courses appear in Table 1.

<table>
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<tr>
<th>Course Title</th>
<th>Number of Classes</th>
<th>Number of Instructors</th>
<th>Number of Students</th>
<th>Number of Hours at the Center for Active Learning</th>
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<td>75</td>
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<td>Physics 2</td>
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<td>2</td>
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<td>5</td>
</tr>
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<td>Differential Calculus 1</td>
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<tr>
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<td>1</td>
<td>38</td>
<td>4</td>
</tr>
<tr>
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<td>254</td>
<td>18</td>
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</tbody>
</table>

Table 1. Introductory Science Courses in the Study

During the semester, we conducted two interviews with each instructor. The first interview occurred at the beginning of the course, i.e., during the 2nd or 3rd week of the course. The interviews had several goals:

1. to evaluate which student difficulties arose, as a result of the innovative teaching method,
2. to investigate the actual teaching methods used, and
3. to identify the instructor’s challenges.

In the interview, the instructors were asked if certain problems occurred in their courses. These problems, which involve learning and teaching, were taken from the research literature. Table 2 presents the degree to which the instructors were aware of these problems. From Table 2 we can conclude that instructors are awarding to most of students’ difficulties. But, they met a great challenge to answer on these difficulties in the conversional lecture hall. Dudu: I don’t know what you want to say here. The sentence is worded poorly and needs to be changed.

The second interview occurred at the end of the course, i.e., during the 12th and 13th week. The aims of this interview were: understanding the various difficulties associated with the adoption of innovative learning method, learning about successes, understanding in the changes in teaching approaches and evaluating the influence of this experience on the student and teacher attitudes. Below are the main reactions of the academic staff involved in the implementation of new teaching methods. These reactions have been collected via interviews, workshops, and working groups, which took place over a time period of 10 months:
Table 2. Staff Awareness of Learning and Teaching Problems. (The √ symbol represents awareness and the - symbol represents no awareness.)

(a) Freedom vs. control. Traditional lecturers face a big difficulty, when required to give up the control they normally have during a conventional class session. The new class session, designed according to the principles of active learning, allows for greater freedom in planning the class session, but during the implementation stage the lecturer needs to fit a variety of teaching methods into a rigid schedule, which dictates a limited time for implementing each of these methods. Every change requires the instructor to relate to the complete set of components which make up the innovative learning environment. During the traditional lecture courses, we noticed that when the instructor met with difficulties with the new teaching methods, he tended to return immediately to the traditional methods with which he was comfortable, i.e., the well-known approach of “chalk and talk.” We assume that this is a common tendency.

(b) Work overload. Adopting active learning methods requires extra work for the academic staff; they are exposed to new learning materials and teaching methods, which they need to assimilate into their teaching. As one example, one lecturer reported that, after he decided to integrate the method of computer simulations into his course, he proceeded to review about two thousand simulations! During this process he chose about 60 simulations for use in his semester course. This intensive effort took many days, and it was only part of what the lecturer had to do, in order to adopt this new teaching method.
(c) **Challenges of new educational technologies.** In addition to understanding and adopting new educational methods, in order to work effectively, staff members also need to understand and use new educational technologies. They need to master computer systems which include a wide variety of programs to manage the teaching and present the course content; to operate a sound system, a video system, a system for collecting real-time data and a student feedback system. In contrast to the technology of the traditional lecturer, who operates the technology of “chalk and talk,” this technology is much more complicated. Moreover, difficulties in operating these new technologies can be risky, i.e., they can be the source of serious problems during the actual class sessions. In order to deal with this difficulty the instructors are accompanied with a computer technician, from the beginning of the implementation stage until the time when the instructors feel competent operating these systems.

(d) **Dilemmas arising from finding new learning materials.** The adoption of new teaching methods requires the academic staff to venture outside the closed circle of their well-known teaching methods and into a wide world of new teaching methods, through which they can engage their students in active learning, as described earlier in this article.

(e) **Creativity.** The new Center requires the academic staff to critically re-examine their beliefs regarding teaching methods and their implementation, in light of the many options offered them. Although the decision to establish the Center was made by the College, the choice of innovative teaching methods required the instructors to devise solutions which would fit their personalities, as well as the subject matter of the courses. The information technology tools which were made available to the instructors gave them the opportunity to present complex and dynamic course content, which up to now had been presented in traditional ways. Some of them were creative enough to develop new methods and to write new and more appropriate learning materials for students.

**Discussion**

Our study investigates how innovations in teaching methods are adopted in an institution of higher learning. It presents the process of introducing innovations, both from the organizational perspective of the institution as well as the implementation perspective of the individual instructors. In keeping with Roger’s model, an important initial condition for the adoption of innovations is the existence of some degree of dissatisfaction with the existing situation (Briscoe 1991). At the ORT Braude Engineering College, there was a real sense of dissatisfaction with the state of science teaching at the institution, starting with the teachingal methods and ending with the low level of student achievement in the introductory science courses. This dissatisfaction was characteristic of all of the seven instructors who participated in the study; they were able to identify student difficulties arising from the traditional teaching methods and they were aware of
the need to change these methods. These initial conditions encouraged a small group of staff members to introduce the long and complicated process of learning, trial and development of innovative learning environments.

In contrast to traditional teaching, which was the pedagogical background of the instructors who participated in this study, innovative teaching – as exemplified by the work of the Center for Active Learning – demands a great deal of preparation. The ideal condition to implement a teaching method is for an expert instructor – who has mastered the innovation in practice – to accompany the instructors who are novices, in regard to the innovation. This condition did not exist at the college. Instead, development teams for each of the courses were established. Teams were combined from 3-4 faulty members. In most cases, each team had both young and senior faculty members. Teams met every week in order to develop teaching materials and pedagogical approaches; they met every month with an expert in science education. Based on interviews and observation data, participating instructors demonstrated a high degree of variability regarding their levels of innovation adoption, as illustrated in Fig. 4.

This variability can be explained by the behavior of the development teams and the instructors, in each stage of the Roger model of the innovative-decision process (Fig. 2), as described below:

1. Knowledge Stage.
The development teams and the instructors were prepared to engage in deep learning, regarding the theoretical background behind the respective innovations. This learning focused on student learning processes, student difficulties and how to deal with them.

2. Persuasion Stage.
The development teams and the instructors developed a model of active learning that was adapted to their own beliefs. Although active learning has been adopted by a number of different institutions (Beichner et. al. 2000; Dori & Belcher 2005a,b) it cannot be adopted blindly. While developing learning materials for the courses, at the Center for Active Learning, the academic staff developed teaching methods which expressed their beliefs. These teaching methods usually were a compromise between the traditional teaching model, to which they were accustomed before the introduction of the change, and selected components of the new learning environment.

3. Implementation Stage.
During the implementation stage, we identified two main factors which can explain the wide variability regarding the degree of innovation adoption:

(a) Instructor expertise in information technologies. A great degree of variability existed between the participating instructors regarding their expertise in utilizing the various information technologies available at the Center for Active Learning, e.g., using computer simulations, controlling a classroom of
computers, employing computer assistance to check student work, and using a computer system to gather personal responses (PRS).

(b) Instructor design of creative solutions to problems that arose during their teaching. During their class sessions, while the instructors attempted to implement their new teaching methods, students often behaved differently than expected. There was a constant need to quickly analyze these new challenges and to react accordingly. Some instructors succeeded in doing this, thereby developing the new teaching method. For example, the mathematics team decided to present theorems to the students, leaving them to work out the proofs via group work, in which each group worked on a different theorem. Each group then presented its proof to the entire class and received feedback for the other students and the instructors; this approach was designed to develop student confidence in their own abilities (Van Heuvelen 1991). However, some of these instructors reverted to traditional teaching methods, as soon as problems arose. In another example, toward the end of the semester, one of the physics instructors decided to return to his regular classroom, because he found it difficult to present lectures in the Center for Active Learning.

Today, after three semesters of work at the Center for Active Learning, we can say that the process of acculturating the academic staff to teaching in innovative and complex environments is a long, multi-year process, as documented in the research literature (Fullan 2001, Louchs-Horsley et al. 1998). The most difficult stage, it appears, is at the beginning of the implementation stage, when instructors come face to face mostly with difficulties and unexpected situations in the innovative learning environment. By being forced to focus on student difficulties, the instructors became acutely aware of the gap between their expectations and their students’ abilities (McDermott 1991). Dealing with these difficulties resulted in frustration and different reactions from the instructors. Some of them decide to revert to their prior traditional teaching methods. Some argue that they have not been sufficiently prepared and others are willing to “take the plunge” and develop creative and innovative teaching methods in their teaching.

The seven instructors who taught in the Center for Active Learning reached two major conclusions, as a result of their efforts. On one hand, the students were more active and involved in their learning and, as a result, understand the basic concepts much better. They also succeeded more on tests, during the semester, than similar students who learned in the traditional settings. On the other hand, the learning pace was slower which resulted in students learning less than expected in the course.

In order to sustain an innovative learning environment, which offers many information technology options, many instructor workshops are needed. During the 2005-6 school year, a workshop was established for the academic staff. Its goal was to critically examine different aspects connected with the change from traditional to active learning. The workshop was guided by a teaching expert, who invited the instructors to present difficulties and to discuss issues related to this
change. The instructors were assisted by a technician who helped them use a wide range of technological learning aids in the Center for Active Learning. Based on our observations, during the first semester only a part of these options were utilized. Implementing the innovative teaching methods took much longer than expected.

The teaching expert also helped instructors who were involved in developing the new learning materials to confront difficulties involving the process of changing to the innovative teaching method. This process assisted the academic staff to deal with the frustrations which are a normal part of changing from a traditional to an innovative teaching method, which focuses on helping to develop student understanding of scientific concepts in new ways (Goldberg & Bendall, 1995).

Based on the many difficulties that the instructors faced in preparing for their courses, we can offer two suggestions:

1. Instructors who desire to use new teaching methods (e.g., those presented in this article) need to participate in appropriate workshops which focus on the mental changes that instructors undergo when a significant amount of the responsibility of learning passes from the instructor to the students.

2. Instructors should be accompanied by knowledgeable assistants, so that they can discuss their difficulties, as they arise, and offer possible solutions. These assistants can help the instructors successfully deal with their tendency to revert to their well-known prior traditional teaching methods.

This article presents the way one academic institution dealt with the introduction of changes in teaching in introductory science courses. This process of change was guided by a theoretical model which made it possible for the management and academic staff of the college to identify and to deal with various difficulties during the process of introducing these changes. Our day-to-day work, with the assistance of the theoretical model, helped us to identify and reinforce successful learning and teaching processes, and with the help of these processes we hope to expand active learning in the college, by reinforcing its benefits.

Bibliography


Evaluation Methodologies in Science Education

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Introduction

Any educational approach requires an empirical evaluation detailing the plus and minus of an approach. By applying quantitative and qualitative methods, in general teachers and pupils are monitored to reach this goal. For both methods, valid and reliable tools gather information which by solid psychometric procedures has to be assured. This is especially important when selected features very often are labelled as soft features needs evaluation. Science education settings with its complex environment with many and very often unknown variables, therefore, challenge any evaluation efforts. It is not always easily possible to isolate the intervention momentum entirely although psychometric measures allow reasonable answers. However, every evaluation design focuses on quasi-experimental designs in order to answer survey questions with regard to educational treatments. In general, a pre-test / post-test design is applied.

The CONNECT approach

In the CONNECT project, the empirical evaluation faced the main question whether an advanced technology (AR, CVD, Internet) might add any value in its wider sense to science learning within the context of a school-museum programme? In other words, under what conditions will an augmented exhibit experience (supported by a specific internet platform) be better than similar (conventional) exhibit experience. Hereby, another regular problem within educational settings originates in time limitations available for a questionnaire application. Overburden of young students with questionnaires may very soon limit any learning success. Application of empirical measures, therefore, has to take this into account and to select specific measures which never cover all desired variables. The evaluation design focussed on measuring the possible “added value” of the CONNECT approach. A quasi-
Experimental design generally includes two different treatment groups, in the case of CONNECT, of classes visiting a museum exhibit without any CONNECT technology (the platform & AR) and another making use of this technology.

**Evaluation Design of CONNECT Project**

The “added value” in terms of student variables was measured with regard to a cognitive achievement increase, to intrinsic motivation, to interest scores, to interactivity and to an understanding of an exhibit’s content. In each of the four participating countries (Greece, Sweden, UK, Finland) the learning experiences of the participating students before, during and after their visits to the science centres were documented. The presentation concentrated on quantitative data alone.

**Examples of the approach**

Three examples of results are taken to describe the evaluation methodology: A cognitive achievement scenario, a motivational and an attitudinal one. All scores are detailed as box-plots (also known as a box-and-whisker diagram or candlestick chart) which is a convenient mode to graphically depict a five-number summary consisting of the smallest and largest observation, the lower and upper quartile as well as the median score (Tukey 1977).
In both experimental approaches, the participating students add cognitive knowledge which they learn. The difference in the experimental approach appears as bigger although a so-called “ceiling effect” occurs, which is, many students already reach the highest possible level of achievement. One has to take into account that the comparison group also experienced an hands-on approach (as the experimental did) just with the difference that the latter additionally had an AR-support. Thus, even a short educational intervention (as such the AR technology can be seen) adds cognitive knowledge when appropriately prepared by pre-visit activities.

The motivational situation details a more dichotomous pattern. Pupils in the AR-approach in general were more interest, saw more importance in their participation and scored it as more valuable. The basis for this survey was the Intrinsic Motivation Inventory (IMI) of Deci & Ryan (1992).

As a third example, finally, the individual rating of interaction monitored as a semantic differential. In both approaches, students scored very high which is not surprising since both approaches included hands-on activities.
### Studying science in my class has been:

<table>
<thead>
<tr>
<th>Important</th>
<th>Not important</th>
</tr>
</thead>
<tbody>
<tr>
<td>Not clear</td>
<td>Clear</td>
</tr>
<tr>
<td>Enjoyable</td>
<td>Unenjoyable</td>
</tr>
<tr>
<td>Well Organized</td>
<td>Poorly Organized</td>
</tr>
<tr>
<td>Not interesting</td>
<td>Interesting</td>
</tr>
<tr>
<td>Easy</td>
<td>Difficult</td>
</tr>
<tr>
<td>Providing free-choice activities for students</td>
<td>Very Structured</td>
</tr>
<tr>
<td>Hard to Understand</td>
<td>Easy to Understand</td>
</tr>
<tr>
<td>Trivial</td>
<td>Essential</td>
</tr>
<tr>
<td>Interactive</td>
<td>Not Interactive</td>
</tr>
<tr>
<td>Old</td>
<td>Original</td>
</tr>
<tr>
<td>Encouraging students to ask questions</td>
<td>Discouraging to ask questions</td>
</tr>
<tr>
<td>Encouraging student Team-work</td>
<td>Discouraging student Team-work</td>
</tr>
<tr>
<td>Useful</td>
<td>Useless</td>
</tr>
</tbody>
</table>

All responses to the Semantic Differential were analysed by extracting three major factors (Principal component analysis): Interaction, Interest and Understanding/Learning.
Based on the empirical data, relationships between the scores detail important information. For instance, a positive correlation between the intrinsic motivation scores and the achievement scores are expected measures. Similarly, the intrinsic motivation scores relate closely to the semantic differential ones. The scores can reach high values such as 0.7 which for empirical analyses are quite high. Thus, the relationship points to expected directions such as, the more students are interested in an educational activity the more they value it and the more they learn (and understand).

<table>
<thead>
<tr>
<th></th>
<th>IMI-valid</th>
<th>IMI-effort</th>
<th>IMI-intst</th>
<th>SD-intst</th>
<th>SD-affect</th>
</tr>
</thead>
<tbody>
<tr>
<td>IMI-effect</td>
<td>.650(**)</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>IMI-interest</td>
<td>.733(**)</td>
<td>.644(**)</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>SD-interest</td>
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<td>.485( **)</td>
<td>.559( **)</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>SD-affect</td>
<td>.532( **)</td>
<td>.409( **)</td>
<td>.647( **)</td>
<td>.480( **)</td>
<td>1</td>
</tr>
<tr>
<td>SD-underst</td>
<td>.151( *)</td>
<td>.173( **)</td>
<td>.192( **)</td>
<td>.430( **)</td>
<td>.135( *)</td>
</tr>
</tbody>
</table>

(**) p<0.001

**Conclusion**

In general, under certain conditions, the CONNECT approach with its AR technology during a museum-school programme provides an added value to science learning. This may derive from two central factors: (a) increased student experimentation and (b) increased student interest. In other words, under the
conditions identified and described above, the AR condition can function to provide a stronger context for student investigations and for the development of student interest than the non-AR condition. The AR-related features can originate for these differences including the opportunity for students to make more precise measurements, a deeper personal experience with the scientific phenomenon (as a result of increased experimentation), and AR graphic visualizations of the unseen but vital factors

**References**


The Reality and Virtual reality of an International Frontline Physics Experiment

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Abstract

The futuristic scenario of a world-wide frontline physics experiment entering the classroom is being realised. In 2007-2008 the largest and most complex scientific facility for the investigation of the fundamental processes in nature will be ready at CERN, the European particle physics laboratory. The aim is to explore the fundamental building blocks and forces of nature, and to probe deeper into matter than ever before. The huge ATLAS detector is one of the experiments at this new particle collider. ATLAS is primarily a basic research facility, but will also be devoted to education. Information from the same particle collisions that thousands of scientists around the world use in their research to explore the fundamental processes in the interior of matter and the very beginning of the universe, will be used to make physics and technology more interesting at school. Advanced animation techniques are used to describe the construction and functioning of the giant ATLAS detector and new analysis tools are being explored to make the physics of the basic building blocks of nature available for schools.

Introduction

With the new proton collider at CERN [1] unprecedented collision energies will be obtained, making it possible to observe processes taking place at large energies and short distances, typical for the very early universe. The collision points of the accelerated proton beams are surrounded by the largest particle detectors ever constructed. The ATLAS detector [2] is a precision instrument the size of a seven-storey building presently being installed in the underground cavern at CERN (Fig.
1). With the extraordinary possibility to make groundbreaking discoveries, the ATLAS Experiment at the Large Hadron Collider at CERN can play an important role in promoting contemporary physics at school. For many years ATLAS has had a substantial collaborative Education and Outreach (E&O) project in which physicists from various parts of the world take part. The role is to inform and enthuse students and teachers about today’s frontline physics and support the members of the collaboration in their education and outreach activities.

Fig. 1 The ATLAS detector being installed in the underground cavern at CERN.

The accelerator and the ATLAS detector

With the new 27 kilometre circumference proton collider at CERN (LHC, the Large Hadron Collider), situated more than 100 m underground, it will be possible to create particle collisions in the laboratory that were typical for the very early universe. The particles are accelerated and steered inside the underground tunnel by thousands of superconducting magnets and acceleration devices. There are two particle beams very close to each other with bunches of billions of protons going in opposite directions. At a few places along the tunnel the two beams are steered to collide head-on.

The ATLAS detector, (Fig. 1 and 2) the largest particle detector ever constructed, is 22 m high and 45 m long and surrounds the collision points of the high energy proton beams. A variety of techniques are used in order to determine the properties
of the particles produced in the collision. The unprecedented collision energies of the Large Hadron Collider allow ATLAS to decode the “events” that unfold after the head-on collisions of protons (Fig. 3). These events and will reveal much about the basic nature of matter, energy, space, and time. Around 1700 physicists (including 400 students) from more than 150 universities and laboratories in 35 countries from all over the world participate in the ATLAS experiment and the exploration of the tiniest building blocks of matter.

Fig. 2 The ATLAS detector with people to indicate the scale.

Fig. 3 A simulated particle collision, “event”, as will be seen in the ATLAS detector. The woman is shown only to indicate scale.
Methods

Particle collisions will be available on the web for education purposes, plus background material describing the technicalities of the detector and the dynamics of the particle processes. The main part of the education package will be the 3D handling and analysis package for the exploration of the high energy particle collisions. The analysis package is an important technological improvement of the internationally-awarded web-based education package Hands on CERN [3, 4]. In addition the ATLAS collaboration has produced brochures, posters, films and animations of how the detectors work.

ATLAS Student Event Challenge

The ATLAS Student Event Challenge (ASEC) will make it possible for students and teachers to explore the particle collisions taking place in the ATLAS detector at the highest collision energies available in the laboratory. ASEC will meld together several state-of-the-art capabilities. The most important components are:

- Particle collisions (events)
- Analysis package and website
- Detector and physics animations
- Virtual reality event display

Real particle collisions in ATLAS will be available on the web when the new CERN collider is ready in 2008. Until then simulated events will be used to develop the different components of ASEC. The students will be able to analyse the events using the analysis package and the virtual reality event and detector display. The project will use the best aspects of technical animation by allowing students and others to manipulate 3D images of the detector, and then look to see how particles are detected as they pass through. In addition, students will look at 3D animations of events representing new physics processes, and analyse these to see if they recognize patterns of new physics processes.

A prototype version of the analysis package is being developed. The 2D event display shows the trajectories of the particles produced in the collision and other windows contain information about the detected particles. From the detailed particle information it is possible to reconstruct invisible particles. This technique is particularly used to discover new, very shortlived particles, which decay close to the collision point where there are no detector elements. The existence of invisible particles is established via the particles they have decayed into.
A three-episode set of animations will show how ATLAS is being constructed and assembled, how the different detector elements function to detect the passage of particles, and how the physics is revealed in the proton-proton collisions. The first two of these episodes are finished and can be downloaded from the ATLAS public website [2]. The third episode, describing the physics processes in the particle world, is expected to be finalised in 2007. The 3D virtual event display will be an ambitious technical part of the ASEC project, allowing the students to explore particle collisions in 3D and manoeuvre around inside the ATLAS detector. A prototype version of the 3D event display exists and is shown in Fig. 4.

**Target audience**

The ATLAS Student Event Challenge will enhance student education and be a resource for the teachers. The two successful education projects, Hands on CERN [3, 4] and QuarkNet [5] will serve as models for the education project using ATLAS data. This project - the ATLAS Student Event Challenge - will build on the best practise of those projects, in which we have substantial involvement. The ATLAS experiment is primarily a basic research facility, but the collaboration has also demonstrated an interest to be a participant in physics education [6].
Summary

The vision of how to use scientific data in an advanced school project and to demonstrate how advanced animation techniques and new analysis tools can be used with a frontline physics experiment is presently being realised in the ATLAS experiment. The innovative program will use cutting-edge technology to enhance student education, inform the public, and initiate new exhibits in science centres. It will provide these audiences with access to real and simulated data and the opportunity to participate in new discoveries. It will use the potential of frontier science and grid computing as a vehicle to promote and improve the teaching of fundamental science.

Acknowledgements

This work is being performed within the ATLAS Collaboration. We are very grateful to J. Pequenao who produced all the 3D animations and to C. Kourkoumelis for the work on the event analysis package.

References

1. CERN website: www.cern.ch
2. ATLAS website: atlas.ch
3. Hands on CERN website: www.hands-on-cern.physto.se
5. QuarkNet webpage: http://QuarkNet.fnal.gov and documentation references
Bridging the Digital Divide – The Zeus project

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Abstract
Experiences and findings are presented from the implementation of the ZEUS (Satellite Network of Remote Schools) project, which aimed to show how good-quality distance e-training, enriched with broadband applications, can be delivered to teachers working in multigrade schools in remote areas of Greece, overcoming the deficiencies in terrestrial telecommunications infrastructure through the use of satellite telecom systems. Following initial background information on rural multigrade schools and the need of teachers working in them for in-service training and support, the concepts and tools of the ZEUS project are presented as a response to the challenges posed, followed by a discussion of findings and conclusions.

Multigrade Schools Teachers: ‘Borderers’ of the Education System in Need of In-Service Training

In many primary schools of the Greek provinces there is not one teacher available for each of the six grades: the low number of students statutorily justifies the employment of less than six teachers –even of one or two–, who nevertheless are expected to cover the needs of a full school. These schools, known as multigrade schools, fulfil a function of national importance, as they provide the children of remote and less accessible areas with the access to education which all children of Greece are entitled to.

Teachers of multigrade schools are confronted with significant challenges. In particularly farraginous classes, they have to teach simultaneously two or more age groups and possibly more than one curriculum subjects. Teachers’ initial professional training does not suffice and the need for continuous training is evident
– especially in the light of the fact that typically inexperienced, newly-appointed teachers are posted to remote schools for a short term service. However, providing teachers from remote areas with in-service training is not easy. A teacher’s round trips between their remote school and an urban training centre tend to be costly, if not virtually impracticable, given that there may not be a colleague available to replace them during their absence. At the same time, teachers at remote schools suffer the consequences of the digital divide between rural and urban areas.

The above described difficulties of multigrade teachers working in remote areas are not unique to Greece. Internationally, the shortage of teachers in rural and remote areas, and the weaknesses of the education systems in the provision of training and professional support to these teachers, have been well-documented in the literature (Forbush & Morgan, 2004; Helge & Marrs, 1982; Ludlow, 1998; Miller & Sidebottom, 1985; Ankrah-Dove, 1982; Coldevin & Naidu, 1989; Benveniste & McEwan, 2000). However, these problems appear to be in sharp contrast with a growing recognition of multigrade schools as not only a necessary, but indeed a good-quality option for education systems, believed even to have some advantages over single-level classes (cf. Cook, 2000; Lloyd, 2002; Boss 2000).

The Use of ICTs

As a response to the obstacles described earlier, the use of different forms of technology-supported learning and distance education models have been advocated for the enhancement of quality and accessibility of teacher training programs in rural areas (Squires, 1996; Ludlow, 2001). Relevant attempts have followed the technological trends in the field of computer-supported learning, while the content of training delivered via the different technologies varies greatly, from conventional seminar-type lessons to classroom observations at a distance (Kendal, 1992; McDevitt, 1996; Ludlow & Duff, 2002; Kraft, 2002; Forbush & Morgan, 2004).

Building Europe’s Knowledge Society through Satellites: A Case for Distance Education

For the realisation of EU’s aspiration to become a truly knowledge-based economy, widespread availability and usage of broadband and high-speed Internet throughout the EU is considered necessary. However, the digital divide in Europe remains large, and for more than fourteen million European households in remote areas the digital divide is actually growing. The proportions of rural populations living in geographically disadvantaged areas and suffering from the digital divide are significantly higher in the new Member States and accession countries, which results in significant socio-economic effects and challenges (Cohendet 2003).
It is therefore a stated strategic priority for Europe to use to the full the potential offered by all available broadband technologies, including satellite communications, to bridge the digital divide (European Commission 2003). Satellite telecommunications can indeed play a crucial role in the creation of a balanced Knowledge Society without discriminations, as they can secure broadband access to the Information Society for those who geographical and other adversities have kept in digital isolation. In recent years there have been several initiatives in the field of satellite telecommunications applications addressing the needs of rural communities. As Cartheron (2003) shows, under certain conditions, satellite solutions prove competitive among other broadband access technologies, for the reduction of the digital divide in Europe.

Distance education is one of the major fields of application in this area, satellite communications being considered as an innovative delivery option facilitating access to new student populations in distance locations (Littman, 2000). Significant experience has already been gained internationally, particularly in the United States and in Australia (e.g. Boverie et al, 2000; Boylan, Wallace, & Richmond 2000), as well as in other less developed countries with populations distributed over large geographical areas (e.g. Al-Sharhan, 2000; Cohen, 2002; Lorenzo, 2002).

**ZEUS’ Response to the Challenges: A High-Quality Learning Environment over Satellite**

This growing mass of international experience clearly demonstrates that emerging technologies offer promising solutions to the challenges of providing accessible and appropriate training to rural educators. Making this its central concept, the ZEUS project (2003-2005) came as a mature cooperation between technological and pedagogical experts, who joined forces to offer a genuine response to the above-described challenges through the provision of distance e-training for multigrade school teachers in remote and less accessible territories in Greece via the use of broadband satellite networks. The project developed and used an advanced, content-rich e-learning environment based on the use of satellite telecommunications for the delivery of synchronous and asynchronous e-learning over broadband connections. The output of this procedure was a distance in-service training programme, which was piloted with multigrade school teachers in diverse remote and disadvantaged locations throughout Greece.

**The ZEUS Training Programme**

Based on an analysis of teacher needs conducted at the outset of the project through the administration of questionnaires and literature research, the ZEUS training programme aimed at helping multigrade school teachers to develop their
professional skills along two main axes:

- Use of ICT in their work, both for teaching/learning and administrative purposes.
- Application of teaching and learning approaches which are most appropriate for the multigrade classroom, with some special interest in the advantages that cross-curricular approaches can offer.

Through satellite/ICT installations at schools the training programme became available to teachers at ten locations in the extremities of Greece. The selected pilot sites reflected the diversity of conditions and circumstances in which a remote school may be found to operate in Greece. The selection of teachers, on the other hand, served the intention of the project to use expertise and knowledge already available in multigrade schools. Therefore the sample included teachers whose experience and background in multigrade teaching was higher than the average (see Figure 1).

![Figure 1 Sample of Teachers involved in the Pilots](image)

**Technological environment.** The ZEUS e-learning environment was realised through technologies exploiting satellite telecommunications for broadband delivery of rich educational content. Due to some limitations in the technological possibilities (based on DVB) offered by the Greek satellite, HellasSat, at the early stages of the project, the architecture of ZEUS foresaw the use of broadband satellite links for downloading data to user workstations, while uploading and feedback was sent by the user through existing terrestrial infrastructures (typically ISDN lines, available to virtually all schools). It is noted, however, that recent developments in the telecoms market in Greece already allow for two-way broadband satellite connections (based on the DVB-RCS protocol).
The applications mainly used for the delivery of training were: a) a synchronous e-learning suite for use over satellite platforms, supporting videoconferencing, application sharing, and chatting, all integrated in the same interface; and b) a specifically designed asynchronous e-learning environment, a dedicated web platform developed within the project, which provided secure and structured access to a rich pool of educational content.

Focus on pedagogical design. Although technical specifications do play a crucial role in a distance-education-via-satellite scenario, the success or not of the effort mainly depends on the underlying pedagogical design (cf. Lim, 2002). In line with this, ZEUS produced a genuine training programme aiming to cater for both flexibility and guidance, both interaction with others and self-paced learning. To this end, a comprehensive model for training delivery developed and tested (see Figure 2). The central event for each lesson was a live videoconferencing session, using the synchronous e-learning suite, which covered the need of isolated teachers for communication and real-time interaction with colleagues and instructors (cf. Shrestha & Sutphin, 2000, stressing the importance of interaction in similar settings).

Fig. 2 The ZEUS model of training delivery

As can be seen in Figure 2, however, both before and after the live session there was learning activity taking place independently in the working environment of the trainee. Through the use of web-based instruction techniques course participants were offered on-the-job training opportunities through tasks and materials that allowed them to work at their own pace, interact with the instructor and other practitioners as needed, and receive individual feedback as they applied information to their classroom settings. For each lesson, there was introductory
information on the topic covered, preparatory activities, the outcome of which was then reported by participants in the web environment and during the live session, as well as post-session consolidation and conclusion activities.

**Evaluation Methodology**

One of the major aspects of the ZEUS project was the evaluation of the piloted solution for e-training multigrade school teachers via satellite. The aim of evaluation was to assess the appropriateness of the choices made during the design stage of ZEUS, and the overall effectiveness of the solution, at three levels:

- at the level of the technology used (user-friendliness, functionality, reliability, efficiency);
- at the level of the content of training offered (structure, completeness, clarity, variety; attractiveness); and
- at the level of the procedures followed (planning and organisation; educational methods; implementation).

The views of users (teacher trainees and instructors) on these aspects of ZEUS were collected through a variety of tools, including online questionnaires, interviews, as well as field observations and video recordings in the schools and classrooms of the participating teachers, in an overarching case-study oriented approach. Questionnaire responses were analysed quantitatively, while data from the interviews and observations were analysed qualitatively, making use, among other tools, of specialised software for the demarcation and analysis of video data.

For evaluation purposes, as well as for the introduction of improvements at a middle stage of the implementation, the course offered was organised in two consecutive cycles. As a result, evaluation activities clustered around three main points in the timeline of the project: before the outset of the course, after the completion of the first cycle, and after the completion of the whole course, at the end of the second cycle. In this way, the evaluation methodology sought to take record of the conditions prevailing in the participating schools before the programme, after its first cycle, and after its eventual completion, so that any changes effected by ZEUS could be spotted and hopefully interpreted. In particular, the outcomes of evaluation at the end of the first cycle were useful for the introduction of any necessary improvements in the second cycle.

**Findings and Conclusions**

The effort invested by the ZEUS partnership in the evaluation of the project and of the training programme in particular yielded outputs of considerable value. The quantitative and qualitative data gathered and analysed revealed positive as well as weak points in the design and implementation of the project, bequeathing rich experiences and good practices for future efforts in the field.
Overall, the trainees evaluated very positively the content and procedures of the training offered; a few technical problems and faults did slightly decrease teachers’ enthusiasm, but in the whole they did not lead to a much lower overall appreciation of the deployed technological solution. The ZEUS experience clearly showed that satellite data telecommunications can effectively support the provision of training and professional development at a distance, particularly to professionals such as teachers who work in remote and isolated areas. Nevertheless, ZEUS also clearly indicated that significant technical difficulties, which in some (limited) cases even caused obstacles to the smooth running of training, would have been avoided if a more advanced model of satellite internet provision (DVB-RCS) had been available, not demanding the use of non-broadband terrestrial infrastructures.

In general, the attitude of the participating teachers towards the training programme was very positive. In their majority, they were dedicated to the course, and prepared to withstand any difficulties arising out of technical or other problems. This interest in ZEUS was found to be due to factors such as a decrease in their feeling of isolation and increased opportunities for communication with colleagues, new opportunities for access to up-to-date information, as well as the good relations and rapport developed between the trainees and the staff supporting them.

In addition, given the situation in schools as recorded before the beginning of training, multigrade school teachers in Greece seem to be in real need for training in the use of ICTs, as well as in new, less conventional pedagogical approaches, which would help them better respond to the particularly high demands and challenges posed by multigrade classrooms. Observations made in schools at the pre-course stage revealed a very low level of use of ICTs, as well as traditional methods of teaching and classroom management that did not appear to offer the best possible solutions for the particularities of the multigrade classroom.

Another very clear outcome of ZEUS was a corroboration of the predominance of the appropriate pedagogical design over mere availability of new e-training technologies via satellite connections. The different media, tools, and contents need to be orchestrated, according to clear pedagogical planning principles, into frameworks enabling substantial learning experiences and maintaining learners’ interest unabated, so that specific training goals and objectives are achieved. The findings of the evaluation confirmed the appropriateness of the procedure proposed by ZEUS for the preparation, realization and support of e-training (training delivery model; see Figure 2 above).

Of particular use are also teachers’ expressed suggestions for the introduction of improvements in future realisations of the training programme. Figure 3 depicts teachers’ response to various relevant items in a list, revealing the respondents’ preference for more synchronous interaction and exchange as well as the involvement of school students too in the training process.
An equally interesting and useful conclusion of the project refers to the unique opportunities for better understanding multigrade education through close observation and in-depth analysis of the video recordings of multigrade classrooms. To illustrate this point, reference can be made here of the findings of the analysis.
in terms of lesson time allocated to the different types of activity, of the video data from the classrooms observed in the framework of the case studies conducted (see Figure 4).

\[Fig. 4 \text{ Profile of classroom activity}\]

As can be seen in the chart, the distribution of classroom time in the five activity categories was found to have changed after the training: from a strongly teacher-centred, lecture- and assessment-oriented approach, typical of most schools in Greece—including multigrade schools—, the experience of the training programme may have lead teachers to experiment with more student-centred approaches.

On the whole, running ZEUS was a rewarding experience, which, on the one hand confirmed the usefulness of satellite telecommunication systems for the provision of support to remote and isolated communities, starting from teachers working in such communities; and on the other hand, suggested ways for introducing improvements into, and furthering our work in this field.

**Note**

More information about the ZEUS project can be found at www.dias.ea.gr. The ZEUS project was partially funded by the General Secretariat for Research and Technology of the Greek Ministry of Development, within the Concerted Programme for Electronic Learning of Measure 3.3 of the Operational Programme Information Society (Community Support Framework 2000-2006).
References


A theoretical approach for polymorphic distance education

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Abstract

The dialogue about the theoretical approaches of distance education in recent years brought about many questions and created new ones. The form of distance education and the modes of its implementation, especially with the development of technologies, changed its character. For a period of time, this created confusion to the people involved. However, what seemed as confusion was, in fact, no more than a ‘bubble which burst’ thereby revealing the parameters of a scientific field that is governed by a number of principles, axioms and pedagogical applications. The following text sets as an aim to process and document some theoretical data, in order to put into relief the scientific and methodological dimension of a theory of distance education.

Introduction

This presentation seeks to explore certain logical systems which together comprise a theory and a philosophical approach to distance education. Scientifically and methodologically, these logical systems form those measures, beliefs and values which in theoretical and empirical terms comprise the functional framework for a theory of distance education. As is true of every theory, this functional framework is typified by the existence, documentation and development of its complexity.

These thoughts on the theory of distance education lead us to define a broad-ranging field which, though influenced by a number of other scientific fields and disciplines, constructs its own ontology. This ontology renders it autonomous and independent, and documents a scientific field which bears the seal of the theory of distance education and its applications. In the pages that follow, we shall adopt a polymorphic approach to distance education in which distance education is defined not on the basis of a single methodology and conception of realization, but
on the basis of a polymorphicity which allows it to function flexibly, to adapt itself to specific sets of conditions, and to adapt all the educational data it employs in its application to these conditions. This statement forms a point of reference whereby the flexibility of form displayed by this type of education constitutes a polymorphic approach to distance education.

A few words of clarification

The term ‘distance education’ was first used in the nineteen seventies. It was officially chosen in 1982 when the International Council for Correspondence Education changed its name to the International Council for Distance Education. The Council is currently called the International Council for Open and Distance Education.

Issues raised internationally in recent years as to the nature of distance education lead us to ask what constitutes a distance education system. Such a system consists of more than a pedagogical framework: there is also an integrated fragile subsystem that supplies the applications of distance education institutionally, organizationally and functionally.

At the same time, distance education applications have featured a large number of models, proving thereby that there is no one way in which distance education functions and can be applied, nor one way in which it can be implemented. This statement stems from certain theoreticians’ approach to what distance education is, and from the various definitions and interpretations of distance education.

Polymorphic distance education stands out in that, while it borrows from the theory of other forms and experiences of education and their application, it is different from them. On the one hand, unlike primary or secondary education, it is not itself a complete formal system or educational level, and while it is not an educational policy or strategy in the manner of lifelong learning or continuing education, nor does it belong to the sphere of adult education, which is aimed at particular population or age groups and is generally linked to lifelong learning and continuing training. Moreover, like other educational academic fields, it does not comprise a whole with guidelines along the lines of “practical application guidelines” or “the A-Z of the good distance teacher”.

On the other, it is neither defined as training requiring specialized capabilities for recipients and those involved, nor is it an educational technology in accordance with which specific techniques and technological teaching and learning applications are—at best—employed.

As a flexible educational application, polymorphic distance education is linked to absolute freedom of choice when it comes to the means employed in communicating and conveying information. Moreover, in its management of these means and points at which teaching and learning processes are involved, polymorphic distance education follows an independent route with choices that make it an autonomous scientific and research field within the educational sciences. That it also includes
economic and psychosocial elements as well as involving educational strategy and policy only serves to highlight this autonomy.

Defining distance education as education in which there is a physical distance between a source and recipients is at best simplistic, and leads to oversimplified misinterpretations of the sort common in the past. The concept of polymorphicity was first proposed in 1998 (Lionarakis, 1998) and stresses the problematic and disorientating dimension of ‘distance’ when it is interpreted simplistically as a physical state rather than in educational or pedagogical terms. More specifically:

The term ‘polymorphic education’ is proposed, which delimits the distance dimension within an educational framework of approaches a) to quality and b) to the use of means and tools. By its very nature, distance education should contain educational material that is oriented towards learning and teaching. The means used (printed and audio-visual material, new technologies etc.) is not always founded in a quality approach. However, from the moment these facts are covered and distance education embraces the means but also the principles of learning and teaching, it becomes a separate entity which can be called polymorphic education. The term ‘polymorphic education’ therefore acquires a special resonance and indicates the quality education that operates with learning and teaching principles in a distance environment (Lionarakis, 1998).

Earlier still, Devlin (1989), in a critical reply to Holmberg regarding the extent to which distance education can be considered an independent discipline, notes that: “the concept of ‘distance’ is a self-evident though misunderstood point of reference. The concept should be replaced by its geographical and spatial interpretation and provided with a psychosocial framework”. Along with the psychosocial framework, it is also in need of a pedagogical and educational dimension which would shed light on a number of teaching and learning issues as well as on educational choices of various types, and which would mark distance education out as an independent field within the educational sciences subject to clear and specific influences from other disciplines which we will analyze below.

‘Polymorphic distance education’, or more simply ‘polymorphic education’, is a term which conveys the actual dimension of our selected definition. ‘Distance’ still defines the geographical and spatial capability of alternative choices; ‘education’ places it squarely in the sphere of pedagogics, educational institutions and the educational sciences; and ‘polymorphic’ defines the multiple choices and approaches available, rendering it an educational process with content similar to that of formal or informal educational of every type and form.

The polymorphicity of distance education represents a perception, a dimension, a philosophy and a methodology of specific pedagogical practices of learning and teaching. In practice, it is multidimensional, multi-functional, flexible, mass, individualized, democratic, adaptable, high quality, effective, distance, face to face, conventional, interdisciplinary, multi-level, complementary, open to digital technology, and receptive to a number of alternative choices and applications.
The theory in outline

Demou (1990), interpreting Popper (1980) and Herrmann (1978) on the construction of scientific theories, stresses that “only a theory that has established itself and holds can be applied, which is to say that the technological (methodological) practices of the position can be revealed. These technological positions, which is to say the practical problem-solving measures, cannot be derived from a logical transformation of the theory. Even when there is a current theory on practical problems, the solutions (technological positions) to these problems must emerge through research, apart from the theory, and not be deduced from it solely as a logical consequence”. These solutions must to some extent be led by theoretical hypotheses. The technological positions, which also define the empirical methodology of the knowledge fields, must function and be applied and tested so as to be compatible with the theory in question. As Demou goes on to mention, the issue here is that should the theory, the technological positions and the methodology be incompatible, one of two things holds true: either the theory is not ‘true’, or the technology is not as effective as the theory supposes. He concludes by noting that for every current theory there must be an empirically and methodologically tested technology, or, put differently, every effective technology presupposes a current theory. Theories are always tested empirically as they take shape. To be tested, it must become operational: to define certain presuppositions that will permit it to function and to be applied.

Once science was established, scientists’ first endeavour was to keep the positions and principles of every science separate, while simultaneously creating a common hub of research interest in the nature of the educational process (Carr & Kemmis, 2002). Although this process lasted many decades, because, stemming as it did from the development of psychology, education took time to establish itself as a structured theory, it succeeded in the early 20th century in developing in tandem with new sciences such as medicine, psychology and sociology.

Hirst (1966) defines the features of this educational theory thus:

• It is a theory within whose framework principles defining what must be done with regard to a series of practical activities take shape and acquire legitimacy.

• The theory per se does not constitute an autonomous form of knowledge or a science in its own right. It enjoys neither exclusivity, nor its own conceptual framework with its own logical features, nor special tests of validity. Many of its central questions are in actual fact ethical in nature, and relate to a specific level of generalization; meaning they are questions that focus on educational practice.

• Educational theory is not a purely theoretical sphere of knowledge since it aims at the formation of practical principles. Nonetheless, it is complex in nature, just like other, similar scientific fields.

• The legitimacy of educational principles rests entirely on forms of knowledge which drawn directly on fields such as the natural sciences, philosophy, and history. It requires no theoretical composition above and beyond these forms of knowledge.
In the case of distance education, with the exception of Holmberg’s theoretical analyses, recent years have not witnessed the development of an analytical, philosophical approach to theory formation. The reasons why this is so may well also explain the lack of systematic philosophical analyses in general for a theory of distance education. These reasons focus on the nature of distance education, given that the emergence and—especially—the development of distance education stemmed from various scientific and philosophical views and practices. There can be little doubt, therefore, that distance learning began with the educational sciences, developed in tandem with theories of communication and the mass media, was enhanced by the development of new approaches to the educational sciences (counselling, adult education, anti-authoritarian and collaborative learning, lifelong learning, new issues raised with regard to theories of learning and teaching techniques/theories, etc.), before finally entering into an intense discourse with information and communication technologies (Figure 1). The main reason is the continuation, and ultimately the completion, of the quest for thematic convergence with regard to the nature of distance education, as well as its delimitation in a structured and clear theoretical and empirical dimension.

Before we embark on a journey through the complex aspects of distance education, we should clarify certain points that will help us have and understand a common language with common symbols and semantic references. There points are centred on the following thematic spheres:

- On the relations that take shape as part of education—conventional, but distance, too—pedagogics, theories of learning, communication, the sociology of education and its technologies;
- In the concept—interpretation—delimitation—definition of distance education itself;
- In the ways in which—and criteria with which—we select, employ and define concepts such as teaching, learning, education, open education, pedagogics, communication, evaluation, counselling, research, teaching materials, learning materials, learning and teaching environment, interaction, feedback, design and involvement, student, teaching, teacher, guidance.

It is very wrong to view distance education fragmentarily and independently of other scientific fields or academic disciplines. Just as the interpretation and understanding of conventional education and pedagogics reference and are akin to a series of other academic fields, so too with distance education. Being at a ‘distance’ does not legitimize it as something apart from conventional education. It is still education, and still contains all those elements that define it at every stage in its application. The difference is that the concept of ‘distance’ brings certain new elements into play that need to be defined with the utmost care, and which must satisfy the requirements and preconditions of any educational schema which functions at a distance. And there are many. They apply a strategy that forces them to create educational models adapted to their needs, whether these are open universities, distance education units within conventional universities, educational schemata at a primary or secondary level, or professional training. This is the only
explanation for the wide range of distance education institutions which are often significantly different in terms of their infrastructure, teaching, student support, choices regarding the means of conveying information, etc. It is these new elements that define distance education which we are called upon to define, analyze and differentiate so that the theory and practice of distance education can achieve integration as a structured and expanded scientific field. Distance education is an amalgam of various forms of the educational act, which led, through a prolonged practice of application and through maturity, to a contemporary and integrated educational whole. Older educational forms including adult education, education by correspondence, anti-authoritarian education, open learning or open education, part-time education, lifelong learning, technology-assisted or based education, counselling etc. whose features developed gradually over time, led to a contemporary system of education capable of functioning with all the requisite features of a conventional educational system.

In 1983, Moore published a research paper in which he surveyed and analyzed 2000 articles relating to adult, open, independent, informal education. He concluded that all the above present two significant variables for research: infrastructure and autonomy.

Saba (2005) argues that most technological institutes in the US approach distance education through a natural sciences perspective and not as an integrated system. It is indeed the case that a perspective which begins in various technological institutes interprets distance education mechanistically as a practice in which the teacher and the learner are at a distance in spatial and temporal terms. Though this perspective is wrongly conceived, it does constitute a half truth. The contemporary interpretations and approaches of recent years define distance education in a social context. More specifically, the relationships that develop in an educational environment between those teaching, those being taught and the educational material, comprise an exchange which functions in social terms.
Criteria for a theory of distance education

According to Popper (1980), theoreticians and researchers aim to locate and explore explanatory and interpretative theories based on true logical thoughts; which is to say they aim to explore theories which describe structured qualities of the world and which, with the help of certain initial preconditions, allow us to make conclusions that demand explanations. Demou (1990), interpreting the models proposed by Popper (1980), Albert (1972) and Opp (1972), states the need for certain preconditions and elements without which we are not in a position to establish a scientific theory. Accordingly, a theory must “inform”, must be “true” and “clear”, must be in the form “if this, then that”, and be “free of social and moral rules and values”. We shall return to these preconditions once we have examined the approach taken by Holmberg (1986) with regard to the formation of a theory on distance education. Holmberg’s approach is primarily of interest in allowing us to examine the specific features of distance education. We shall have to approach Demos’ preconditions on the basis of the features to be analyzed in order to be ready to draw up a plan of action. A nodal point in both approaches is the consistency of “if A then B” or “the larger A is, the larger/smaller B is” hypotheses.

It would be at best unfair to omit to mention that Holmberg’s approach is based on principles current in the early 1980s, when certain preconditions of an educational nature were in force which also shaped his philosophical approach. Fully aware of the significance of this, we should note that a series of fundamental principles and conditions then current have since acquired a different weight. And there is something else: key elements of distance education defined on the basis of the educational background of Anglo-Saxon societies in the planet’s Northern hemisphere and considered self-evident educational criteria at the time are not self-evident in the southern hemisphere or in other areas with diametrically opposed educational backgrounds and academic environments.

Holmberg sort the points involved in producing a theory of distance education into three categories:

• General principles
• Methods and means of distance education
• Organization

Though we will not dwell on these points, which are beyond the ambit of the current paper, we can take time to define those points which have been largely responsible for moulding the core of distance education in recent years, and which are not a functional element of Holmberg’s approach. That he does not touch upon issues relating to the use of communication and information technology in the distance education process is typical and understandable given when he was writing. Also typical—though not, in this case, understandable—is his point to mention not the interaction between those being taught and the tutor/counsellor/educational institution, but the interaction between those being taught and the teaching material. Although he does refer to the special educational features of the developed world, he does not focus on typical features of distance education in
terms of interactive teaching material and, more generally, on the methodological and qualitative prerequisites of the material. The academic environment and educational background are assigned an importance whose consequences we have witnessed in a number of languages / countries, too. I am referring, as Holmberg seems to be doing, to the lack of structured analytical and scientific writing with references to the Anglo-Saxon methodology which focuses on the explanatory clarity of academic discourse.

Let us return to the approach outlined in Demou (1990), which lists certain prerequisites for our being in a position to establish a scientific theory. According to Demou, a theory must “inform”, must be logically “true” and “clear”, must be in the form “if this, then that” and be “free of social and moral rules and values”. What we do is to implant certain elements of distance education amidst these elements with a view to mapping a theory of distance education for the first time, though with one difference: we clearly diverge from Demos’ last point in relation to the theory of distance education. An educational theory cannot and must not be exempt from social and ethical rules and values. Distance education theory is a critical theory which circumscribes all those elements of social thought that define people’s values, crises and ethical rules. The theory exists in a context which is addressed by the social sciences. At the same time, the theory of distance education does not conform with normative generalizations which can be used to make specific predictions of a technical nature. Not does it conform to the desires of certain social groups by producing desirable situations and directed critical thought. Rational thought remains scientific thought and cannot be deprived of values, moral laws, or critical and evaluative constituents. In the sphere of social scientific principles, the theory of distance education is clearly rational, demands scientific thought, and forms values and social givens into critical theory.

The theory of distance education is, first of all, true, because the positions with which it informs and functions hold as events and facts. They hold, because the history of distance education theory, which is limited to a few decades, has worked effectively and productively while being enriched both by our experiences and by historical discoveries made during those decades (radio, television, video, information and communication technology, enhanced printed material, effective studies and specific curricula, effective evaluation of the act of education and its methodology etc.). Distance education has functioned effectively on the basis of its independent and critical scientific field, which has been enhanced by related scientific fields and by the application of specific tried and tested criteria, methods and means.

It also provides information on the whole range of its activities, on the field of knowledge it negotiates, and on the educational conditions and experiential applications with which it works. Together, its research, theoretical approaches and integrated academic functions compose a knowledge field which has provided samples that go a long way towards documenting and explaining phenomena, events and problems.

The theory of distance education is clear with respect to the manner in which its particular features and content are depicted. Its contribution to the points of clarity became boundless when the theory began to function and develop worldwide, having delimited and interpreted a series of concepts, key words, learning and
teaching processes and educational terms which form the core of its tools.

Distance education theory is in the form “if this, then that” because it is clear that the ‘if’ precisely determines the ‘then’. At this point, the dimension of measurability—a prerequisite for its efficacy—imposes a logical consistency beginning with its theoretical and empirical points of reference. In the formation of a scientific application, distance education records the “if this” and ensures that it is availability when it comes to confirming the “then that” in practice.

As a critical social theory, the theory of distance education is not free of social and moral rules and values, and can be described in advance or in retrospect as good or bad, beneficial or not, proper or improper.

In addition, it can be assessed in terms of its determinism in relation to moral questions, because, being independent of rules and values, it also functions as a specific scientific field with specific educational applications. Interpreted in social terms, it boasts a potential which assigns it a social role and a responsibility to achieve its goals and maximize its effectiveness. Its availability in lifelong learning and its functionality in the formation of democratic educational practices in issues relating to its accessibility and flexibility to the benefit of students, makes it intensify its presence and its necessity. Yet this ab initio potential in no way effects its moral rules, actually rendering it independent and autonomous in its scientific activities and applications.

A theory on education is also a social theory which defines a series of social actions and which must respond to the major issues facing society. At the same time, however, we have reached the final point which determines the social conscience of a scientific theory. The exchange between a scientific and social theory on the one hand and social facts, moral laws and accepted values on the other, does not legitimize arbitrary action taken in the name of scientific thought; it makes it the judge of social and educational applications. The application of and search for scientific thought is not a technical matter; it does not seek to answer “what happened” or “how something happened”. A structured theory of polymorphic distance education provides an answer to the question “what should happen”, “why it happened” or “what should have happened”.

**Conclusion**

This attempt at outlining a distance education theory synthesizes theoretical approaches and experiential applications which have arisen from the research conducted by the international academic community and out of the first stages in the creation and operation of several Open and Distance Universities. This approach undoubtedly constitutes a step towards the formation of a theory of distance education, which is apparently passing from childhood to a prestigious maturity of proven scientific applicability. Its academic substance will inevitably be enriched by the steps it takes in the future; steps which will certainly render it more effective. Moreover, its educational practices and all that they entail will allow an analytical and interpretative mapping of distance education theory to be drawn in the near future.
The critical approach adopted in Carr & Kemmis (2002) confirms the view that the typical features of a scientific theory are its inductive nature and its ability to be monitored experientially. In the context of today’s self-satisfied science, critical theorists sensed that contemporary society was in grave danger: the end of logic was looming. Logic had been replaced by technique, critical social thought by scientific norms. The success of the physical sciences had created conditions under which the imaginary quests of the scientists in the realm of the unexplained had become compatible with established modes of thought. Science became ideology, a way of viewing the world, a cultural and social factor moulding and guiding social activity. The role of science was therefore to ‘legitimate’ social action by providing ‘objective events’ which would provide a justification for the processes of the action. Questions relating to the values underlying these action processes lay beyond the horizons of science, and remaining unexplored as a consequence. Scientific conclusions differed solely in being more or less effective modi operandi and explained how things happened and not whether they should have been allowed to happen. Science, far from being pure research into the nature of society and social behaviour, was in danger of taking the forms of social life as given and only investigating ‘technical’ matters. Carr & Kemmis (2002).

References

4. Devlin, E. Lawrence, (1989). Distance Education is not a Discipline, 2: Distance Education as a Discipline: a Response to Holmberg, Journal of Distance Education, Vol. 4.1/10
Open and Distance Learning (pp 499 – 505). European Distance Education Network, University of Bologna


Promoting broadband connections and interactive content for educational purposes in the context of modern European policies: The case of the D-Space Project

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Abstract

The aim of the present work is to discuss how several European initiatives (as performed in the context of modern innovative activities) with particular emphasis given to the outcome and/or the procedures considered from the latest progress of the European “Discovery Space” Research Project (eTEN 2004, Grant Agreement C517339), can either facilitate didactic purposes or support advancement of novel educational and learning facilities in the scope of the converged electronic communications market. More specifically, we focus our study upon two major European policy priorities which also constitute strategic requirements/pre-conditions for the successful development of the “Discovery Space” Project. Thus, we examine the expansion and the efficient dispersion of broadband (Internet-based) infrastructures (and of related facilities) in parallel with the creation and the efficient adoption of interactive (multimedia-based) thematic content, both acting as practical “enablers” for the immediate realization of the European expectations in the sector. We explain how targets and experiences gained from the specific Project’s activities are all fully aligned to European main concerns for broadband penetration and for the creation/distribution/offering of innovative digital content, thus fulfilling fundamental European expectations for growth.
Introduction – the European Evolutionary process towards an “Information Society for All”

In the framework of the rapid evolution of the European internal market, various digital communications-based activities have become an essential priority for both governments and businesses. In particular, all these constitute important elements for widespread access to the information society for citizens and enterprises, towards designing and properly developing a modern “knowledge-based economy”, in order to cover multiple areas. Innovative technologies (and the related commercial initiatives) affect numerous sectors of our every-day life, reduce social exclusion and create the potential for growth and employment, by opening new ways of participating in society. The dispersion of creative electronic communications services and facilities, together with the extended penetration of the worldwide Internet (and of all related “underlying” network infrastructures) have totally transformed the “layout” of modern societies, thus offering significant advantages for further progress [1].

In fact, stimulating use and creating new services has become the “central goal” of modern European policy objectives (as clearly expressed in remarkable strategic frameworks, like the “eEurope-2005” [2] and the most recent “i2010” [3]). The overall aims expressed in official European Union’s (EU) documentation are that Europe should have modern online publicly accessed services (i.e. e-Learning, e-Government, e-Health) and a dynamic e-Business environment, based on the ubiquitous availability of broadband access at competitive prices, and a secure information infrastructure. The core objective is to “make the EU the most dynamic, competitive, sustainable knowledge-based economy, enjoying full employment and strengthened economic and social cohesion”.

The D-SPACE project as a “Driver” for the promotion of e-learning facilities

Among the most significant priorities of the European “digital economy” are several selected initiatives for the effective promotion of e-Learning applications, mainly to enhance tomorrow’s education and to make stronger Europe’s global competitiveness. The use of new multimedia technologies and the Internet [4] can improve the quality of learning by facilitating access to resources and services, and support remote teaching exchanges and international collaboration. The target is to allow Europe to take advantage of its strengths and to go beyond any potential barriers restraining the uptake of digital technologies. Thus, specific care has been already spent in the areas of research, innovation, education and training, aiming to increase efficiency efforts by pursuing a more integrated approach and by placing these policies under a common banner: an everlasting European area of knowledge!

The recently developed European “Discovery Space” (“D-Space”) Research Project
(http://www.discoveryspace.net) aims at adding its contribution to the main objective of the European eTEN Work Program 2004, which is the deployment of services for “An Information Society for All”, mainly following the targets of the fundamental e-Learning thematic activities.

The prime purpose of the Project [5] is to establish a modern distributed virtual “network” of science centres and robotic telescopes all over the world, accessed by students, educators, researchers and the wider public (e.g. amateur astronomers, visitors of science parks, etc.) via the universal Internet. This can be performed through the appropriate usage of a modern web-based interface that will provide automated scheduling of the telescopes, together with a great variety of tools for data manipulation, analysis and access to an unlimited “library of information” and to extended resources/material, for lifelong learners. Thus, potential users can continuously enjoy professional-quality data collected from local sites via the operation of modern broadband (Internet-based) facilities, permitting (always-on) on-line connection, at high speed, and supporting multimedia options. The Project seeks to enhance science education and enable learners to participate in the procedures of knowledge by designing and carrying out astronomy observations, and promoting their own science activities and works. In this way, apart from its purely educational- and scientific- oriented purposes, the Project can serve the purpose of “making astronomy a popular science for the non-professional users” and offer modern forms of digital content, originating from quite fascinating areas of sciences [6].

Moreover, the “D-Space service” is focusing on defining the potential changes and the qualitative upgrade that may be brought to the teaching procedure through the use of innovative technological applications (such as the on-line use of robotic telescopes). Thus, it is aiming at providing a better understanding of how e-Learning can improve and enrich teaching and learning, both in science and technology.

**Broadband Evolution: A pre-requisite for the effectiveness of the D-SPACE initiative**

As already mentioned, the D-Space portfolio of services intends to promote (and gradually to fully adopt) the usage of broadband communication channels as the “basic means” of interaction and data transfer mechanism between the telescopes and the remotely located users around the world; in this way, the effective and fast response of all related applications offered can be adequately safeguarded, thus offering a variety of significant benefits to the end-users involved; the latter cover several distinct categories, but they all act in the wider environment of the digitally converged world: In fact, the nature of the entire scope of the facilities offered by the D-Space Project is fully conformant both to the specific requirements and the benefits the “broadband” perspective. (Actually, the European Commission has aligned the current eTEN initiative -where the D-Space Project performs its variable activities- with the goals of modern policy initiatives, which include the
wide availability and use of broadband, aiming to accelerate the expansion of information and communication technologies (ICT) in general interest services and in modern areas, such as e-Learning) [7].

In particular, broadband communications can create a physical backbone for bringing the knowledge economy to every part of the world. Consequently, the ability to generate and use knowledge - be it through science, skills or people as happens in the case of the Discovery Space Project - is the key to ensure that market operators can continue to innovate and compete and that citizens can participate more fully in society. Simultaneously, broadband offers significant options in terms of the quality of services delivered. For example, distance education (using e-Learning) and entertainment/informative activities can become more practical and often feasible only through the high-speed provided by broadband access, permitting the combined use of multimedia facilities, in various formats. (For example, according to the eEurope 2005 Action plan, Member States had to ensure adequate broadband infrastructures for all schools, universities, museums, libraries, archives and similar institutions, able to play a key-role in e-Learning). The adoption of such applications into our daily life, and the opening of new corresponding markets, can improve quality of life, increase productivity and stimulate innovation [8].

Broadband is currently available mainly over existing infrastructure, in particular over the telephone copper network using ADSL (Asymmetric Digital Subscriber Line) technology, and over cable TV networks using cable modems. (However, under suitable terms and/or conditions, broadband access can be also delivered over new types of networks, such as fibre optic, fixed wireless access (FWA), third-generation mobile systems, R-LANs (Radio Local Area Networks), satellite communication systems, free-space optics and through electric power line transmission, depending on the extent of the penetration of such facilities in the relevant “underlying” electronic communications markets). Under this scope, actions on broadband can further affect the roll-out of Internet-based infrastructures and stimulate the development of all relevant content and applications, as “fast Internet connections are the essential basis of a world-class infrastructure for the knowledge-based society”. Internet has nowadays become the most important medium for the transmission of information and communication, and its efficient usage and penetration are expected to be higher in the future. High-speed and permanent connections (“broadband capacity”) permit the instantaneous transmission of large volumes of data, therefore changing Internet’s overall presentation. Due to its “open” and transparent architecture, to its “unlimited” opportunities and to its innovative profile which is very easily accessible by anyone, at any time, from any place, the Internet is an ideal “platform” for the promotion of innovation, especially in the context of e-Learning facilities, thus allowing for easy adaptations/modifications. Consequently, broadband Internet access is a key-factor for improving the performance of the wider knowledge-based economy, as a whole [9]. The D-Space service is directly addressing this goal by using the possibilities the Internet offers in order to transform the today’s classroom to an innovative research laboratory.
Achieving widespread access by all citizens to new information society services and applications is one of the major goals of the EU. The possibility to access such services and applications via multiple terminals and by using several possible network platforms creates significant economic and social opportunities, advances innovation, offers freedom of choice and enhances market competition [10]. These are basic pre-conditions for the success of the D-Space Project, as it intends to serve multiple users, in multiple areas, and to offer access to interactive multimedia options (on real time).

**Creation and Distribution: A pre-requisite of innovative content and services**

The evolution of the digital era and the emergence of broadband influence the life of every citizen in the EU by, inter alia, stimulating access to knowledge and new ways of acquiring information, thus increasing claims for new content, applications and services. At present, innovation in services is mainly driven by new offerings that respond to customer demand(s). But increasingly services are also driven by higher research investment and depend on the adoption of new technologies.

The D-Space Project has been planned and developed in the scope of the existing digital convergence of information society and media services, networks and devices, aiming to offer inventive content from an immense variety of astronomy-related fields. Its strong relation to educational and learning policy priorities, to fulfil variable requirements from different audiences, imposes the necessity for the creation, update, distribution and classification of innovative multimedia-oriented digital content in several (combined) formats (e.g. video, audio, films, images-photographs, texts, etc.). The thematic sources of astronomical activities are practically “unlimited”, while these have always attracted human interests, for different reasons. As there major opportunities to examine/study live scientific phenomena and experiments, the Project intends to provide adequate information to satisfy diverse users’ needs, particularly to encourage e-Learning options. This constitutes a “core” feature which also promotes the need for strong interactivity and easy access, so that to facilitate the emergence of new services that are “born digital” [11].

Technological advances offer the potential to add value to content in the form of “embedded” knowledge and to improve interoperability at the service level, which is fundamental to accessing and using digital content.

In any case, it is a major priority for Europe to support and to ensure the availability of on-line digital content for high-speed networks, by increasing legal and economic certainty to encourage the occurrence of new services (as digital content is completely machine-processable information). Since a large number of users now have access to (Internet-based) infrastructures and services, this allows the delivery of many types of digital data, thus creating huge market
opportunities in the development of attractive content (and services) that will benefit both the user and the economy [12]. The D-Space Project fulfils quite satisfactorily the essential challenges for the creation/offering of content, ensuring lasting accessibility and the development of novel services. Simultaneously, the management and dispersion of content offered, due to its nature, can support creativity, collaborative work, adaptability and intercultural communication. The entire Project’s effectiveness is to make the relevant digital information more accessible, usable and exploitable, to facilitate construction and diffusion of data and to stimulate content enrichment [13] especially in formal education and training programmes, in non-formal general education and in continuing vocational training courses, as well as for self-learning.

As the nature of content is very rapidly changing in a fully converged environment, this may occasionally create several “weaknesses” in the on-line distribution and information activities carried out on global networks. Thus, any choice to encourage the development, promotion and delivery of audio-visual content and of multimedia-based products, towards promoting the dissemination of suitable scientific and educational activities over the Internet, can be a “proper” response to the corresponding challenges.

Audiovisual and multimedia content are driving forces for the success of the new technologies (in general and broadband in particular). Consequently, it is important for the EU to play a guiding role in the global sector, e.g. by supporting content providers and fostering the emergence of (added-value) innovative services. Experience has demonstrated that the advance of new services and content can be delayed by a variety of obstacles [14]: Some are of a regulatory nature, such as the development and acceptability of systems that allow the legitimate use of content compatible with existing rules on intellectual property rights. Others are linked to the market place, such as the difficulty of establishing systems or problems of interoperability, lack of user friendliness and accessibility (at affordable cost) and situations where new services compete with already existing ones. It should be expected that the growth of the market for modern services and related content will depend on the capacity to find adequate solutions to this long list of issues, which concern both the public and the private sectors [15].

However, especially for the D-Space Project, most of these “barriers” seem to have been already successfully overcome, as the context of the novel facilities offered implicates proper market practices, fully aligned with European priorities for growth. In addition, when adequately placed at the heart of competitive and liberalized business activities (as exactly happens in the Project) research and innovation can become motors of wealth generation and growth.

The Project can affect and enhance education and training systems within a lifelong learning European (and global) perspective, creating a virtual network of excellence in research and education.
Conclusion

The European economy and more specifically the education and training domains are facing significant challenges in the scope of the modern, digitally converged, “era”. In fact, all efforts for the promotion/enhancement of e-Learning activities necessitate fundamental prerequisites, among which are reliable ICTs with high-bandwidth connectivity and high-quality content (and services), able to support innovative approaches-methods for educational and teaching purposes.

The European “Discovery Space” Research Program has been successfully developed to support novelty in the sector of the knowledge economy. Among its core achievements is the requirement for the establishment and usage of appropriate (fixed and/or wireless) broadband communications together with the development/offering of new forms of interactive content, able to be efficiently accessed on multimedia environments, thus contributing to learning and teaching activities. Both these issues are at the front-line of the contemporary European policies, as they help generate demand for new applications and services and provide means for market actors to increase productivity through process innovation.

References


The Contribution of Inquiry-Based Argumentation in Science Museums to Scientific Literacy of Students and Citizens.

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Abstract

Activities in science museums have a great potential for meaningful learning in science, which may promote scientific literacy. They attract and engage the students, as well as enabling them to experience and experiment with “hands on” activities. However, this potential is not always fully tapped. Combining inquiry-based and argumentation-based approaches, we believe that integrating computerized discussions using Digalo (a tool for graphical argumentative synchronous discussions) with instruction and exploration of exhibits, through carefully structuring and sequencing activities, may be an effective solution. In this paper we present an argumentation-and-inquiry-based layout for a school students’ visit in a science museum using a structured sequence of activities. Initial observations of 2 such visits are reported and analyzed and conclusions are briefly discussed1.

Introduction

The need for science literacy in our era is very significant. A multitude of products, events, media channels and even our understanding of the way our own bodies

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1 This research was conducted under the EC-funded ESCALATE project.
function, call for scientific literacy. But what is the appropriate way to gain scientific literacy for students and for citizens in general? Within the formal framework of science learning it is very difficult to attain real scientific literacy, due to various reasons. One of them is a strict curriculum, imposed by schools and institutional authorities. Another reason concerns the setting of learning in schools, where science lessons are conducted away from real scientific phenomena. More than that, educational institutions are currently emphasizing the delivery of scientific information (Johnson, 2002).

Learning in science museums, on the other hand, has no such curricular constraints and enables the learners to select their own learning path within an exhibition. Informal learning within science museums is based on the “attraction → engagement → ownership” model (Johnson, 2002). Additionally, the learning environment in the science museum enables learners’ “hands on” activities (Johnson, 2002), allowing for experimenting with the phenomena discussed within a real scientific context.

It would appear then, that activities in science museums have a great potential for meaningful learning in science, which may promote scientific literacy. We must consider, then, how to efficiently tap this potential.

In this paper we present an argumentation-based layout for a school students’ visit in a science museum using a structured sequence of activities. Argumentation-based learning environments, widely recognized in recent years (Kuhn, D. 1993), have had an effect on the understanding and design of learning and teaching in different disciplines (e.g Duschl, R.A., & Hamilton, R.J. 1997). Science education, in particular, is gradually moving towards learning through argumentative reasoning and argumentative communication (Schwarz, B. B., & Glassner, A., in press). Such activities are often ICT-mediated. Science education also favors an inquiry-based approach where students can experiment with and create artifacts and models for scientific work.

This research was conducted under the Escalate project No: 020790 which focuses on disseminating inquiry-based and argumentative activities in science teaching, both in formal and informal environments.

The technological tool we use is DIGALO (http://dunes.gr), a graphical e-discussion tool in which discussions are held within an object space called a “map”. Users contribute to the discussion by adding shapes representing argumentative ontology, and typing their text into them. Users may also link shapes to other shapes using different types of links (support, opposition, reference). Using Digalo in the context of a science-museum activity enables the visitors to elaborate on their scientific concepts regarding certain exhibits, to express their views and pre-conceptions and to benefit from the views of others. The instructor in the museum may use the tool to facilitate discussion about crucial scientific issues related to the activities undertaken, and to do so in a way that will promote participation and engagement. These advantages are valuable in formal learning but they have a special importance when it comes to activities in science museums, because of the “ad hoc” characteristics of such activities, forcing the action to be well designed and well thought out.

Due to the richness of the science museum’s learning environment the students are motivated to understand why a certain phenomenon exists. This initial willingness
may be capitalized upon using a structured sequence of activities, in which they are first triggered by hands-on activities, and then guided to discuss their experiences, pre-conceptions and opinions in an inquiry-based and argumentative manner. The discussion stage is done f2f and with the use of the Digalo tool. This “preparatory stage” leads the students’ attention and curiosity to the subsequent summary of the scientifically-accepted facts and definitions conducted by the instructor. We believe that this sequence allows for a “bottom up approach” of relying on students’ talk and actual understanding of scientific phenomena in scientific explanations.

**Methodology and procedure**

In this pilot stage, we have observed 3 groups during two visits to the Bloomfield Science Museum, Jerusalem, as explained below. Using free observation, videotape recordings and Digalo maps, our pedagogical experts combined qualitative and descriptive approaches to offer insights and directions for future research and development.

1. Visit 1: The visitors were 22 girls (8th grade) from a school for girls in Jerusalem. The visit took place on 30.11.2006 and lasted for 2 hours and a half.

2. Visit 2: The visitors were 18 students, a mixed group of boys and girls (grades 8th up to 12th). The visit took place on 5.12.2006 and lasted for two hours.

**Detailed description and observations of the museum visits**

Visit 1:

Two group of 10-11 students worked in parallel.

The first group’s sequence:

1. Light bulbs Workshop: the girls were given the assignment of using various materials in order to find an appropriate one to use in an incandescent light bulb.

2. Free tour: guided “hands on” tour in the science museum.

3. Different kinds of light bulbs: the girls were introduced to different kinds of light bulbs that are based on different principles and have different properties.
4. **Digalo discussion:** the girls had a workshop in which they had to discuss the following question: “which bulb would you suggest to use in a sewing factory. The tool used for this discussion was Digalo. They worked in 3 teams of 3 members each. Every team presented its opinion and related to other teams’ opinions via adding shapes and links in the Digalo discussion map (see fig.1). During the activity there have been different kinds of light bulbs which the girls could use and test for examining their attitudes.

5. **Discussion in the plenary:** The instructor presented the Digalo maps created by the groups and a discussion took place.

6. **Spectrum workshop:** the girls had a workshop in which the light spectrum and its different kind of radiations were introduced.

The second group’s sequence was:

1. Different kinds of light bulbs.
2. Spectrum workshop.
3. Light bulbs Workshop.
5. Digalo discussion
6. Discussion in the plenary.

There were some other differences between the two groups:

**Presenting the question:** the girls of the first group were instructed to think (specifically) about a sewing factory. They had to consider various aspects such as cost and quality of light. The second group was told only that they had to suggest a light bulb for a factory producing very small products, i.e. the instructions about aspects to consider were more general.

**Tables:** the second group was given tables showing characteristics of different light bulbs which the first group didn’t get.

**Digalo:** As the students had to work in groups with the Digalo maps, they were negotiating their ideas prior to adding their written contribution to the map. It was apparent that the group members were typically very cautious when contributing. Interesting points during the discussion in Digalo:

- The second group (who had the tables) tended to concentrate on the tables rather than on testing the light bulbs. On the other hand, the group compared data that appeared in a table with the real bulbs exhibit.
- The second group conducted a discussion about light bulbs, using data from the table.
Fig 1. The first group

Fig 2. The second group
It seems that the map created by the group that got the tables (the 2nd group) was richer than the other group’s map. Our observations of the videos from these activities show that the use of the tables (which contained useful data about bulbs) helped the students with their arguments. Also, while reading the data the students turned to the exhibits to confirm their observations regarding the color and strength of light.

In the second group we see three main opinions: one opinion favoring the discharge bulb, using its high efficiency and long duration as explanations, a second opinion favoring the sodium bulb and explaining this choice with its low cost of use and high efficiency, and a third opinion favoring the mercury bulb for its very high efficiency and its very white and strong light.

Discussion in the plenary: the average time for this discussion was 15 minutes.

- It was interesting to note that in many cases the students used their written sentences in the Digalo maps as an opening for their presentations even in cases where they didn’t actually see the maps beforehand. During the plenary, students were challenged to say something new, and were criticized by their peers if their contributions they presented (in the map) repeated arguments which were already stated orally.
- One girl in the first group searched deliberately for opponents to her view.
- One girl in the second group said that first we have to find the appropriate bulbs and then to see which is the least expensive among them.
- The third team in the first group was disappointed. The team said that after the two other teams presented their views and explanations, they haven’t been left with nothing new to say.
- In the first group the girls were introduced to the kind of light bulbs used in the science museum for strong lighting. They were told that the need to use such a strong light derives from the great height of the ceiling in some places in the science museum. Part of them tended to suggest alternative solutions for posing the light bulbs, although they weren’t asked to suggest such solutions.

Visit 2:
In contrast to the first activity, all 18 visiting students were instructed and activated as one group. The activity lasted 2 hours.
The group worked according to the following sequence:

1. Presenting exhibits: The students were introduced to four different “hands on” exhibits. One exhibit concerned transmitting communication through copper wires, a means of communication that allows eavesdropping on the transmitted data. Another exhibit concerned transmitting communication via light, through optic fibers, a means of communication that doesn’t allow eavesdropping.
2. Digalo discussion/workshop: The group members had a workshop in which they had to discuss the following question: “the city of Modi’in has a built-in optic fibers network for communication. Is the choice of optic fibers as a means of communication good? Explain your opinion and compare this choice to alternative possibilities”. The tool for discussing this was Digalo, as in visit 1. They worked in 4 teams of 4-5 members each. Every team presented its opinion and related to other teams’ opinions.

The question was selected because of the personal context (the students were from Modi’in).

During the discussion, the students were given the opportunity to use the nearby exhibit of optic fibers they had experienced before. Also, a miniaturized model of this exhibit was placed before them for the duration of the discussion, and they were able to use it when needed. During the work with Digalo, 2-3 students have used this miniaturized model. During the work with Digalo, students preferred to used only the miniaturized model.

3. Discussion in the plenary: every group sent a delegate to present its opinion. A discussion developed. Sometimes discussions occurred in small groups in parallel to the plenary discussion. The instructor presented the Digalo maps to the students and further discussion took place. The discussion in the plenary concerned aspects such as the high cost of optic fibers in contrast with the low cost of other alternatives, technological problems and the dangers of cellular communication (one of the alternatives for communication). One student said that the problem with using copper wire (rather than optic fibers) is that it’s not flexible. This erroneous statement was addressed by the guide who presented the student with the correct fact – the copper wire is flexible. The discussion was very enthusiastic and students said they enjoyed the activity. The escorting teacher, who participated throughout the visit’s activities, also expressed her satisfaction.

Discussion

Benefits
Based on our observations of the visits described above, we believe that inquiry-based argumentation in science museums may have several possible benefits regarding science literacy. These benefits are related to motivation, scientific discourse, and the relationship between the context and the students’ involvement.

Motivation:
The integration of inquiry and argumentation seems to strengthen the wish of the participants to involve in scientific activity through argumentation. Evidence to this is the interaction of the girls’ group in the first visit and the very enthusiastic and enjoyable discussion in the second visit. The inquiry-based argumentation approach’s contribution to the students’ motivation seems to have been twofold: the opportunity to interact with the science museum exhibits and the opportunity
to discuss a question together, based on the experience gained with these interactively used exhibits.

**Scientific discourse — the way science is being done:**
The students’ actions during these visits suggest they may have assimilated the scientific approach. One indication of this from the first visit can be found in a girl who searched for opponents to her view, an action similar to the peer review practice in science discourse. Another indication is a girl who said that first we have to find the appropriate light bulbs and then see which is the cheapest among them. Although it is an indication of assimilating a logical approach in decision making in general, it is also a common characteristic of the science process. A similar indication can be seen in the second visit, in which the plenary discussion concerned aspects like high costs, technological problems and dangers. Some students in this visit were also used a model of the exhibit to examine thoughts, a common action done by scientists.

In this regard, the use of Digalo was crucial. By documenting and reflecting the students’ thoughts and opinions, Digalo leveraged and upgraded the quality of scientific discussion. It enabled them to get a broader, clearer perspective of the discussion and made the differences in arguments and explanations stand out more.

**Context and involvement:**
The students in the two visits seemed to be involved and engaged in the activities. In every visit they were first introduced to the museum exhibits and especially to those directly related to the question they later discussed. The discussion phase took place in the setting of the museum, which may explain the involvement and engagement in the two visits. The visits were especially planned to fit the students’ world, particularly the second one (regarding the use of optic fibers in the students’ own city). The choice of the appropriate question to be discussed may have contributed to the high level of students’ involvement in the discussion. We can see it also in the first visit in which the girls were introduced to the need to use strong light bulbs in some places in the science museum (an immediate context as the museum was the arena of activity). Again, in this aspect Digalo was crucial because of its reflection possibilities.

**Conclusion**
The experiences presented hereby indicate some possible benefits of using inquiry-based argumentation approach in science museums. One such benefit is empowering the motivation of visitors. This approach may also contribute to assimilating the science discourse. Yet another possible benefit has to do with contextualizing: the inquiry-based argumentation approach is done within a context of interactive science exhibits. This setting is suitable for students’ to experiment and learn about science issues in.

Also, as previously indicated, we believe that Digalo, the graphical e-discussion tool
used by the visitors to represent their views, has a crucial importance to leverage and upgrade the inquiry-based argumentation approach in science museums. The science museum visit need it, because of the “one time use” experience, given only once to each group, forcing the action to be well designed and well thought out.

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References


Innovative School Design for Science Education

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Summary

The improvement of science education and making science more appealing to youth and students, by innovative changes and improvements at the school building and site, as a nearest learning environment, should be considered necessary and beneficial. Thus it would inspire, enrich and refine learning and creative thinking, by means of elements that connect nature and students life in and outside a school. Tracing the efforts of science educators and designers over the world we present a chosen set of design solutions, cognitive installations and patterns that can be combined to make a school building a 3D lecture book. Through such program the schools might approach toward advanced technologies, become the schools of tomorrow, and a kind of dispersed science museum.

Introduction

In designing science laboratory for tomorrow one should respect the fact that the knowledge about basic natural laws has been created and accumulated by greatest scientists through an impressive historical endeavour. This means that students should have the opportunity to repeat their experience and reasoning. Such a goal imposes that a wider space than a classroom is necessary for science education. So, an entire campus and building should be included. One needs a corridor, a courtyard, a roof, a terrace in order to incorporate devices and elements for mapping natural phenomena and studying them [1,2]. This can be achieved
treating the school building and its environment as a 3D lecture book and science lab. It is considered that science museums should and could contribute a lot to this goal.

The term “school building as a 3-D textbook of physics” was coined in 2004 by architect Fielding, founder of DesignShare [3], in a correspondence with one of the authors (M.B). The correspondence was about the project Physics in school architecture (PHYSARCH), initiated in 2003 through the World Year of Physics program of the European Physical Society [4]. Architects Fielding and Nair generated the set of design patterns which breath fresh air into the act of school design. One of the patterns is Sustainable Elements and Building as 3-D Textbook. “In a school setting, sustainable design becomes an excellent teaching tool It can become a dynamic model to teach architecture, engineering, construction, and environmental science in harmony with nature” [5]. Through PHYSARCH program educators developed patterns of educational elements incorporated into school building and its surrounding, which would stimulate and inspire learning of physics, mathematics and natural sciences.

The Annual Award program of DesignShare attracts designers all over the world. Designers of NUS school for mathematics and sciences accepted hole-heartedly the concept of a school as a 3D lecture book of science. The school was erected in Singapore in 2005 [6]. At the International Student’s competition, Design ideas for school as a lecture book of physic (organized in 2005 by the Institute of Physics and Faculty of Architecture, Belgrade) students proposed many interesting and original solutions [7].

The necessity to utilise wider school space for physics and science education has been identified during last decades by many educators. Authors of articles in Deck the Halls columns in Physics Teacher, published from 1972 to 2001 proposed many devices for demonstrations along the hallway. The articles were collected and edited by Pizzo in 2001 [1].

The world wide enthusiasm of school students performing Eratosthenes’s measurement of the Earth radius [8], clearly shows the need for real science done outdoors. Original school version of the experiment was a part of the Earth Science Curriculum Project created in the 1960’s by NSF in USA. The experiment was designed to be done in the classroom with suction cups, sticks and a globe and a light bulb to represent the sun.

J. Meinke, Earth science teacher in high school in Lakewood, Ohio, felt it could be much more real science done outdoors and with partners about the globe, who would communicate via email. Meinke developed in 1989-90 the online version of Eratosthenes experiment on FreeNet in Cleveland, Ohio [9]. Meinke’s first attempt resulted in 250 some participants, representing over 77 locations about the globe, many of which were outside USA. Since then the number of students and schools, performing this experiment all over the world has been constantly increasing. This may be seen by looking to numerous Internet sites, established to coordinate this collaborative experiment [8].

The concept of an experimental zone for developing the human senses, proposed by Hugo Kukelhaus, writer, sociologist, architect, philosopher and artist, lead to creation of Play Stations for Developing the Senses [10]. Because of
anthropomorphic structure of physics, many of these play stations are very useful for physics education. Aesthetic appearance of play stations make them useful for art education, as well.

Cognitive Installations and Patterns

In this section we will present a set of cognitive installations and patterns, proposed and developed by educators and school designers who are active in promotion and implementation of innovative school design. Proposed installations and patterns promote: science & scientific methods; rational thinking technique; scientific concepts and ideas; information & and communication necessity; scientific opinion, debate, critique, dialogue, doubts; overcoming of scientific problem and inter-disciplinary dispense; curiosity, motivation and willingness for engagement; energy saving; new aesthetics. They are applicable to: environmental issues; teaching methods and curriculum; self-education; meeting the scientists; approach to IT resources; research projects; psycho-social activities. Proposed set of devices, elements and decorations, that could be integrated into the total built form in order to serve as fan and teaching tool, includes:

**Message from Lepenski Vir**

![Fig. 1 Home base of inhabitants of Lepenski Vir](image)

Inhabitants of Lepenski Vir on Danube knew 8000 years ago to divide a circle into six equal parts [11]. The remains of their buildings are testimony of their knowledge of geometry. The base of their buildings was a trapeze, cut from an angle of 60° (Fig. 1).

By imitating inhabitants of Lepenski Vir designers of modern schools could easily design signatures of mathematical knowledge which has been crucial for the development of modern physics, geometry, theory of numbers, infinitesimal calculus... This would be very useful for mathematics and physics education.
Concentric circles drawn in a school yard to learn about number $\pi$ and about retrograde motion of planets

The meaning of number $\pi$ would be understood and remembered properly for ever if thought by measuring radiuses $r_i$ and circumferences $O_i$ of many large concentric circles (with drawn radiuses) inscribed in a courtyard. Afterwards, in a classroom students could evaluate the ratios $O_i/r_i$, compare their numerical results, calculate errors, discuss the results etc. These large concentric circles could be used for a student play to simulate the motion of planets around the Sun. This simulation would help a teacher in explaining the retrograde motion of planets on the Celestial sphere, as proposed by authors of Cosmic perspective [12a].

There are also many ways to use a cone with four characteristic sections (circle, ellipse, parabola, hyperbola) as a design element. In addition to being useful in learning mathematics it is helpful in memorizing the classification of orbits in the gravitational field [12b].

Learning about elements of infinitesimal calculus from Archimedes

Infinitesimal calculus is still a horror for most students, despite the fact that basic idea originates from Archimedes’ determination of the area of a circle, 2300 years ago. But, let us imagine that a corridor and a courtyard of a school are decorated with a series of circles having inscribed regular polygons with an increasing number of sides (Fig. 2). Living in such a surrounding students, helped by teachers of mathematics, would be reminded how Archimedes found the formula for the area of a circle. Consequently, the idea of a limit, and its use in infinitesimal calculus, would become familiar to very young students.

A class divided in groups measures circumference of a circle, a circumferences of n-side polygons and the area of their basic triangles. Then, in the classroom they compare their results and utilise the formula for the area of a triangle and for the area of a polygon.

Fig. 2 The series of circles having inscribed regular polygons with an increasing number of sides.
The surface of n-sides polygon $P_n$ is equal to $n$ times the surface $p_n$ of its basic triangle:

$$P_n = np_n, \quad p_n = \frac{a_n h_n}{2},$$

where $a_n$ denotes the side and $h_n$ the height of the basic triangle. With increasing $n$ height $h_n$ approaches the value of the radius $r$ of a circle.

$$\lim_{n \to \infty} h_n = r$$

With increasing $n$, perimeter $L_n$ of the polygon approaches the circumference $O$ of a circle.

$$\lim_{n \to \infty} L_n = \lim_{n \to \infty} na_n = 2\pi r = O$$

From the above relations one finds the formula for the surface $P_0$ of a circle.

$$\lim_{n \to \infty} P_n = P_0 = O \cdot r/2 = 2\pi r \cdot r/2 = \pi r^2$$

**Column for physics and geography**

A vertical column in the school courtyard with inscriptions like the ones at Fig. 3 may serve as a multipurpose educational device for physics and geography. Students could develop a habit to observe how the length of a shadow changes during the day, to note the moment when it reaches minimum and to relate the direction of the shadow of minimal length with a geographic north-south line. A piece of reflecting material posed on the west side of the column would help teachers and students to observe a reflected sun light through the polarizer. Such an observation would be similar to Malus’s contemplation of reflections of the
setting sun from a window of the Luxembourg Palace in Paris. He noticed how the intensity varied when he rotated the crystal. This observation lead Malus to the discovery of light polarization.

Inscriptions of the longitude, latitude and height of the place above sea level, would help students to memorize the values of these quantities in their village or town. The classical measurement of the period of a pendulum, students could do collectively in the school yard. Set of marks along the vertical, whose mutual distance increases as consecutive odd numbers, corresponds to a flash photography of a falling body in a constant gravitational field.

One of the experiments to verify the natural law of falling bodies, discovered by Galileo, uses a ball rolling along an inclined track, above which the bells are situated. Such a device built in XIX century may be seen in the Museo di storia della scienza in Florence, as well as on the Web site of this museum [13]. The distance between bells increase as consecutive odd numbers. A ball produces a sound, each time it touches one of the bells. Using a pendulum, oscillating near the bell and released from the swung position simultaneously with the start of the ball, one can verify that time intervals between sounds are mutually equal. Rašković and Pena proposed (Fig. 4) to incorporate such a device along the handrail of a staircase [14].

![Fig. 4 Tracks along staircase with bells](image)

**Water tank with holes as an educational fountain**

Fountains are very popular objects in any interior. A simple fountain, like the one sketched at Figure 5, would be very useful in teaching the equation of continuity of fluids, gravitational attraction and acceleration, equation of a parabola, maximum of a quadratic function, roots of a quadratic equation...
Let us denote by $y_h$ the value of the vertical coordinate of a hole, made in a tank in which the level of water is kept at constant height $H$. The initial velocity $v_{x0}$ of water emerging from the whole is equal to $v_{\phi} = \sqrt{2g(H - y_h)}$. Each fluid element moves along the trajectory $[x(t), y(t)]$ determined by the law of motion under action of the gravitational force. In the vicinity of the Earth this force produces constant acceleration $g$. Therefore:

$$x(t) = v_{x0}t, \quad y(t) = y_h - gt^2 / 2$$

Because of the continuity of a fluid the form of a jet is identical to the form of a trajectory of each fluid element. This form is obtained by substituting $t$ by $x / v_{x0}$ in $y(t)$.

$$y = y_h - gx^2 / 4g(H - y_h)$$

Range of a jet emerging from the whole at the height $y_h$ is obtained from the condition $y = 0$.

$$x_h^2 = 4y_hH - 4y_h^2$$

By determining the maximum of a function $x_h(y_h)$ one finds that a jet from the whole at height $y_h = H / 2$ reaches maximal distance $x_h = H$.

Since the dependence of $x_h^2$ on $y_h$ is quadratic, there exists pairs of values of $y_h$ for which two jets reach the same point $x_h$ at the surface $y = 0$. These are the pairs...
of roots \( y_{h1} \) and \( y_{h2} \) of the quadratic equation:

\[
4y_h^2 - 4y_hH + x_h^2 = 0
\]

\[
y_{h1,2} = \left[ H \pm \sqrt{H^2 - x_h^2} \right] / 2
\]

The pairs of roots satisfy Viete’s formulas:

\[
y_{h1} + y_{h2} = H, \quad y_{h1} \cdot y_{h2} = x_h^2 / 4
\]

From the first Viete’s formula it follows that jets from two wholes which are at the same distance from the top and bottom, respectively, fall to the same point at the surface \( y = 0 \).

**Melodic fence and echo tube**

From all the noise in the surrounding, an open pipe will selectively reinforce that part of the sound with a wavelength equal to twice the length of the pipe. It follows from this fact that eight pieces of pipe can be cut to reproduce a musical scale. The system of ambient noise resonators assembled by Pizzo [1], is one of the least expensive hallway exhibits that can be constructed. This system is very useful for teaching sound, standing waves and resonance. Melodic fence produced by Richter Spielgerate [10] is also useful for teaching the physics of sound. In addition, one may play on it a specific well known melody. It also conforms to guardrail standards.

Echo tube is a very suitable element for a hallway and very useful for learning about the similarities and differences of electromagnetic and sound waves [1]. An audible spectrum is played out in time by the echo tube just as the visible spectrum is laid out in space by a prism. The dispersive behaviour in an “echo tube” is due to the difference in travel time for different frequencies of sound waves which have been reflected of the wall of the tube.

**Conclusion**

During recent years science educators and architects initiated and cordially are carrying out innovative school design, as well as improvement of learning environment as a whole. In order to turn these efforts into general practice there are other parties that should necessarily fully cooperate: school administration, investors and developers.

Right example for this is a cooperation between School Building Organization S.A. and Government in Greece [15]. In Finland, Finnish National Board of Education organized in 1906 the Conference “The school of tomorrow – learning environment, pedagogy and architecture”. The aim of the conference was to emphasise the
importance of physical factors for the school environment, school work and well-being at school [16]. In USA, the cooperation is developing through Great Schools by Design initiative [17]. This is the American Architectural Foundation’s initiative to improve the quality of America’s schools and communities. In Serbia, this process is on its way to take pace with Europe.

References

1. Interactive Physics Demonstrations, ed. by Joe Pizzo (AAPT, College Park, USA, 2001).
7. http://www.wyp.phy.bg.ac.yu/competition
10. Main catalogue no.9, http://www.spielgeraete-richter.de/
12. J. Bennett, M. Donahue, N. Schneider, M. Voit, The Cosmic Perspective (Pearson, Addison Wesley, San Francisco, 2004) a) Sec. 2.6, b) Sec. 5.2.
Formal and Informal Learning. Scientific Research Centers, Museums and Universities, that contribute to it. A case study with students of an elementary school.

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Introduction

It is generally believed among the members of the elementary education that informal learning happens only in the school premises and through the school book. The students of the sixth form of our school, discovered another type of learning, the informal learning, which is equal to the formal one and happens in the scientific centers, museums and educational institutions different from the institutions known to the students of elementary education. This knowledge is reinforced by the help of Advanced Technologies in education. Informal learning in combination with the formal learning offers great help to the developing personality of the young students.

The first visit was in May of 2006 to the astronomical observatory of the Physics Department of University of Athens.
The second visit was in November 2006 in the Foundation of Mizonos Ellinismou. There the students learned not only for the ancient Militos, but for ancient Greek Mathematics from an exhibition as well.
The third visit was in December 2006 at the Technological Educational Institute of Athens, department of Food and Nutrition. There the students were guided to the libraries and the laboratories of the Institution.

Formal – Informal Learning

Learning activity is one of the basic kinds of activities (next to the play – time and
the work). This activity aims to the assimilation of culture and social – historical experience of humankind, which is stabilized in scientific conceptions. These targets will be reached through the formal and informal kind of learning. As Formal learning we can consider the kind of learning which is obtained through the legislated from the state bearers which are responsible for the education. The learning activity is more intensive in the school years. Through this activity all the basic relations of the child towards society are fulfilled, the personality is developing parallel to the psychological activities.

Having stressed the importance of formal learning which is succeed in the school, we must not ignore the importance of the Informal learning. The learning that is obtained outside educational places. The learning with interactive activities with museums, scientific centers and universities.

Some examples of informal learning in our country are the Environmental Educational Programs and the Health Educational Programs. Another characteristic example of informal learning is the program “YOUTH” (ΝΕΟΛΑΙΑ) of 2000 by the European Parliament and aims to the creation of a platform of cooperation for policies about youth, that are based on informal learning.

Priorities of the modern school is the preparation of students so as to be able to deal with the situations of tomorrow. Education contributes to the satisfaction of social and atomic needs and to the solving of problematic situations, especially nowadays, where there is the tendency of the creation of a global platform, which sets boundaries to new perspectives in the social, economic, culture, communication and technology environment.

The abilities that modern human has to acquire is the ability to search and find the correct information, the ability to communicate with each other, the ability of organizing and using the information and the positive attitude towards lifelong learning. The last decades there is a great effort from educators to send away the traditional way of teaching the various subjects. As a result to this effort is the fact that the student is no longer considered to be a knowledge – receiver. There is an interaction between the student the informal learning and the afforded knowledge.

So many museums in all over the world moving on the axis, have created educational programs which are presented to the visitors by specialized personnel in order to make clearer the understanding of the various exhibits. At the same time many university departments and scientific research institutes move parallel to the museums, by organizing seminars, conferences, symposiums and one day visits to their premises for students of elementary and secondary education. Their aim is firstly to make student’s tertiary education easier and secondly to contribute to the evolution of knowledge, of research and of the adoption of advanced technology.

Students learn, we learn, not only in the school, but in the Museum, in the Research center and in University laboratories. Informal learning can give power to the knowledge of the students providing also pleasure and fun.
Museum – Research Center – University. A Case Study with Students of an Elementary School

The museum was a place dedicated to the Muses (Μούσες) and the arts they represented. The museum was a place of civilization and cultural creation. The exhibits in a museum preserve the historic memory and reach the truth.

The impact of the ideas of the French Revolution in 1789, was very strong and new values came to light. Now on the museum is opened to the people and it is considered to be a place were knowledge is produced. The museum serves education and science.

The new era, museums can preserve historical memory and can formulate the national identity in the platform of the new multicultural societies. With these criteria the museums tend to be places of education and creation of civilization. And having also the help of Advanced Technologies, museums have the ability to create an educational environment suitable to promote knowledge.

Research centers also can contribute to the reinforcement of the informal learning. Many universities have under their supervision a lot of laboratories and research centers, where students of lower educational levels can benefit during a visit to them.

The sixth grade of the 8th Primary School of Vironas had the opportunity to visit such places and taste the informal kind of knowledge.

- In May 2006, our class visited the Paleontological Museum of the University of Athens
- In May 2006, our class visited the observatory of the Physics Department of the University of Athens
- In November 2006, our class visited the Foundation of Mizonos Ellinismou
- In December 2006, our class visited the Technological Educational Institute of Athens, department of Food and Nutrition

In our first visit, to the Paleontological museum of the University of Athens, we comprehended the close relationship which is being created between museums and schools. We also understood that the museum is the social institution which works as a transformer of knowledge.

In our second visit to the Gerostathopoulou Observatory of the Physics Department of the University of Athens there was a totally overthrow to the ideas of the students. The researchers of that center showed to the students the work they did. They showed them photographs of the moon, the stars and the planets of our solar system. They saw in the computers everything that is related to the astronomy and the knowledge about it. Finally the students were led to the telescope, but the vault was closed as it was daylight. This visit was the best according to the students’ opinion.

In our third visit we had the opportunity to visit the Foundation of Mizonos Ellinismou. In that foundation the students learned about Miltos, an ancient City in Asia Minor. In that Foundation there was also an exhibition about ancient Greek Mathematics. In this exhibition there were seven stands each one treating a specific part of mathematics. The students said that this was the best lesson of mathematics they had in their school life. It was not held in a classroom and
it was made in an interactive manner which made students learn better some mathematical concepts.

The fourth visit of our class was made to the Technological Educational Institute of Athens, department of Food and Nutrition. It was the first time for the personnel of that institution to have visitors from an elementary school. They showed us how they examine foods and how they check every nourishment that comes to our dish. They also showed us the techniques they use for examining the dairy products.

Conclusions

The visits of our school were educational in their real meaning. Modern pedagogies give great emphasis in the acquisition of knowledge not only through the traditional ways of learning, but through the informal learning. Visiting museums, research centers, and institutions under the supervision of universities, can make students learn in a more effective way. And we could say that we are led to new kinds of education, as there is a need for joining the education to the learning activity and especially to the life long learning.

The use of Advanced Technologies in today education is not a cure for every bad that is happening in it, but they can be used effectively so as to make some domains of knowledge more reachable by the students.

Formal and Informal learning, can be used by the teachers of every educational level so as to make knowledge more accessible to the students for whom every educator labor everyday in the classroom.

References


4. Αγγελόπουλος Η., Καραγιάννης Π., Καραντζής Ι., Φραγκούλης Ι., Φωκάς Ε. (2004): Η διδασκαλία των μαθημάτων του δημοτικού σχολείου με τη χρήση ηλεκτρονικού υπολογιστή, Αθήνα, Καλειδοσκόπιο
EU4ALL: European Unified Approach for Assisted Lifelong Learning

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Introduction

The Lifelong Learning paradigm recognises that, in a knowledge based economy, education and work are integrated throughout people’s lives. All citizens need ongoing access to learning to enable them to work. Technology is playing an increasing role in mediating this learning. However, if this technology is inappropriate and introduced with insufficient support, disabled people will face even further exclusion from the interlinked worlds of education and work.

To address this, the EU4ALL project sets forward the concept of Accessible Lifelong Learning (ALL) uniting 3 key strategies:

1. That the technology that mediates lifelong learning does so accommodating the diversity of ways people interact with technology and the content and services it delivers.
2. That this technology is used to bring support services to disabled learners.
3. Providing support services and technical infrastructure that enable teaching, technical and administrative staff of educational institutions to offer their teaching and services in a way that is accessible to disabled learners.

The aim of EU4ALL is to improve the efficiency and efficacy of implementing these strategies by developing an open service architecture for ALL. To achieve a wide impact the approach taken is not to develop a single EU4ALL system but a standards based framework that facilitates the integration of the approach with a wide range of eLearning systems. More specifically the goals of EU4ALL are to:

1. Design an open service-oriented architecture for ALL
2. Develop the software infrastructure for ALL services (including content, support and access services)
3. Provide technical standards/specifications for ALL applications integrated
with current and emerging eLearning standards
4. Validate the results in large-scale higher education settings

Two broad user groups benefit from the EU4ALL project:
1. End-users: Adult learners with disabilities, teachers, and tutors
2. System-users: Providers of eLearning systems, content and services

Project Objectives

The Lifelong Learning (LLL) paradigm, which supports the idea that learning should occur throughout a person’s lifetime, is intended to integrate education and work in a continuous process in which all citizens should be able to access to knowledge and perform work at 20, 40 or 60 years of age or even older. To support this valuable paradigm students are to be equipped, following a student-centred approach, with the attitudes and skills to learn for themselves both in formal education and long after they have graduated.

Strikingly, though, this “student-centred approach” is inappropriate for an increasing number of students, who are supposed to be benefited from this paradigm, but in fact have to face social, physical and cognitive barriers because they have special needs and do not meet “standard ways of doing things”. This issue is palpable for those involved in providing assistance to learners with special needs in educational institutions, where the mere lack of information or access to pre-established procedures, not to mention the difficulties in providing the required infrastructure, may become insurmountable barriers for students interested in making this paradigm come true.

To tackle this problem this Integrated Project focuses on developing a flexible, open, standard-based architecture of services to support the LLL paradigm in higher education institutions for people with special needs, with special attention to people with disabilities and elderly people. Thus, the scope of EU4ALL is a subset of the general concept of “Assisted Living”, namely Assisted Lifelong Learning (ALL).

Furthermore, students and professionals with special needs have problems in accessing LLL due to what can become a crooked path of barriers that many times are involved in the various stages required to realise their learning goals. From enrolment to assessment, students have to negotiate a pre-established general procedures, which are intended to fulfil a “standard” set of needs but are far from considering their individual needs and preferences. Nonetheless, learning should be a personalised and adaptive process for all, which from start to finish should consider the learner’s needs. In fact, it is disturbing to note that most service providers, educational institutions and corporations as well, do not attend properly the most basic requirements of people with special needs. In particular,
this problem is even more urgent in the so called mega-universities (e.g., The Open University, U.K., UNED in Spain, and the Fern University in Germany) where an increasing number of students with special needs have to be assisted (e.g., nearly 4,000 in the 2005/06 school year at UNED and more than 9,300 at The Open University in February 2006 representing 5.5% of the student body). Furthermore, it is well known for those involved in providing support services for ALL, that very often there are difficulties in managing beforehand information or pre-established procedures to attend particular needs and the multiple barriers that have to be overcome to provide the required infrastructure.

The disabilities to be covered by the project are the following:

1. Visual impairments: people who are functionally blind, as well as those who have partial sight; this will include people who have been blind since birth, and those who have lost their sight later, so have greater understanding of visual concepts.

2. Hearing impairments: people who are profoundly d/Deaf, as well as those who have varying levels of hearing impairments; this will include people who are pre-lingually deaf and may well use sign languages, people who lip read and people who use hearing aids.

3. Physical impairments: people with impairments that affect their interaction with a computer environment that require alternative interaction devices (e.g. control, tremor).

4. Cognitive impairments:

5. Specific learning disabilities: particularly dyslexic and dyscalculia.

6. General cognitive impairments: as directed by user groups (one possible example people with Alzheimer’s).

These objectives will be reached through a well balanced partnership, consisting of:

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Figure below shows the EU4ALL Partners through the value chain

Validation and Evaluation

One of the core objectives is the involvement of major stakeholders in validation and evaluation. Various major service providers will be brought together, like mega-universities to foster the awareness of best practices in providing educational services for ALL. The services and the standard-based framework will be assessed and validated at a large scale and at European level via the involvement of potential users and other relevant stakeholders. Specifically, the architecture and services will be validated in learning scenarios involving hundreds of users (adult learners with special needs and teachers) from two big European universities involved in the project. Measurement criteria will be the user satisfaction and the stakeholders’ interest on provided services and the standard-based developed framework. The validation will cover an amount of 200 users and at least the 4 categories of disabilities, namely visual, hearing, physical and cognitive impairments.

The validations and evaluations will be analysed and results will be used to refine and enhance the architecture and the services implemented.
The core of the work will be conducted in the second 18 months of the project, but preparatory work to establish the Validation and Evaluation Methodologies and Plan will start at Month 15. The work will be undertaken in an iterative manner, with a series of validations and evaluations taking place when appropriate and information being fed back as rapidly as possible.

The detailed objectives are:

- To integrate all the developed services in a seamless way.
- To research and develop the common API's, platform and components for the online services. In particular the implementation of a reliable service architecture, not only from the user’s standpoint, but also from the experts standpoint. Issues to address include:
  - Web Services
  - Content Management and Portal technology
  - Media
  - Scalability
  - Load-balancing
  - Reliability
  - Security
  - Portal accessibility and usability for people with special needs
- To design the validation and evaluation methodologies and plans to be used of the services and the architecture.
- To design scenarios aimed to different user groups, for use in the training materials and in the validations and evaluations.
- To design and evaluation training materials for the services to be validated and evaluated.
- To carry out the training activities needed to familiarise the users with the services.
- To conduct the validations of the architecture and services provided following the methodology previously defined.
- To analyse the results of the validations and to produce recommendations for the refinement and improvement of the architecture and services provided.
- To conduct the evaluations of the services provided, following the methodology previously defined
- To analyse the results of the evaluations and to produce recommendations for the refinement and improvement of the services provided
- To provide a demonstration of the EU4ALL service architecture and services.

Integration, validation, evaluation and demonstration of services are vital links in the innovation process: all services developed will be validated by experts – and evaluated with end-users. The validations and evaluations are expected to give valuable feedback to refine and improve the service architecture and the services developed. They also closely support dissemination of innovation and technology.
transfer to stakeholders and interested parties such as user organisations.

The major challenge is the co-ordination of the validation and evaluation of the service architecture and services on a European scale. Contributions are expected from partners based in seven different countries, so a coherent strategy is vital in assuring that project resources are deployed efficiently for meeting the significant requirements.

User trial and evaluation activities are organised around two main centres and a support centre:
- The two main centres will be located in the UK and Spain
- An International support centre, co-ordinated by European Association of Distance Teaching Universities (EADTU) will also supply user evaluation input for international benchmarking.

EADTU’s role in the project is to be a “stakeholder evaluator” that would organise informal evaluations by Higher Education institutions (outside the consortium). This is envisaged as being done in conjunction with its Annual Conference and workshops to make the informal evaluation attendance less dependent on undue time commitment by non consortium organisations and thus boost its chance of success. Dedicated sessions may be organized where experts and staff of EADTU member organisations will be invited. The focus will thus be on evaluations by staff as stakeholders and experts. However possible arrangements of student sessions will be looked into. EADTU further provides the opportunity for stakeholder feedback through their Academic Networks and Task Forces. This will be done by EADTU contributing under a so-called “support centre”, focusing on their members base of Higher Education institutions inside Europe, but now also expanding to Eastern Europe including Turkey and Russia, on the issues raised by EU4ALL.

For the large scale validation of the prototypes to be performed in Spain and the UK the organisations involved will set up the needed infrastructure. This in addition to the evaluations undertaken by the host universities will be used to support the experts’ validation of the prototypes to be performed by various organisations within the consortium. This will be readily possible because of the nature of the EU4ALL approach, namely the remote delivery of services. The production or commissioning of any content required by these other organisations for their evaluations will be their responsibility. The expert validation of the prototypes will cover issues like enhanced accessibility, usability and technical validation against the appropriate guidelines, standards and specifications. The expert validations will address technical quality assurance and activities designed to ensure that the software is operating reliably and according to the specifications set forward.

It is envisaged to have the following type of evaluations:
- expert evaluation - 2-3 experts (accessibility, eLearning, ICT) from each organization. An experienced evaluator (with HCI background and sometime
having a disability themselves), with extensive experience on a wide range of assistive technologies will undertake an evaluation of a piece of software. Using a scenario based approach, the expert will go through different tasks the student may need to undertake in turn and noting functionality that can not be achieved, usability problems, unexpected behaviours by the software (bugs).

- **User Evaluation** - Small scale (10-12 users) and large scale (100+ users in Spain and the UK). Methods used would include a combination of simple satisfaction surveys (for small and large scale), observational studies (for small scale) of interaction and semi-structured interviews with a sample of disabled students and tutors of an appropriate academic background and presenting a range of disabilities. Lessons learnt from the observational studies would be integrated in further developments of the service infrastructure.

- **EADTU would provide support/feedback to the user evaluation**

To support the validations and evaluations, the main centres will dedicate various servers to support the system portal and data bases. All the services will be fully accessible online and learners and other users will be using computers and assistive devices (sometimes of their own and sometimes provided by the organisation leading the evaluation – see UNED’s case below) to access the services.

- **Evaluation in the UK**: The subject’s participating in evaluations at The Open University will be drawn from disabled students registered on courses at the time (currently numbering 9,350). Disabled students studying in the UK above a threshold of % of time in study qualify for national government grants called Disabled Student Allowances which includes an element of approximately €7,000 for “specialist equipment” i.e. Assistive Technologies. To meet the needs of other disabled students who do not qualify for these grants the university maintains a loan-pool of assistive technology which can be lent to students for the period of their study. Further to this the university operates an Access Centre and uses similar services elsewhere, hence it will already have appropriate assistive technology and will not need this to be provided by the project. This is a preferred way of working anyway because there is a learning curve for the students when they get new assistive technology so if is preferable to work with them and the assistive technologies they have been using for some time. Further there is an ethical problem of supplying assistive technology just for a trial when students may become dependent on it and then removing it afterwards.

- **Evaluation in Spain**: The subject’s participating in evaluations at UNED will be drawn from disabled students registered on courses at the time (currently nearly 4000 students). Disabled students studying in Spain do not get national government grants for specialist equipment or assistive technologies. For this reason, UNED’s Disability Support Unit will provide the required assistive technologies for those students taking part in the evaluations who do not have the appropriate devices. This unit has already different types of assistive devices obtained from agreements with foundations such as ONCE (Spanish national organization for blind people). However, it may be necessary to buy some additional devices.
Users involved in large scale evaluations:
An initial suggestion is to follow the proportion of students currently enrolled at mega universities.

At the UK the following proportions are based on a total of 9,615 students (Dec-05)
- People aged 40-59 represent 45%
- People aged 20-39 represent 43%
- People over 59 represent 11%
- People under 20 do not represent a significant proportion

In Spain the following proportions are based on actual data available at the “Disability Support Unit”, which is currently managing over 3,700 students at UNED.
- People aged 35-55 represent 60%
- People aged 20-34 represent 20%
- People aged 56-65 represent 20%
- People aged 65 and over do not represent a significant proportion

User Training for Validation and Evaluation
The EU4ALL project aims to co-ordinate a significant research effort to develop, test and evaluate a range of e-learning services. Training activities will play a major role in supporting the innovative process and for setting up sound foundation for uptake and dissemination of project results.

The main objective is to provide accessible training material to end users. It will be fulfilled by establishing a coherent training strategy at a European level and by developing appropriate training material. Training material will be provided online (through the EU4ALL e-Learning platform) and off-line (manuals, multimedia).

Training workshops will also be organised in order to give maximum visibility to the project activities and to train the trainers. The training activities are organised around:
- two main centres located in Spain and the UK (UNED and The Open University)
- three supporting centres in Austria, Italy and Greece. These are the pilot sites, only small implementation will be undertaken and if content is needed it will be local content, in order to avoid the need for extensive translations.
- An International support centre, co-ordinated by EADTU, will also supply input for international benchmarking.

The major challenge is to assure cost-effective development and delivery of training material for the various services under development. Contributions are
expected from partners based in five different countries, so a coherent strategy is vital in assuring that project resources are deployed efficiently for meeting the significant training requirements.

Training workshops and user training will start at the end of this 18-month period and will continue during the validation and evaluation periods. There will be a minimum of eight workshops in agreed selected partner countries within an agreed schedule.

**Validation and Evaluation of Service Architecture and Services**

The objectives are to:

1. Organise and prepare the infrastructure needed to implement validations and user evaluations (small and large scale) of the EU4ALL approach, services and architecture.
2. Support and carry out the validations and evaluations foreseen following the Validation and Evaluation Plans produced in the project.
3. Feed the redesign cycle with feedback analysed after each validation or evaluation iteration.

The iterative design cycle will be a direct consequence of each validation and evaluation process. Results from the validations and evaluations will be analysed and fed back as rapidly possible to allow improvements and refinements to the architecture and services.

The user evaluations will be organized at centres in two European mega universities located in Spain (UNED) and the UK (The Open University), plus several smaller scale evaluation exercises based at the institutions of other partners.

Evaluations will start at the end of the first 18-month period and will continue until the end of the project.

**Conclusion**

The main goal of EU4ALL is to design and implement an extensible “architecture” of European-wide services to support assistive life long learning for adult learners with special needs, which guarantees that the provided services are open, secure, standard-based, accessible and interoperable, while also ensuring the most extensive and intensive evaluation possible, ensuring that the final framework properly addresses the needs of the targeted end-users.

EU4ALL is a 48-months European integrated project in the area of eInclusion. More information about the project can be found at http://www.eu4all-project.eu.
Heuristic Evaluation for Artificial Realities Tool and its Application for the Evaluation of Educational Technologies

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Abstract

Recent developments in usability evaluation have centered upon the formulation of quick-fire methodologies and tools for purposes of rapid prototyping and redesign specification. This paper presents an overview of the Heuristic Evaluation for Artificial Realities’ Tool (HEART) that consolidates many of the philosophies and techniques of these methods, stimulating a template for effective and efficient report authoring. HEART has been conceived to support evaluation for technologies of mobile Augmented and Virtual Reality systems and their applications within education and training. The tool has a threefold purpose: in providing guidance towards the initial design supporting generic user needs, evaluation in accordance to severity and in providing a summative and quasi-quantitative analysis of the results. The paper presents an example application of the tool for the mobile Augmented Reality CONNECT system, a science education technology.

Simplicity is the ultimate sophistication – Leonardo Da Vinci.

Introduction

Commercial awareness of Human Computer Interaction (HCI) evaluation methods and the integral necessity within the design and implementation lifecycle has been addressed throughout the past three decades [1] [2], consequently leading to a rise in the availability and application of discount usability engineering methods [3]. This has been in direct response to the long-standing paradigm that procedures of traditional HCI evaluation are expensive, cumbersome and take too long to initiate, often leading to a delay in the final product launch [4]. The Heuristic Evaluation (HE) is the most documented and widely employed of usability inspection methods [5]. The structured heuristic framework identifies
the greatest magnitude of usability problems including the most severe and is relatively low cost and straightforward to implement [6]. The primary malady of the approach is the usability expertise required to perform the inspection and the need for several evaluators, roughly estimated at 3-5 [3]. This paper focuses upon the modus operandi of the generic approach that HEART advocates, regarding guidance towards the initial design and supporting generic user needs: evaluation in accordance to severity and in providing a summative and quantitative analysis of the results. The work does not persist in presenting the current choice of heuristics, in detail, rather it presents the overall methodology used.

**The HEART Approach**

HEART is a simple tool that has been developed in Microsoft Excel®, for the following reasons:

- Ability to accommodate numbers, text, formulas, and Visual Basic programming, thus allowing for ease in customization to meet specific needs.
- Familiarity of the Microsoft Excel® environment to many users.
- Cross-platform nature, permitting PC and Macintosh users to use the application.
- Ability to chart results in various ways, hence facilitating efficient analysis.
- Small disk space requirement for the actual tool (assuming that Microsoft Excel application already exists on the computer).

(Adapted from [7])

![Fig. 1 Screenshot of the heuristic content of HEART](image)
In essence, the tool is reliant upon the incorporation of the original 10 heuristics detailed by Nielsen [3] supplemented by a further 10 bespoke heuristics identified as high-level user needs for the purpose of artificial realities. Thus, acting as guidelines designed to allow non-usability evaluation experts to apply such methods during the lifecycle of their products and provide a referent for further evaluation, within an iterative lifecycle. Furthermore these heuristics are supported by technology restrictions, which account for the current state-of-the-art in interactive technologies, as detailed in Figure 1. Such technology restrictions provide an opportunity to consolidate and account for the inherent low-level limitations enforced on modern technologies. Both Usability and Technology Considerations/Restrictions Heuristics are rated with a severity figure that ranges from 1 to 5: 1 being “no problem”, 2 being “slight problem”, 3 being “minor problem”, 4 being “major problem” and 5 “catastrophe”. For the CONNECT project, we selected severity of 3 as the level of acceptance and tolerance of any device, in terms of usability and technology restrictions. Figure 2 shows the interface of HEART and how Microsoft Excel’s graphing capabilities are utilized to produce a comparative quasi-quantitative analysis for rapid report generation.

![Screenshot of a device evaluation](image1)

*Fig. 2 (left) Screenshot of a device evaluation; implementing drop-down boxes to rate severity toward each heuristic; (right) summative analysis comparing devices, exploiting Microsoft Excel’s comprehensive graphing capabilities.*
The Applicability of HEART to Artificial Realities Usability Evaluation

Technologies of Artificial Realities are context sensitive. In particular, the field of Augmented Reality (AR) is regarded as highly context sensitive [8][9]. Therefore, heuristic evaluation alone is not sufficient to capture all issues of usability relating to context. However, the latest research in mobile device evaluation shows that in combining HE with scenarios of use, more formally known as the Heuristic Walkthrough (HW), greatly improves the effectiveness of HE at capturing such contextual issues [10]. The authors stipulate that a Contextual Walkthrough approach (quintessentially, the HW method conducted in situ) embraces contextual cues from both the scenario and the intended situation of use and it is appropriate for the contextual evaluation of AR applications. The proposed method, HEART, is therefore intended to be deployed in a way is a method that encompasses scenarios performed in situ.

It has also been suggested that the HE method of evaluation is disassociated with the end users’ thought and opinion, and therefore fails to evaluate user satisfaction and efficiency [11]. The flexibility of HEART extends to address these in that the tool can be used as a post-evaluation summary to collate the results from user testing within a formalised framework.

4 Example use of HEART
A persistent indication toward the flexibility of the HEART methodology can be realized by way of its use within an EU IST funded research exercise, the CONNECT project. The main aim of the CONNECT project is to analyse how new techniques in mobile AR systems and associated communication technologies can integrate formal and informal learning. As an initial test-bed HEART has been utilized to evaluate various technology options for usability of AR technology, in order to justify technology acquisition decisions based upon a human-centered approach. Each device (i.e. Trackers, head mounted displays and interaction devices) was rated according to severity ratings on the usability heuristics and technology limitations and then analyzed to present a deliverable grade document recommending a complete technology solution based upon an assessment of scientific underpinning.

In the context of the CONNECT system the following devices were evaluated using HEART:

• Trackers
  o Intersense 600
  o Intersense 900
  o Computer vision tracking
  o Hybrid ARToolkit with Inertia cube 2
  o Intersense IS-1200 VisTracker

• Head Mounted Displays
  o Sony Glasstron (Device D4)
  o Saabtech Addvisor 150 (Device D5)
  o Cybermind hi-Res900 3D (Device D12)
  o i-glasses SVGA 3D Pro (Device D13)
- Shimadzu Data Glasses 2/A v 2.0 (Device 14)
- Liteye Systems LE 500 (Device 15)

- Input Devices
  - Speech Recognition (IBM viovoice)
  - 3D Pointer incl. Buttons
  - Trackball
  - Gesture recognition

- Headsets
  - Sennheiser Professional Audio Heads
  - Logitech Bluetooth headset
  - Creative headset
  - Logitech Premium Stereo Headset

In the following paragraphs, we will provide for the purposes of illustration, some specific results and analysis based on the HE of a group of the above devices, that is the Head Mounted Displays. Note that the device labeling here is not sequential, rather it is arbitrary. From figure 5a, it can be inferred that device D4 is rated best in terms of overall usability, followed closely by D13. Additional weighting would give a more accurate usability score. Device D12 suffers from multiple critical usability issues; in that it is highly susceptible to user interference, cannot cater for special user groups and like D5 is bulky and has high power consumption. Based on this analysis alone the choice for the CONNECT system was made to be between devices D4 and D13.

Fig. 5a (left): The usability evaluation chart shows a cumulative bar graph, the smaller the score - the greater the usability of the device. The complete bar represents the overall score, while each Heuristic score is represented with a different colour.

Fig. 5b (right): The technological considerations chart shows each device by a different coloured line. The performance of each device toward each technological heuristic is shown; the orange line is the tolerance level for CONNECT representing a severity level 3 in the HE severity assessment; any point above this line represents either a major (4) or critical (5) problem.

From figure 5b, one can see that devices D4, D12 and D13 are superior to device D5 in terms of technological consideration, as they do not display any issues that
exceed the severity level 3, which had been identified as the level of tolerance for the CONNECT project. Device D5 has a critical problem with heuristic IV: wireless capabilities due to the need for all wires to be connected to the laptop - onboard with the user – and requires an external mains power cable. Device D4 suffers from a minor problem in that its’ display has only a see through capability of 30% and therefore cannot perform in low light conditions. Devices D12 and D13 suffer from minimal technological limitations. Devices D14 and D15 are both optical HMDs, and have become available at reasonable cost since testing the first CONNECT mobile prototype system. These systems are the Shimadzu and the Liteye respectively. Preliminary evaluations using the HEART method identifies that there are no significant technology restrictions from either system and all heuristic severity scores fall below the acceptance level of severity. In terms of usability, the Shimadzu system has significant problems with user interference – due to the small screen sensitivity in alignment which can prove difficult to adjust and maintain aligned throughout the interaction. The Liteye HMD performed significantly better in respect to the aforementioned points, resulting in a more robust and user friendly solution.

Conclusion

There are numerous techniques for extensive and laboratory-based evaluation within the domain of usability and the suitability toward each application should be carefully considered within the jurisdiction of a full cost/benefit analysis. With some sense of irony many of these methods fail to comply with the ISO 9241-11 definition of usability, in terms of being efficient, effective and satisfactory in their applicability, in particular within the commercial sectors. Ultimately there is no ubiquitous or all-embracing technique, but the authors advocate that the HEART technique focuses the ability to rapidly evaluate future interactive systems, providing useful cues to redesign and encapsulate the inputs from designers, usability specialists and end-users alike.

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References


7. Excel Datalogger: http://www.userfocus.co.uk/resources/datalogger.pdf [Visited 01/03/04]


Wearable Computing Technologies: Applications in Science Education

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Abstract.

The recent technological advances in wearable computing have found their way into many applications that support and enhance everyday human activities. Wearable technology can sense human actions and adapt accordingly, depending on the context of use, providing a new way of human-technology interaction that augments human cognitive abilities and performance. The use of wearable technology in the context of education is new, and has been mainly linked to the concept of experiential learning. The paper describes the development of wearable technology for two technology enhanced learning projects, namely the Lab of Tomorrow and the CONNECT projects. In the Lab of Tomorrow project, students and their teachers can use mobile and wearable computing technology to perform daily activities and, through the measurement of human performance, understand the natural world around them. Teachers can link such life-like related experiences to promote experiential learning within the context of the formal educational curriculum. In the case of the CONNECT project, mobile wearable computing is used to create Augmented Reality experiences of interesting phenomena that students observe in an informal and experiential learning scenario, while visiting science museums and centres. The paper conjectures on how, in the future, wearable technology can support experiential learning activities within both formal and informal education, by exploring the technological advances of the technologies used in the example projects reported in this paper.

1 The SensBelt Wearable System has been developed and designed as a pre-industrial prototype by the R&D Division of ANCO SA (44, Syngrou Avenue, 117 42, Athens, Greece), one of the participating partner SMEs in the Lab of Tomorrow Consortium.
Introduction

Over the past ten years, we have been witnessing a rapid technological development of embedded and wearable computing technologies, leading to innovative applications for the novel use of computers in our daily life [1]. In a broad sense, wearable computing technology can be defined as information and communication technology that is subsumed into a user's personal space, "a small body-worn computer system that is always on and always ready and accessible" [2]. Wearable computing presents a paradigm shift in human-machine interaction. Such technology, usually attached to the human body, can sense the environment, provide useful measurements of activity-related human actions, and adapt according to the context of use to augment human cognitive abilities and performance [3]. A variety of applications exist, where wearable computing technologies have been successfully employed to support human activities and improve task-related performance. Wearable computing devices have been implemented for activities such as mechanical vehicle maintenance support [4][5], support of automation in factories [6][7], engineering technical inspection, such as bridge [8] and aircraft inspections [9], patient monitoring [10] and support of paramedics in the emergency services [11], military combat and command & control operational assistance [12] [13], scientific fieldwork [14], etc.

The use of wearable technologies in the context of high-school education is new. A successful application of wearable computing technologies in education has been demonstrated through the Lab of Tomorrow (LoT) project, an EU funded research exercise (IST-2000-25076) in the Framework V Programme. The aim of the LoT project was to develop a pedagogical framework for the successful application of the emerging wearable technology in teaching science through everyday human activities. Students and their teachers can employ mobile and wearable computing technology to perform daily activities and, through the measurement of human performance, understand the natural world around them. The use of wearable computational tools and instrumented artefacts in the assessment of human performance, within the context of physical activities, encourages students to understand basic concepts in science by planning and implementing simple scientific experiments, forming and validating hypotheses, and elaborating on the formulation of new ideas for further understanding of everyday experiences in the natural world. Teachers can then link such life-like related experiences to promote experiential learning [15] within the context of science education and as part of the formal educational curriculum. We have further explored the extension of this type of experiential learning with the CONNECT project. The main aim of the CONNeCT project (IST507844) was to analyse how new techniques in wearable mobile AR systems and broadband – communication technologies can be integrated into a combined informal and formal learning context for high
school students. AR is used to enrich the visiting students physical view by virtual extensions (e.g. showing physical imperceptible phenomena like magnetic fields). This helps the students to understand phenomena (e.g. about magnetic fields) that are hard to teach in school and perhaps even open new domains in teaching. Usability problems while using such systems [16] can be handled better and better with improving technology. Sparacino [17] favoured an approach of an AR system adjusting itself according to the behaviour of the museum visitor. The CONNECT system allows the educators to adjust the AR experience to the pedagogical needs of the students. Broadband technologies are used to stream the visitors AR view into schools, providing (together with a bidirectional audio connection) even students in the classroom the ability to interact on exhibits in distant science centres.

In this paper, we report on the relevant technological, pedagogical and human factor considerations for the development of wearable technology in the context of high-school formal and informal education. We conjecture on how, in the future, wearable technology can support experiential learning activities within the formal educational school curriculum.

**Supporting formal curriculum education through an experiential learning approach: the role of wearable technology**

John Dewey, the renowned American philosopher and educator, strongly advocated that “... there is an intimate and necessary relation between the process of actual experience and education.” [18]. The concept of linking individual experiences to one’s learning has led to the development of experiential learning theories and models [15][19][20], which consider the process of “learning by doing” achieved in a variety of human activities and everyday contexts. The most well know model of experiential learning is that of Kolb [15], which breaks the process of leaning in 4-key stages: (a) concrete experience; where individuals encounter an every day experience, followed by (b) reflective observation; where individuals consider that experience in a reflective way in relation to their personal knowledge and other life experiences, forming the way to an (c) abstract conceptualisation; where individuals can describe their experience in terms of generic concepts, principles and rules, so that they can test the implications of these concepts, principles and rules with (d) active experimentation when new situations (i.e., new concrete experiences) arise.

Such experiential learning models can be applied by high-school teachers, in a controlled manner, to encourage a hypothetico-deductive approach to science education, where students through observations and use of evidence can conceptualise abstract scientific concepts. For instance, by using an artefact or tool to perform a specific human activity, pupils can form a concrete experience that relates to an observation of a phenomenon occurring in the natural world, resulting from that activity. By reflecting on this experience, pupils can be encouraged to
form hypothesis that might conjecture on the cause-effect relationships observed through their concrete experience and then conceptualise the principles and rules that underlie their observation. Through active experimentation, they can test these principles, by creating new contexts of use for the artefact or tool.

Evidence originating from large-scale studies [21][22] shows that an experiential learning approach is beneficial in the development of the modern science education curriculum in high-school level, while it is desirable to be implemented with the use of technology-enhanced solutions [23]. In the Lab of Tomorrow project [24], we hypothesized that embedded and wearable computing technology can be an ideal vehicle for implementing technology-enhanced experiential learning in science education. The main premise of our hypothesis was that such technology, either embedded in everyday artefacts or subsumed in a person’s personal space through clothing and on-body attachments, can be useful in sensing, recording, processing and transmitting data relating to human activity. The concrete experiences relating to the observation of such data would allow pupils to reflect and to conceptualise principles that relate to Newtonian physics, principles that could be used in the design of new experiments and thus lead to the creation of new concrete experiences. In the context of science centre visits and informal learning through the use of mobile AR technology, as envisioned by the CONNECT project [25], users are able to visualize the “invisible”: physical phenomena and concepts, such as magnetism, the Bernoulli effect (and the associated visualization of airflow) and the existence of fields and forces, become visible as synthetic objects superimposed on actual real exhibits, that demonstrate these phenomena and physical laws. Within an AR environment, the “mixed-reality” of synthetic visualizations and real science centre exhibit objects, allow users to conceptualize knowledge, interactively and in real-time, while offering the possibility for personalization of the information available to the user. This information can include micro and macro level explanations of concepts, animations, 3D notice boards, interaction instructions, and self-reflective learning elements (such as questions, quizzes, etc.). As a consequence, different perspectives and views can be made available to each different student-visitor of a science centre exhibit, while these views can be combined and communicated in a collaborative fashion, providing a catalyst for an informal and interactive learning experience through enjoyment and entertainment.

**Designing wearable technology for science education**

In the initial stages of the Lab of Tomorrow project, and in order to facilitate the creation of concrete experiences relating to the observation and manipulation of human activity data by pupils, we have used sensor, computational and commutations technology to be embedded in sports appliances (e.g. an instrumented football) and in cloth, (e.g. a specially modified instrumented shirt, the SensVest [26]). Both types of embedded and wearable technology were designed for the appropriate collection of meaningful data relating to human physical activities, in order to be transmitted and stored for further analysis and manipulation.
In particular, the SensVest is a novel item of wearable physiological monitoring system [27] that measures, records and transmits specific aspects of human physical activity and function (such as heart rate, temperature, movement, etc.). The prototyping and implementation of the SensVest had followed a participatory design approach, in order to identify appropriate scenarios of use that can facilitate an experiential learning framework for physics and sports education. The device includes an array of sensors that can be used to passively record data that relates to specific activities of the wearer, without requiring the users to perform either some extraneous activity or manipulate a tool or artefact in order to collect the data. The choice of type and number of different sensor devices, their positioning and embedding within the cloth, have been realised in a way to create a multiple-sensing device that is safe, comfortable and usable as wearable technology for monitoring complex activity in physical education. In addition, the design is robust so to sustain damages that might originate from demanding and strenuous physical activities. Our design was further informed by the identification of important human factor considerations derived from usability/wearability evaluation trials of the technology in different contexts of use [28]. The above mentioned features make the SensVest (and its subsequent pre-industrial evolutionary prototype development, the SensBelt wearable system) unique, when compared with other commercial wearable systems that usually perform limited (single-sensor) physiological monitoring (see figure 1).

In order to study particular basic principles in Newtonian physics (such as force, displacement, velocity and acceleration), basic principles relating to human physiology and performance in physical education (such as heart rate and temperature), and more complex principles relating to both physics and physiology (e.g., energy expenditure, cardiac output, etc.), we have selected sensor devices and technology that could be easily mounted on a shirt or the human body, be lightweight and easily transportable within the real-world environment, while their cost remained relatively low and affordable for educational purposes. Simple accelerometer devices have been used for the measurement of acceleration and the derivation of physical measurements of force, displacement, and velocity. The use of simple heart monitors and temperature sensors, have allowed us to deliver measurements of human heart rate and temperature, and from such measurements derive energy expenditure, while allowing pupils to understand concepts of human physiology, such as cardiac output [26].

The x4 Wearable Platform was custom designed by the University of Birmingham as a standard platform on top of which many different aspects of wearable computing and associated problems could be tested in the CONNECT project (figure 2) [25]. It differs from most research offerings because it is a complete system, housed in a ruggedised aluminium case ensuring that it is cooled efficiently. The weight of the x4 is 970 grams (compared to the a standard laptop solution of average weight of 2300g) plus each battery pack is 190 grams each. One battery pack is required, two improves longevity and therefore reliability to the user, and significantly lighter than the 850g of a standard laptop. Furthermore the original solution utilised a baby-carrier to house the system, adding 1650g to the combined weight. This
gives an overall weight reduction of over 400%, as well significant advances on the ergonomic posture adopted by the user of the wearable. It is not with in the scope of this paper to elaborate on the posture assessments. The power consumption of the x⁴ is regarded to be very high performance, of similar graphics and processing capabilities to the laptop, with a significant (1/3 or so) of the consumption, which naturally means 1/3 of the power consumption and perhaps more importantly 1/3 of the total heat output in Watts.

Fig. 1 (a) The initial prototype of the SensVest wearable technology, as demonstrated at a Teachers’ workshop in context of the Lab of Tomorrow Project, (b) the SensVest, a physiological monitoring device of human activity in sports’ trials (cycling and treadmill exercises) and (c) the pre-industrial evolutionary prototype development of SensVest, the SensBelt Wearable System.

Fig. 2 University of Birmingham 4th generation wearable computer: x⁴

A combination of Wearability and Technology Acceptance Model studies has shown that the x⁴ Wearable Platform is comparable with previous TAM studies, in particular that it has verified the findings of studies into experiential factors. The core user adoption characteristics of a mobile Augmented Reality (AR) system for science education have proven that this type of wearable technology fits the purpose of its design, by identifying the key influences of user adoption practitioners into assessing the appropriateness of the technological solution to the specific needs of the learner.
Concluding remarks

Our account of the relevant technological, pedagogical and human factor considerations for the development of wearable technology in the context of high-school education has shown us, through specific examples, that it can support experiential learning within the formal and informal education of high-school learners. The experience acquired from the development of the SensVest and other associated embedded and wearable computing technologies (x4) can inform the future design and implementation of wearable technology for technology-enhanced learning.

However, the use of such technologies must be considered with respect to their limitations. For instance, in the case of SensVest one has to take into account that accelerometer devices are affected by gravity; as such their orientation must always be taken into account during the design of experiments or the gravity effect must be assumed to be negligible. Using temperature sensors, subdued in the human body, requires that the user be aware that the temperature value is affected by ambient conditions and so may best be used for assessing relative changes and not as an accurate measure of body temperature per se. Another important set of limitations relate to the mounting of technology (wearability) on the person. Inappropriate design can lead to impairment of movement, while there are associated risks with having electronics in the vicinity of the human body. Appropriate wearability and usability evaluation trials should always be conducted in order to achieve a refinement of the technology and identify its fitness for purpose.

References


6. C. Thompson, J. J. Ockerman, L. J. Najjar, and E. Rogers, Factory automation support technology (FAST): A new paradigm of continuous learning and


27. C. Baber, A. Schwirtz, J. Knight, H. Bristow, T. N. Arvanitis and F. Psomadelis, SensVest: on-body physiological monitoring systems, IEE Eurowearable’ 03, 2003; 93-98.

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