Guide of Good Practice



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CONNECT

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ISBN No. 978-960-6701-31-3

European Commission

Information Society Technologies



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The CONECT project is co-financed by European Commission within the framework of ISTprogramme.

European Commission

Information Society Technologies

Contract Number: IST-507844

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Printed by EPINOIA S.A.

ISBN No. 978-960-6701-31-3

CONNECT

Designing the Classroom of Tomorrow by using Advanced Technnologies to connect formal and informal learning environments

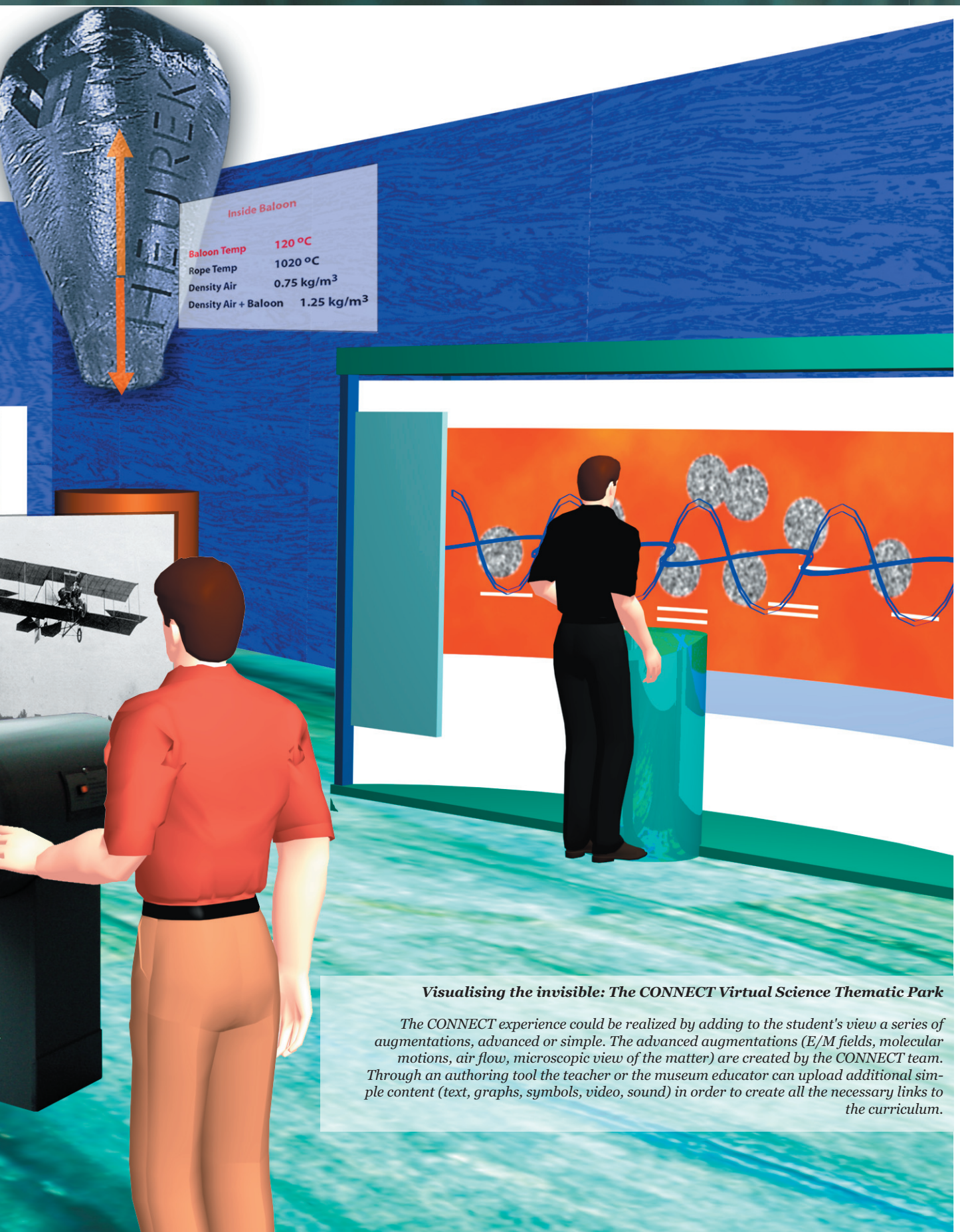
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Visualising the invisible: The CONNECT Virtual Science Thematic Park

The CONNECT experience could be realized by adding to the student's view a series of augmentations, advanced or simple. The advanced augmentations (E/M fields, molecular motions, air flow, microscopic view of the matter) are created by the CONNECT team. Through an authoring tool the teacher or the museum educator can upload additional simple content (text, graphs, symbols, video, sound) in order to create all the necessary links to the curriculum.



1. Introduction

Informal learning should no longer be regarded as an inferior form of learning whose main purpose is to act as the precursor of formal learning; it needs to be seen as fundamental, necessary and valuable in its own right (Coffield, 2000). Fortunately, in the past 5-10 years, interest in this area of research has grown tremendously. Special interest groups for informal learning appear in research bodies all over the world, e.g. the American Educational Research Association (AERA) now has an Informal Learning Environments Research Special Interest Group. The National Association for Research in Science Teaching (NARST), a membership organization based in the United States, recently published a policy statement suggesting that informal learning is an invaluable part of the learning a person undertakes in his/her life. It also suggests that more investigations are needed to understand the potential relationships and synergies that could be nurtured between formal and informal learning environments (Dierking et al, 2003). In order to tap into the enormous wealth of learning and teaching opportunities which out-of-school learning environments afford, a possible approach is to wed the best informal, or "non-formal" (Eraut, 2000) learning approaches with those best approaches in formal environments.

The CONNECT project proposes to create a learning environment that will undertake just such an effort, wedding 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.

The proposed approach will impact upon the fields of instructional technology, educational systems design and museum education.

First, for the field of instructional technology the project consortium examines alternative instructional systems that attempt to blend informal and formal learning and to situate learning in real-world contexts. This is critical since in-

structional designers have recently been challenged to align their practices with constructivist cries for learning that is situated within authentic contexts (Bednar, Cunningham, Duffy & Perry, 1991; Brown, Collins, Duguid, 1989; Jonassen, 1991; Winn, 1991). However, while there are many cries for embedding instruction within real-world situations, there are few descriptions of existing systems that attempt to do so. In most science-education settings, there is a sharp division between the physical and the virtual. There is a rich tradition of using physical materials for hands-on science inquiry, but that tradition has had little influence on the ways computers are used in educational settings. The CONNECT approach to bridge this divide, introduces new technologies and activities that fluidly link the use of physical materials with digital technology in creative inquiry and inventive exploration. It aims to integrate the use of physical objects that are computationally-augmented and to support and encourage face-to-face interaction between students and virtual objects.

For the field of educational systems design, the virtual science thematic park is an instance of designing new systems from the ground up. As such, it aims to inform current burgeoning theory in the process of educational systems design (Jenlink, Reigeluth, Carr & Nelson, 1996), and in systems theory-such as the SIGGS theory (King & Frick, 1996). Additionally, the CONNECT approach provides information for one of the key processes of educational systems design, transcendence. In the Jenlink et al. (1996) model, the authors advocate exposing stakeholders to alternative educational systems during the early stages of design; this helps them transcend their current mindset of traditional schooling. The CONNECT research study creates knowledge regarding a new class of alternative schooling that will be informative to future educational designers.

For the field of museum education, the project will help correct three deficiencies that are restricting current reform efforts to expand the educational role of museums. These three impediments are: a) the limited number of model programs, b) the absence of a body of professional literature, and c) the lack of contact with the broader field of education. The CONNECT approach could provide a framework for a closer and more effective collaboration between museums and schools.

The CONNECT project's approach 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 central research question of the CONNECT project is: Under what conditions can the technology of AR, combined with interactive science exhibits, support student learning? A number of issues arise when investigating this question. Specifically, to what extent and under what conditions:

(1) can exhibits with AR interactive features improve student learning?

(2) can broadband technology support communication and data flow between schools and science centres?

(3) can broadband connections enable students, who cannot visit a far-away science centre, to take advantage of a remote AR visit?

Tackling the research questions of the project demands the coordinated efforts of an interdisciplinary team of workers with theoretical and practical expertise in diverse disciplines. This project brings together schools and science centres, and produces novel computer-based technologies such as augmented reality (AR) and broadband technology. Such interactive learning environments can better contextualize and support learning in school, but also in other settings where children and youth 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 project consortium is a joint initiative of educational, cognitive science and technological experts, educators, and psychologists to research the possibilities of using advanced technologies (Virtual Reality, Augmented Reality, remotely controlled experiments, wearables and mobile devices) for educational purposes in order to facilitate school – museum collaboration. The aim of the project is to explore, test, refine and demonstrate an innovative approach that crosscuts the boundaries between schools, science museums, research centres (e.g. observatories) and science centres and involves students and teachers in extended episodes of playful learning. The partnership aims to develop, test and evaluate learning schemes to facilitate in situ learning that will be implemented in ambient, always available educational environments developed with emerging technology. The goal is to maximize the assimilation of the provided information when the motivation of the student is highest. Practically, the project will map the evolution from the wired virtual learning environment of today, to the wireless learning environment of tomorrow.







2. Pedagogical Approach



[…As a society we need to recognise and support the vast, important and successful learning enterprise that takes place outside of schools and the work-place –learning from museums, libraries, the Internet, TV, films, books, newspapers and magazines. Collectively these experiences encompass what is known as the "free-choice learning" sector…Any public education reform effort that does not embrace the benefits of free-choice learning is incomplete.]

John H. Falk, Lynn D. Dierking, Lessons Without Limit, 2002

According to modern pedagogy, teaching should be guided by a holistic planning process that takes the students' learning processes, the subject matter and the teaching methods into account. Students' orientation is a very important and significant variable which correlates positively with students' performance. It offers students the chance to link the information presented to their prior experience and knowledge. They have the chance to engage in an active and self-guided learning process. Consequently, effective learning processes should be designed with student's prior experience and knowledge.

To learn science in meaningful ways students need to see connections to familiar problems relevant and important in their daily lives. Additionally, situated learning fosters the ability to transfer acquired knowledge to a variety of different situations. Situated learning is an essential component of acquiring the ability for self-organised and self-regulated learning. Ideally schools should provide opportunities for the development of a competence to learn and, an ability to be an autonomous learner in the future. This includes the development of meta-cognitive learning competences like e.g. elaboration strategies or learning strategies and their application and usefulness. Learning processes in the future will be embedded in communicative situations, where teaching science offers good conditions for fostering communication and cooperation in students' experimental practices.



For content orientation, the planned teaching topics should be based on a broad field of knowledge and application. To be effective, the teaching sequences should build up in a way that student knowledge can increase and link, in other words be "constructed" by them. Learning processes in science are orientated to the increasing complexity in science. An increasing process of constructing systems and rules, a more and more theoretical guided model building on the basis of an experimental extraction of a part of reality are features of such scientific inquiry. This necessary systematic, long-term planned and cumulative learning contributes to well-arranged, internally linked and in different situations, flexible adaptive knowledge. Of course, the school is a part of the students' life, but learning in school can only be successful, if the information is also relevant beyond the walls of the school. There should be a guaranteed link to future learning processes. Summarizing these aspects, teaching and learning in science is successful, if it is possible to realize a sequence of topics that equally guarantee a systematic learning (vertical knowledge transfer) and situation-orientated learning with every day tasks and problems (horizontal knowledge transfer). A method orientation expresses the possibility for the students to learn the necessary subject and cross subject methods. In the learning groups there should be occasions for dialogs, at first guided by the help of a teacher, but more and more autonomous and aimed at the development of scientific orientated conceptions and concepts. The students should have the possibility to describe their individual learning pathways and their individual solutions to problems.

In the teaching of school science, curriculum material and instructional strategies ideally should be tailored to the abilities and aptitudes of different types of learners. The overall objective should be to create learning environments which allow students to interact physically and intellectually with instructional materials through 'hands on' experimentation and 'minds on' reflection. Effort should be made to provide materials and instruction that give reality and concreteness to scientific concepts. Ideally, teachers should use a variety of instructional strategies and learning materials with the aim of increasing the impact and the effectiveness of their teaching (Tobin, Carie & Bettencourt 1988; Hofstein & Walberg 1994). The importance of varying instructional techniques has been investigated recently (Hofstein & Kempa 1985; Kempa & Diaz 1990a, 1990b), suggesting that a strong relationship exists between a student's motivational characteristics and her or his preference for particular modes of instruction. This finding is important and should be taken into consideration in the design and implementation of instructional techniques and content. In practice, it is difficult to respond appropriately to students' motivational characteristics and preferred modes of instruction. Informal (free-choice) science learning environments (e.g., science museums, zoos and outdoor settings; science youth programs; science media) could be utilized to maximize this end. Therefore, it would be useful if science educators would consciously utilize (1) a wide repertoire of instructional strategies in their work with learners in schools, as well as (2) a wide range of out of school environments which foster science learning.

Evidence from current research literature suggests that informal science experiences in school based field trips, student projects, community based science youth programs, casual visits to informal learning settings, and the press and electronic media can be effectively used to advance science learning (Hofstein, 1996). In the past, there was a strong link between learning contexts and methods; for example, it was assumed that the compulsory school context was tightly linked with formal learning methods, while the free choice (out of school) context was linked with informal learning methods. This link is at best artificial and at worst harmful to the pedagogy of science teaching and learning. It is artificial because a person's knowledge of science cannot be limited to what is learned in schools, and it can be harmful by limiting the types of learning opportunities available to students.

Based on this perspective, the CONNECT project consortium suggests that learning contexts and learning methods should be mixed, in order to provide an effective blend of learning experiences. In particular, compulsory school contexts should include informal learning experiences, such as those mentioned above.

Why should informal and formal learning experiences be blended together in school science? We believe that in addition to enriching the repertoire of learning opportunities, such blending can help meet the challenge of 'science for all,' i.e., providing science education opportunities tailored to diverse and heterogeneous populations of future citizens (Fensham, 1985, Hofstein, 1996). These populations vary both in their interest in learning science and in their abilities to learn science. Exploring the integration of informal learning experiences with the formal school curriculum could make an important contribution to the field of both formal and free-choice science education. While we have good reason to believe that informal learning experiences can enrich school science, we know relatively little about how these experiences can best be integrated into the school curriculum. Future research in science education should focus on how to effectively blend informal and formal learning experiences in order to significantly enhance the learning of science. The CONNECT project can make such a contribution, by bringing together a very strong partnership with complementary expertise, building upon the results of previous and currently running RTD projects in the field of science education and educational technology. The CONNECT project will be a step towards ambitious comprehensive educational reform, reform which will support people's learning in school and out of school and will take many years to accomplish. High quality science teaching and learning requires the combined and continued support of all involved actors: researchers, policy makers, curriculum developers, science educators in formal and informal environments, students and parents.

2.1 The CONNECT approach

The basic premise of CONNECT is straightforward and yet profound: student learning should be enhanced by integrating state-of-the art principles of learning that connect formal and informal science learning environments. One way to accomplish this goal is to create interactive learning environments that better contextualize and support learning, in formal settings (e.g, school) and also in informal settings (e.g., science centres and the home). This project hypothesizes that by partnering with science centres and using novel computer-based technologies such as Augmented Reality (AR) and Broadband Technology, such interactive learning environments can be created. These environments allow students to visit science centres and perform experiments that are not possible in traditional school settings and then to build on these experiences back at school and at home. Through these "connecting" partnerships, the costs of such an approach, difficult to afford by either schools or science centres alone, are thus maximized with the potential of making significant contributions to the field of science education.

The pedagogical approach chosen to realise the above is the Contextual Model of Learning (CML), developed by Drs. John H. Falk and Lynn D. Dierking. This model posits that there are three contexts that influence the nature of learning: the Personal, Physical & Sociocultural contexts (Falk & Dierking, 2000, 2002; Figure 1) and that in order to design effective learning environments and tasks one needs to consider suites of factors within each of these contexts.

Based on this pedagogical approach, basic principles for scenarios were derived - Personalisation, Interactivity, Collaboration, Perceived Choice and Control, Authenticity and Learning Strategies - which guided the development of specific scenarios.

Three different pathway patterns were identified: (1) having the school take a real visit to the science centre (Standard Pattern), (2) having the school class visit the science centre via Broadband Technology (Remote Visit Pattern) and (3) having two schools visit different science centres, possibly even in different countries (School Exchange Pattern). For each of these three pathways, three phases are implemented: pre-visit, visit and post-visit. The Augmented Reality introduces specific new learning opportunities, such as "making the invisible visible," but also includes constraints. Flexibility in design and planning on the part of teachers and students is particularly situated in the transition from the pre-visit to the visit phase. Also, role-taking and different collaboration patterns are flexible elements during the visit. Four exhibits in four different countries are described and classified in detail, according to the CONNECT purposes. For each exhibit, a learning environment is developed to enable the students to perform a learning process beginning and ending in the science classroom, with an integrated science centre visit. The Report describes how these visits can be adjusted to the needs of different classrooms and how school-museum collaboration might enhanced.

It is one thing to say that student learning can be enhanced by integrating basic state-of-the art principles of learning into student activities and by creating more interactive learning environments. However, it is quite different to decide what model or framework could best guide the development of such an approach. The model needs to be simple enough so it can usefully guide curriculum developers and educators, while at the same time accommodate the diversity and complexity that new research is revealing about the nature of learning.

2.2 The Contextual Model of Learning

The Contextual Model of Learning (CML), developed by Drs. John H. Falk and Lynn D. Dierking, was selected as such a framework. This model posits that there are three contexts that influence the nature of learning: the Personal, Physical & Sociocultural contexts (Falk & Dierking, 2000, 2002; Figure 1) and that in order to design effective learning environments and tasks one needs to consider suites of factors within each of these contexts.

Personal Context factors relate to what each learner brings to the learning task: their interest and motivations, their preferences for how to learn and their prior knowledge and experience. At the heart of this context is the knowledge that learning is facilitated when: 1) the learner is motivated and affected emotionally; 2) when personal interests are tapped into; and 3) when "new" knowledge is constructed on a foundation of prior experience and knowledge. Thus, three aspects of the Personal Context will be emphasized within the pedagogical design of CONNECT by connecting to and facilitating: 1) the prior knowledge and experience of students including efforts to create meaningful pre-visit activities; 2) student interest in, and motivation for, the topic and tasks they are engaged in; and, 3) opportunities for choice and control enabling students to be in charge of their own learning.

Physical Context factors encompass the notion that learning is best facilitated and expressed within appropriate and authentic contexts with objects and experiences from the real world. This is an attribute that the science centres involved in CONNECT bring to this effort. Learners will have

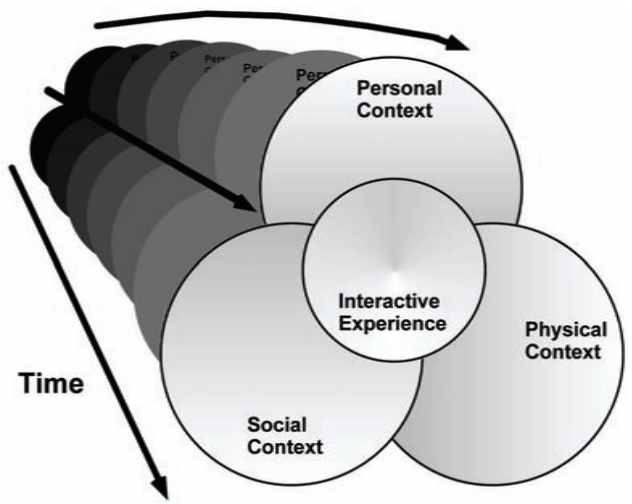


Figure 1: Contextual Model of Learning

opportunities to engage actively in learning tasks, in some cases physically interacting with exhibitions and models and also via the AR system. Thus, through CONNECT, students will be able to interact and experiment with objects in real time in a way not possible in most classrooms. Three other aspects of the physical context will also be highlighted in CONNECT: 1) physical orientation to the space and the experience of using AR (for students at the site and those not at the site); 2) conceptual advance organizers for the concepts presented and the tasks to be accomplished; and, 3) efforts to encourage subsequent reinforcing experiences back at school and at home.

Sociocultural Context factors encompass the notion that learning occurs within a sociocultural milieu; learning is both an individual and a group process. What someone learns, let alone why and how someone learns, is inextricably bound to the cultural and historical context in which that learning occurs and to the people collaborating in the learning process. In fact, for many learners, learning is best accomplished through collaboration and group problem solving so CONNECT learning tasks will provide ample opportunities for collective work on problems or challenges. There will also be opportunities for students to interact with staff and volunteers at the science centres, either physically if they are there visiting or virtually which can also be an important facilitator of the learning experience.

The model also includes a fourth and very important dimension - TIME. Learners build experiences and concepts layer upon layer and the best learning occurs when experiences are reinforced and connected across the settings in which learners participate. In the case of CONNECT students this means actively facilitating connections between school, the science centre and the home.

2.3 Basic Scenario Principles and underlying assumptions

This section describes the basic scenario principles, which emerge out of the pedagogical approach of the Contextual Model of Learning, and the more general underlying assumptions about learning.

A. CONNECT's Central R&D Question

Novel computer-based technologies can help create interactive learning environments that support learning, both traditionally defined and in new ways. The central R&D question of the CONNECT project is: Under what conditions can the technology of Augmented Reality (AR), combined with interactive science exhibits, support and enhance student learning? A number of related issues arise when investigating this question. Specifically, to what extent (and under what conditions) (1) can AR, added to a student's view of exhibits during a science centre visit, improve student learning? and (2) can Broadband Technology support the integration of a science center visit with school learning, e.g. by supporting communication and data flow between schools and science centres?

B. Why Educational Scenarios?

Tackling this central question demands the coordinated efforts of an interdisciplinary team of workers, i.e., those who have theoretical and practical expertise in diverse disciplines such as computer technology, educational technology, AR systems, learning and instruction, museum education, school learning and educational evaluation. In order for all the CONNECT team members to act in a coordinated fashion, it is critical that we all "speak the same language" so we can focus our common efforts on (1) goal analysis ("What are our criteria of success?") (2) product design ("How should we design our product to meet these criteria?"), (3) product implementation and (4) product evaluation ("To what degree does our product succeed in meeting our criteria of success?").

C. What is an Educational Scenario in CONNECT?

The concept of a "scenario" is often useful in the design of technology-related products. A scenario is "a description of a person's interaction with a system. Scenarios help focus efforts on the user's requirements, which are distinct from technical or business requirements." (Gerry Gaffney, www.infodesign.com.au) According to this approach, scenarios can provide a "common language" for team members from

a wide variety of disciplines to communicate with each other. In order to write scenarios, it is necessary to have "an understanding of the tasks to be supported by the system" as well as "an understanding of the users and the context of use." In the process of product development, review of the scenarios should occur on the basis of user feedback, resulting in the modification or even abandonment of "unrealistic or unrepresentative" scenarios.

In the CONNECT project, we define an educational scenario as "(1) the narrative of an hypothesized learning task, relating to interactions in (2) a specific learning environment (e.g., including learning objectives, a learner, a real interactive science exhibit, an AR system and a digital connection to a classroom of other learners), (3) justified in terms of basic scenario principles and (4) broken down into needed resources and tools."

The following paragraphs will expand on each of these four factors:

(1) Narrative of Learning Task. The description of the learning task should ensure that all the design participants understand and agree to the specific design parameters and the interactions that the AR system must support.

This narrative needs to be explicitly well-adopted to the needs of the learning environment, and justified in terms of the basic scenario principles, as described below.

(2) Learning Environment Variables. The learning task needs to have a "good fit" with learning environment variables, which include:

(a) the learning objectives (cognitive, affective, social; prior knowledge needed);

(b) the learner (grade level, learning style, pre-visit expectations and motivations, prior knowledge and interest, perceived choice and control; interaction with other students in the group; interaction with other visitors and/or museum staff);

(c) a real interactive science exhibit (topic of exhibit, design of specific exhibit elements, interaction options, orientation to physical space);

(d) an AR system (specific AR-exhibit interactions) and

(e) a classroom of other learners (i.e., the same variables as in "the learner").

(3) Basic Scenario Principles. Each learning task should have a "good fit" with the basic scenario principles emerging from the underlying assumptions of the CML and described as follows:

(a) Personalization. The learning task needs to be related to the interests and background of a wide variety of different learners and facilitators. It needs to build upon these individual differences, tapping into intrinsic motivation and providing opportunities for choice and control.

(b) Interactivity. The task should be "learner-centered" and should provide learners with opportunities to engage actively in the experience. Interactivity should occur between the learners and the science exhibit, both physically and via the AR system. This emphasis on interactivity implies that there should be a number of different options available to the learner.

(c) Collaboration. Learning is often enhanced by collaborative efforts. The task should promote such collaborative learning, through opportunities for collective work on problems or challenges.

(d) Perceived Choice and Control. As a result of the "interactivity" principle, the learners should have opportunities for free-choice behavior, leading to the perceived choice and control of their learning.

(e) Authenticity. The learning task should be as real-world and authentic as possible.

(f) Learning Strategies. When possible, the learning task should employ effective learning strategies, e.g., the use of advanced organizers, the use of dynamic explanations, making explicit connections between visible and invisible phenomenon, making explicit connections between linked-phenomena which take place on different scales (micro vs. macro), etc.

It is important to note that all of these "basic scenario principles" are based on and consistent with the Contextual Model of Learning (CBL), which emphasizes the importance of the personal context, the sociocultural context and the physical context.

(4) Needed Resources and Tools. After a learning task narrative is well-written (i.e., having a reasonable fit with the learning environment variables and the basic scenario principles) it should be analyzed into the needed resources and tools. This part of the scenario is necessary in order to "translate" it into the next, operational steps of development.

2.4 Assumptions about learning

An important goal of CONNECT is to promote science learning in non-traditional ways. Thus, new learning approaches that support opportunities for students to think about science and actively engage in doing science being created, tested and implemented. These approaches are guided by the CONNECT learning scenario principles that emerge from the Contextual Model of Learning: Personalization, Collaboration, Authenticity, Interactivity and Perceived Choice and Control. The learning scenario principles are based on the idea that learning involves some sort of activity which can be characterized as highly relevant, socially mediated, contextual and self-influenced (Jonassen, 2000).

As opposed to a behaviourist approach to learning, it is also assumed that learning is a process of constructing meaning in which individual perceptions, social interactions, the physical environment and prior knowledge and experience all directly, and uniquely influence and inform the development of mental schema (Ausubel, 1968; Resnick, 1983). Constructivist theory states that learning is always highly individual; exactly how schema change is likely to vary from individual to individual (Pope & Gilbert, 1983). In other words, it is assumed that each individual brings varied and unique prior experiences and knowledge into a learning situation and that these experiences and knowledge directly influence how an experience is perceived and processed. The individual's prior experiences combine with the individual's current experiences to reshape the individual's mental structures; this recombination and reconstruction is what we call "learning." Consequently, what is learned is unique for each individual, and that learning is strongly situated within the context in which it was learned. Thus, the activity that a learner is engaged in should support active engagement by allowing students to apply existing knowledge, to make sense of problems within reciprocal settings (asynchronous and synchronous) and all of the settings in which learners participate including school, home and science centre, to investigate phenomena in scientific environments, and to interact with and control real and virtual objects.

Emphasising these learner-centered principles we heavily rely on Bandura's social cognitive theory (2001), the situated learning theory, and the Contextual Model of Learning (Falk & Dierking, 2000), which advocate a self-initiated, active view of the learning process. The social cognitive theory sees motivational, cognitive and social skills as integrative aspects within the self-regulative learning process. The learning environment in which the activity takes place can support the development of these skills and setting. One way of emphasising active learner involvement is to allow students to shape and manipulate the activity environment. By letting learners be the initiators of the learning process they are able to develop skills that help them to self-regulate the learning-experience (Bandura, 1997). However, it is difficult to create an environment which challenges (and which does not discourage) students to interact with it and with peers who are also involved in the activity. Lave and Wenger emphasise the idea that "social engagements" are essential components for learning to occur (Lave & Wenger, 1991). One of the premises of the situated learning theory is that learning needs to be situated in a context to take place. This context should be complex, as authentic as possible and afford rich possibilities for social interaction to motivate students to actively construct their own knowledge.

2.5 Modelling Pathways in CONNECT

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 in a way the students can learn optimally and the visit can be integrated into the learning process most efficiently so it is not a singular experience. The visit has to be prepared in the classroom before and the learning experience has to be deepened being back in school afterwards. Broadband Technology can help by supporting communication and data flow between the different locations and provide a repository of all digital learning material and outcome. Data produced during the visit while examining the exhibit should be easily accessible when being back in the classroom. The following sections describe three pathway patterns, the CONNECT project proposes for testing the basic research questions formulated in the last chapter.

2.6 Pathway patterns

The presented pathway patterns are designed to support the integration of the informal learning experience in the science centre into the formal school learning processes optimally. It is important to understand that the CONNECT scenarios provide many different learning opportunities for the students, which the teacher can adopt, adapt, and modify as desired. It is important for the teacher to give students the opportunity to play and experiment with the AR system, before and during these activities. We also encourage teachers to make suggestions and develop their own activities (e.g., involving creative problem-solving, role play and student collaboration). The CONNECT project suggests

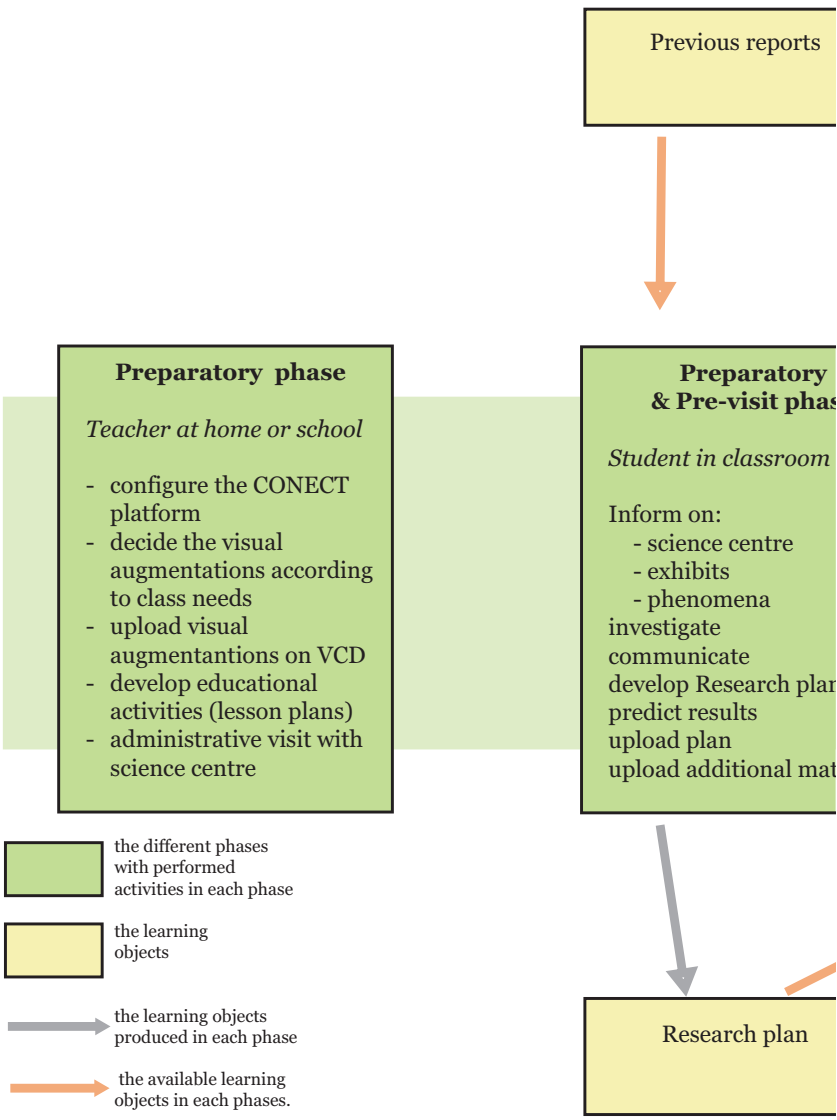
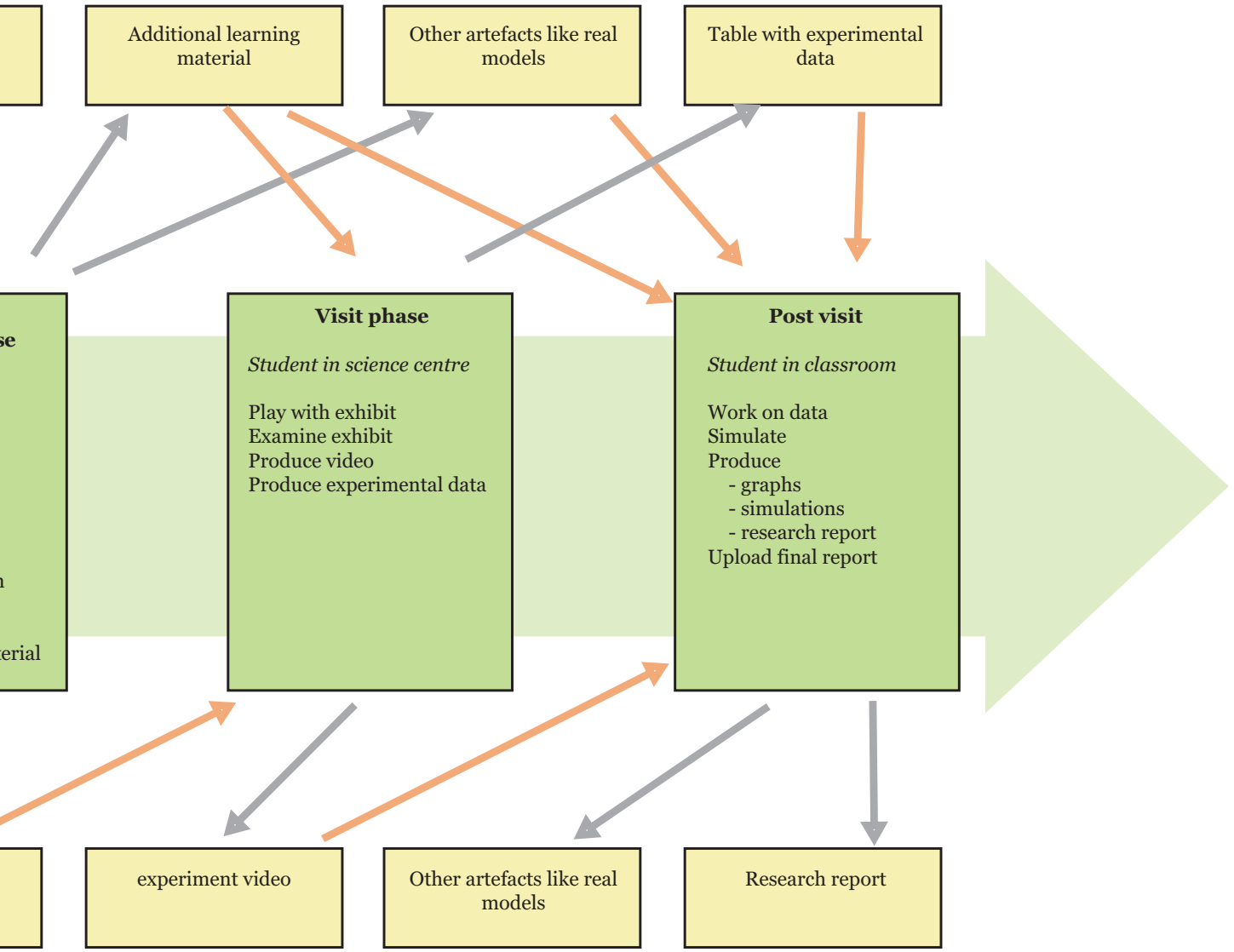


Figure2: Data flow diagramfor standard pathway

a three-phase structure of an educational pathway including a science centre visit. The learning experience should be prepared very well before the visit. After the visit the made experience should be deepened, worked out when back in school. According to this a typical pathway will have three phases: A pre-visit, a visit and a post-visit phase.

The pre-visit phase is located in the classroom. The students are preparing for their science centre visit, have to inform themselves about the domain, the possible research areas and the according exhibits, and have to develop a research plan. Beside this, the students should be supported to develop a relation to the exhibits to be visited and their domains (e.g. by making classroom experiments with self-built paper planes before visiting the aerofoil). Several learning objects could be produced and re-used for learning purposes. For the test run exhibits you will find a collection of suggestions of how to enrich the pathways with specific learning activities producing related outcome in ANNEX B to this document. Later museum staff and teachers can bring in their own ideas and experiences on how to enrich the pathways through their phases by uploading lesson plans and learning material to the repository within the CONNECT platform.

According to the CONNECT research focus on how broadband technology can support learning we will focus in the following on those objects that can be digitized and stored/ exchanged through the CONNECT platform. As described,



this can be enriched in practice easily.

Basic (and visit pre structuring) student built outcome of the pre-visit phase is a research plan which could include:

- a description of the phenomenon the students want to do research on
- a predictive explanation about the phenomenon
- a selection, which exhibits they want to examine
- Concrete examination plans explaining how to proceed for each exhibit. Figure 2 shows the different phases and the data flow that has to be supported by the system.

Dependent on the individual class (even students) situation the teacher has to adjust the scaffolding level (by work sheets, pre selections,..). A virtual portal can support the students' work in this phase by:

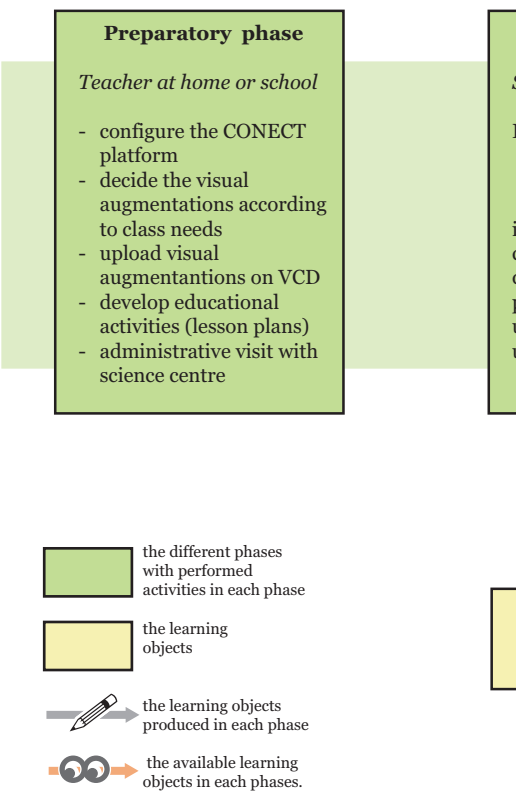
- Delivering easy access to information about the science centre in general, its exhibits and the phenomena research can be done on.
- Enable the students (synchronous and asynchronous) communication with other learners, experts and even current science centre visitors
- Providing a data repository where the student can store the files used or created during his research preparation
- Providing an upload possibility for information needed during the visit phase (like the research plan)
- Access a research report data base of former visits of other schools (if allowed by the teacher)

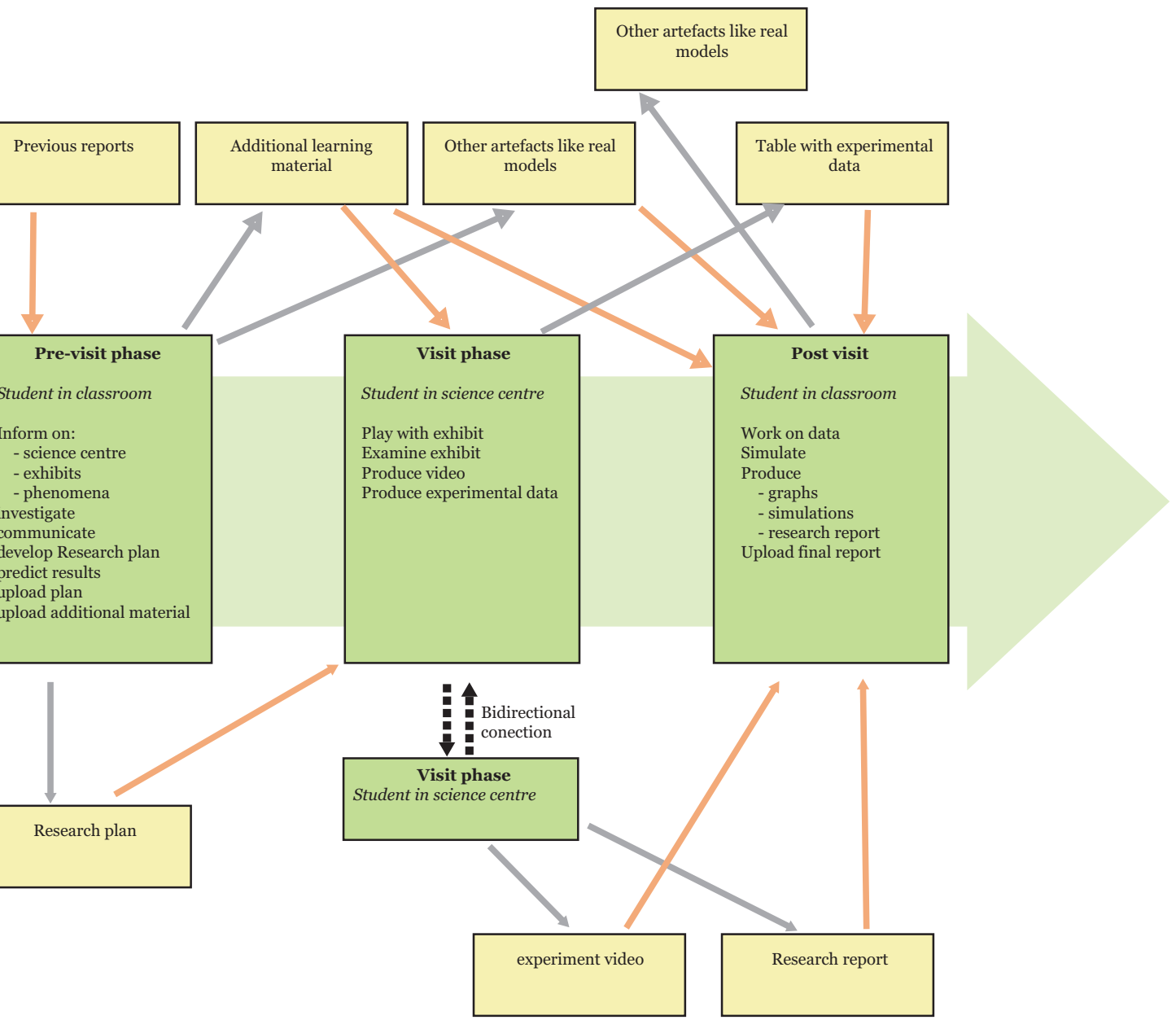
The visit phase will typically be located in the science centre. The students first should have the possibility to play around with the exhibit experiencing its features. To support playful learning we suggest the AR system should include motivating features (e.g. unexpected behaviour) so it is fun to interact with the exhibit. After the first period of approaching to and playing with the exhibit the students are performing their experiments according to the research plans they developed before. How an AR system could be configured to provide the best individualised support will be described in the next sections in further detail.

The post-visit phase is again located back in the classroom, where the students can start to complete their research reports and possibly use additional simulation and visualisation tools. In addition to the computational support by the platform they had in the pre-visit phase they now have access to the experimental data produced during the visit phase, namely the tables with captured values they recorded. 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. Figure 2 shows the different phases and the data flow of the standard pathway pattern.

Next to the standard visit pathway described at least two other possibilities will be considered as part of the CONNECT project. A visit to a science centre is not always possible (imagine a Portuguese school class visiting a Finnish science centre with a unique exhibit), and therefore the remote school visit pattern could apply. Pre and post-visit phases will remain as described before but the students will not leave the classroom for the visit phase. The experiments will be performed by a person in the science centre connected to the classroom through the broadband connection; with the AR view shared. Interaction is possible using an additional bidirectional audio connection. For this pathway pattern broadband technology and quality of service will be of utmost importance. Figure 3 gives an overview about the remote visit pattern.

Figure 3: Data flow remote visit pathway pattern




Other artefacts like real models
Previous reports
Additional learning material
Other artefacts like real models
Table with experimental data
Pre-visit phase
Student in classroom
Inform on:
- science centre
- exhibits
- phenomena
investigate
communicate
develop Research plan
predict results
upload plan
upload additional material
Visit phase
Student in science centre
Play with exhibit
Examine exhibit
Produce video
Produce experimental data
Post visit
Student in classroom
Work on data
Simulate
Produce
- graphs
- simulations
- research report
Upload final report
Bidirectional conection
Visit phase
Student in science centre
Research plan
experiment video
Research report

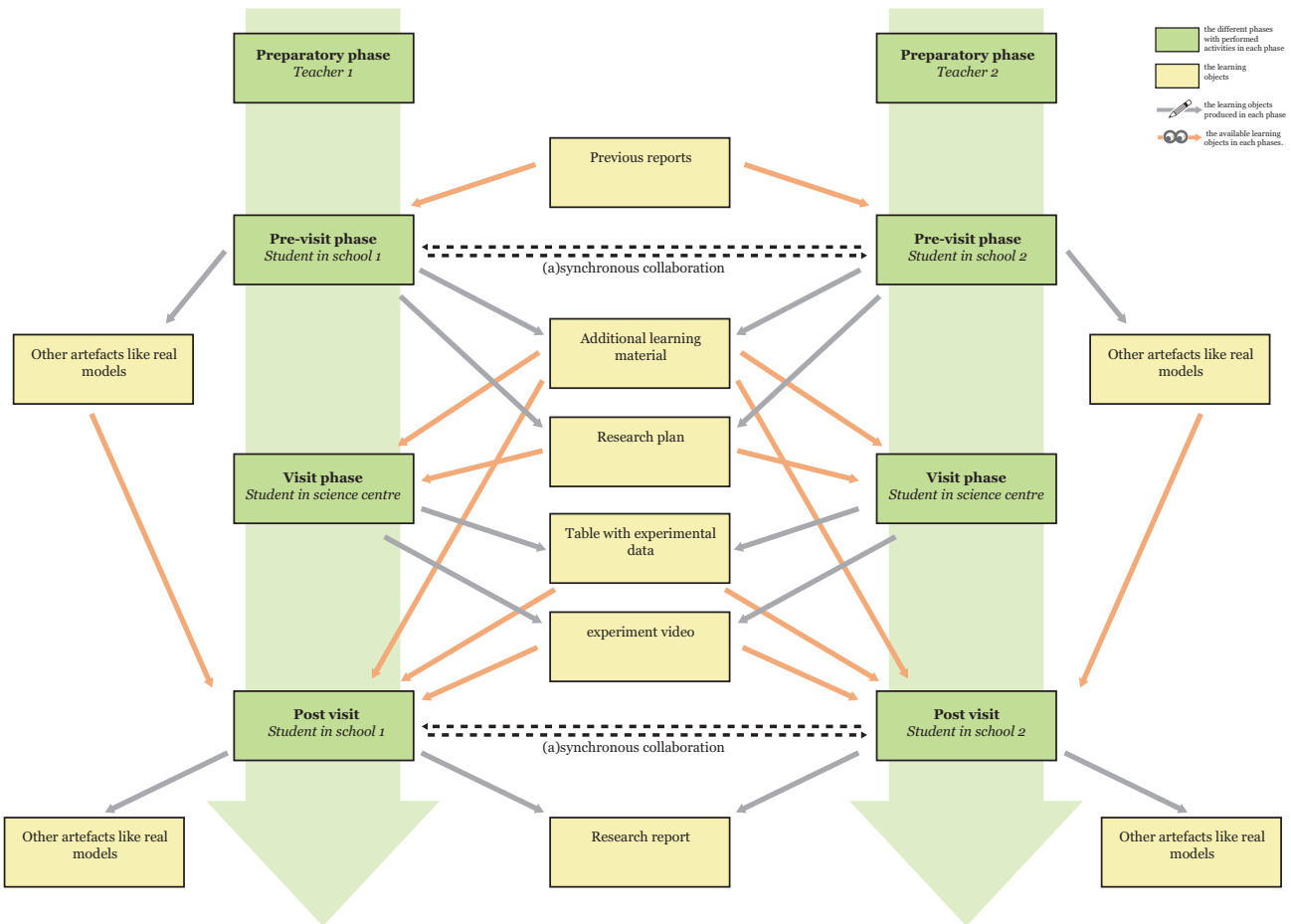


Figure 4: Data flow diagram. School exchange pathway pattern

A third, more sophisticated possible pathway pattern might be the school-exchange-pattern (see figure 4). Two schools collaborate and share knowledge in the pre-visit phase through the platform. They are located in different places (countries) performing their experiments in different science centres during their visit phases. Sharing the outcome of their visits they could even produce joint research reports. The portal is then used to meet in "virtual classrooms" for communication, sharing and collaboration. Like this it could even be worked on more sophisticated research which cannot be done by visiting just one museum. More complicated pathways or combinations of the proposed ones are possible.

On Collaboration

As a typical way of scientific research, collaborative learning is intended to be the standard through all the scenarios. The students should work in groups in the pre-visit phase by distributing work (e.g., one searching the internet by using the link collection provided on the platform, one having a look into the books the teacher provided for preparation). This will normally, but not necessarily, be a face-to-face situation. The school-exchange-pattern suggests the possibility of learning groups with participants from different schools (countries?), further emphasising the importance of reliable communications. Communication throughout the platform should be enabled within the group, between groups, with external learners and experts, and with the current AR system user in the science centre.

During the visit phase advanced collaboration possibilities appear when having several AR systems. The strength of showing personalised information could be used by creating scenario specifications fostering collaboration (e.g. augmenting the students views with different 3d models like lifting force and airflow on a plane wing).

2.6.1 Performed activities

This section gives an overview what activities are performed by the students and the teachers in each of the phases of a learning scenario within CONNECT.

The preparatory phase

Before a learning scenario can be performed by a school class several preparations are necessary. The platform and the AR system have to be adjusted to the school classes needs. Therefore, in a preparatory phase, the teacher of a class and the science centre staff have to perform the following tasks:

- configuring the platform in general (e.g. are the students allowed to view previous research reports of other students?)
- configuring the AR augmentations according the school classes needs
- administrate the visit

Figure 5 gives a more detailed overview about the different tasks the teacher is performing before the start of a learning scenario.

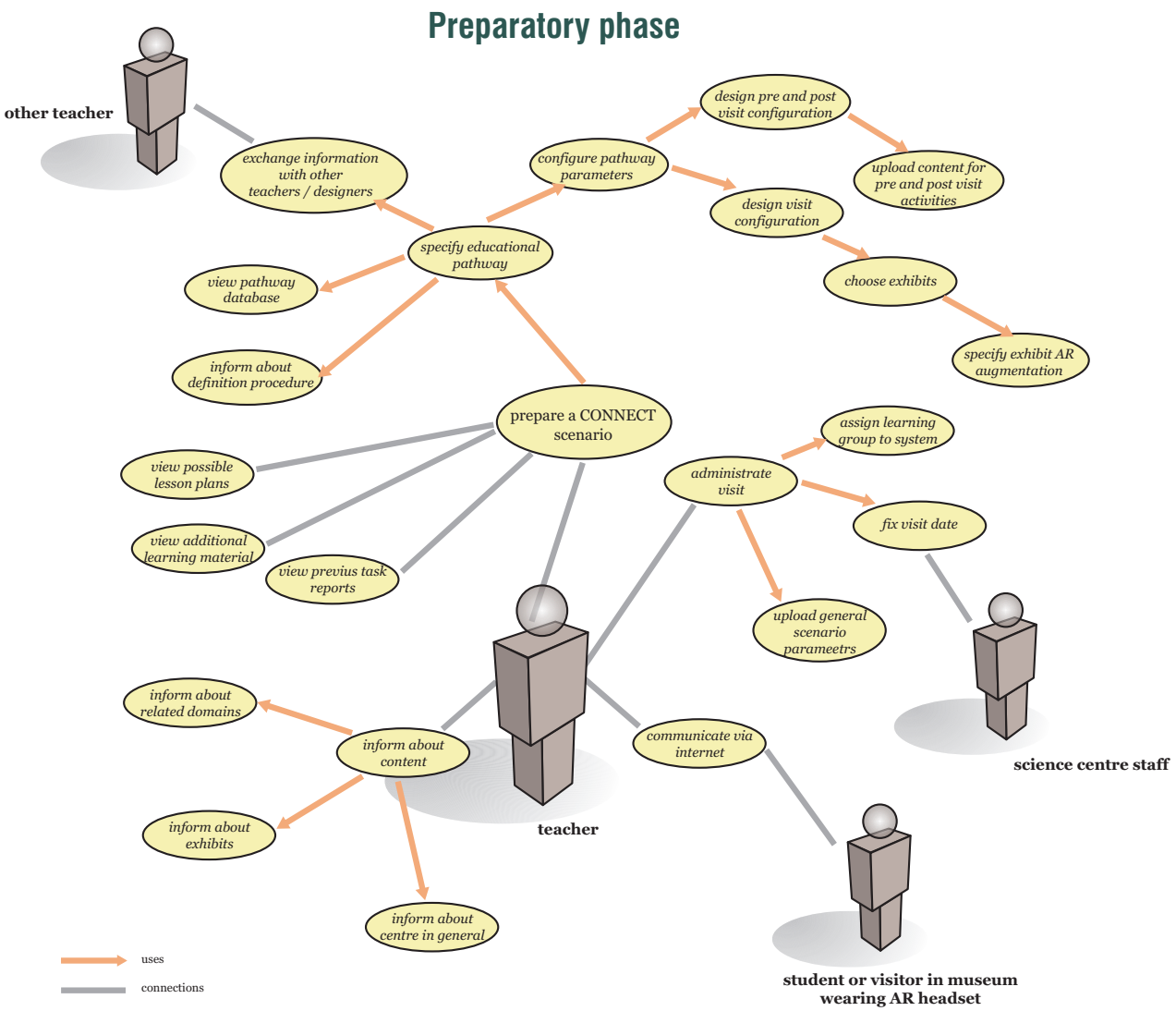


Figure 5: Use case diagram preparatory phase

The pre-visit phase

Within the pre-visit phase the students are preparing the experiments to perform during the visit phase. They first have to inform themselves about the science centre, its exhibits and the related learning domains. Then they have to develop the research question they want to work on during the visit. The teacher has to decide about the degree of freedom for the students while preparing their visits. Perhaps he provides a list of experiments the students can chose from. The students can examine previous research reports written by former visitors, exchange with other learners and perhaps experts, to work on their research question. They have to formulate a research plan, how to perform the experiment and make predictions about the outcome of the experiment. Further on the students can connect into the science centre contacting a current visitor using the AR system. Performing these activities enables the students to be well prepared and motivated for their visit to the science centre.

Figure 6 shows the different tasks the student can perform during the pre-visit phase. Not all these tasks will be realised for the test run.

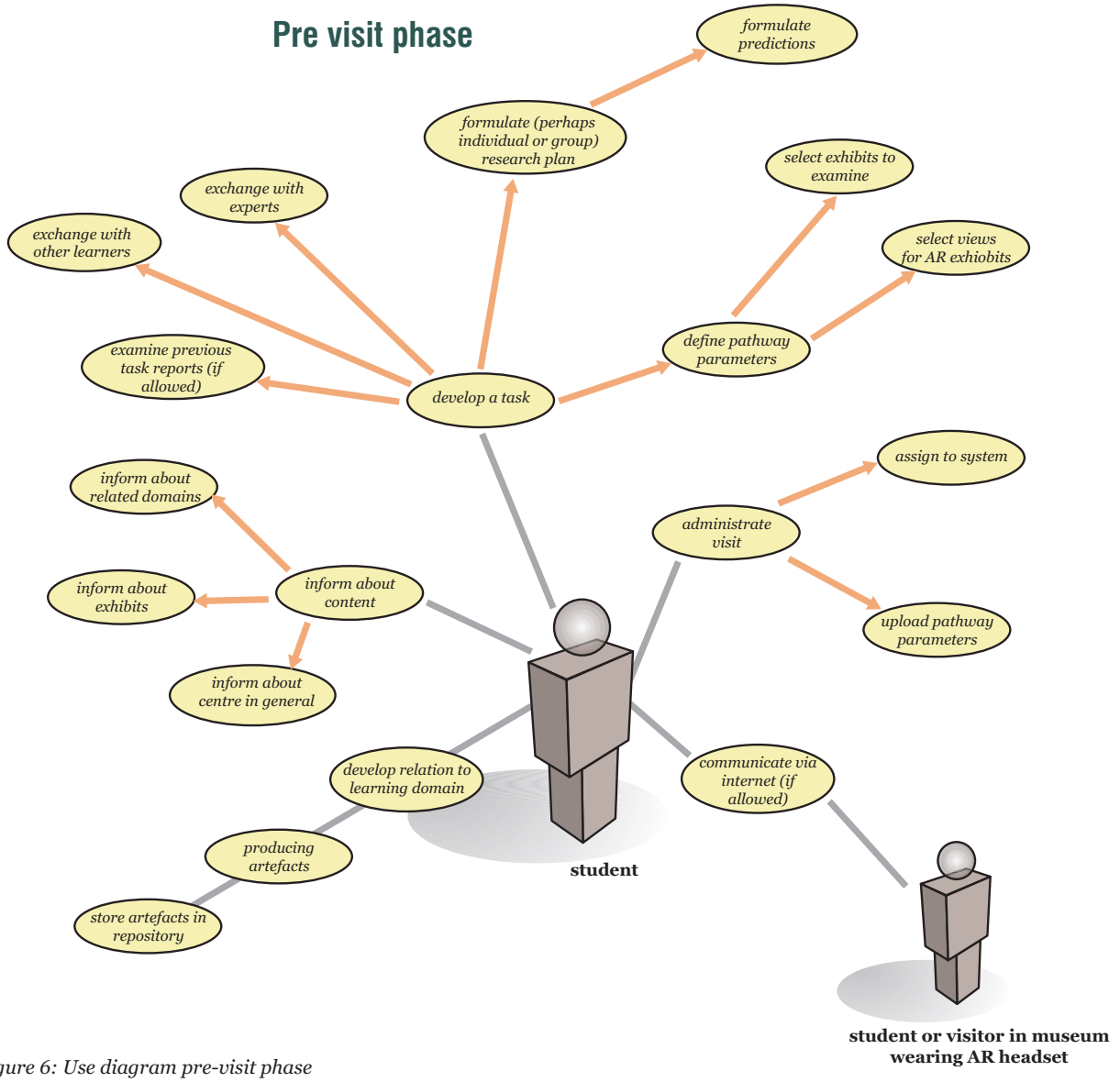


Figure 6: Use diagram pre-visit phase

The visit phase

During the visit phase the students are performing the experiments prepared in the classroom before. As described before, they first should have time to approach the exhibit, play with it and discover its possibilities. Then they will modify exhibit parameters according to their research plans and view the results of these modifications. The AR system will enhance their views by adding virtual objects like 3d models of invisible phenomena, data displays and other content helping to explain the phenomenon or helping to perform the experiment. They will 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 usable are recorded video data and tables with rows of variable values stored several times on students demand according to their experimental purpose. If allowed, the students can communicate with current platform visitors and share their experiment. Figure 7 shows the different tasks the student can perform during the visit phase. Not all these tasks will be realised for the test run.

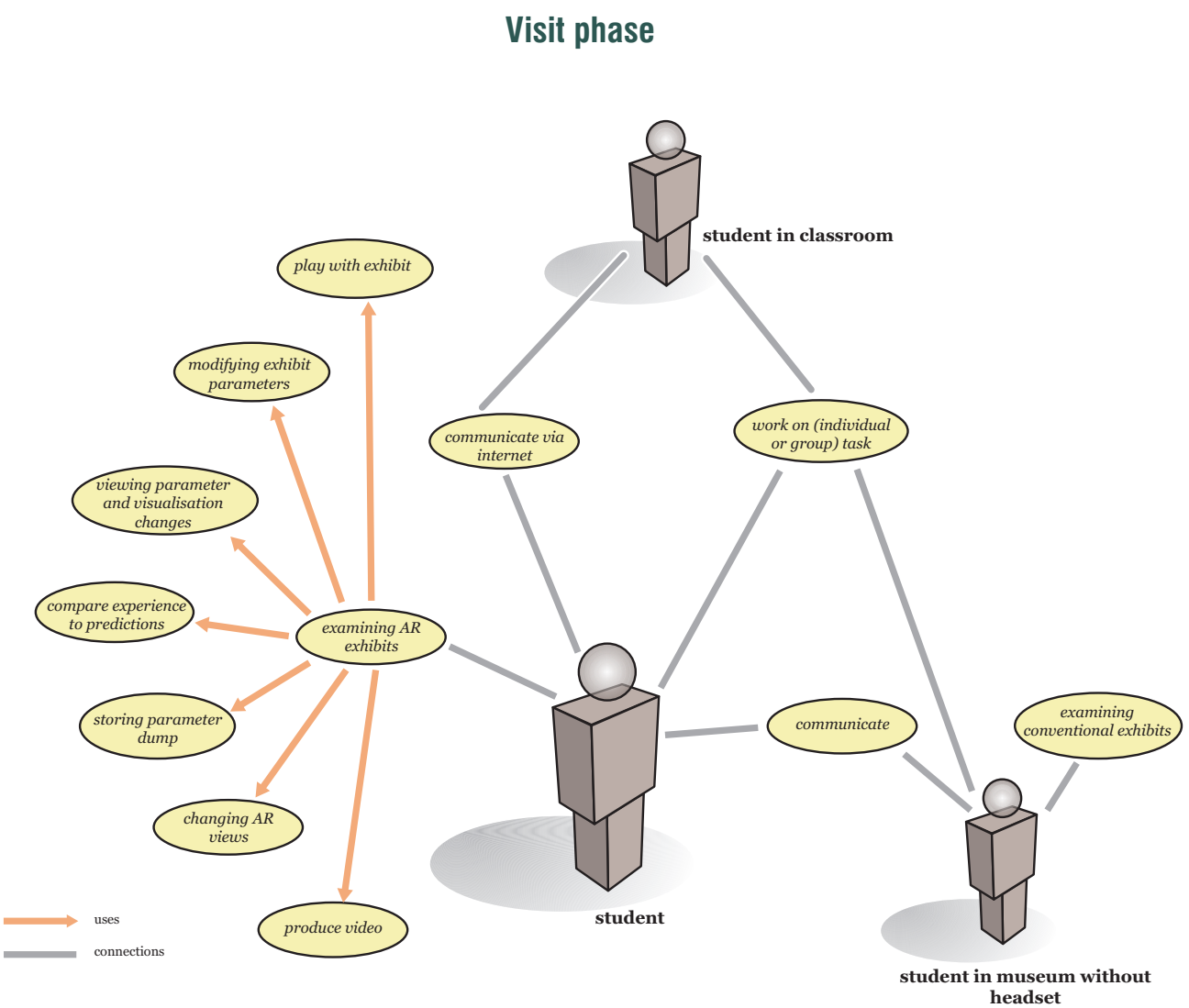


Figure 7: Use case diagram visit phase

The post-visit phase

The post-visit phase takes place back in the school. The platform provides the students with the data produced during the pre-visit and the visit phase before (like the research plan, visit videos and data tables). The students have to work out research reports describing their questions, their predictions, the performed experiment and the results. Therefore they can communicate with other learners and experts through the platform.

Figure 8 shows the different tasks the student can perform during the post-visit phase. Not all these tasks will be realised for the test run.

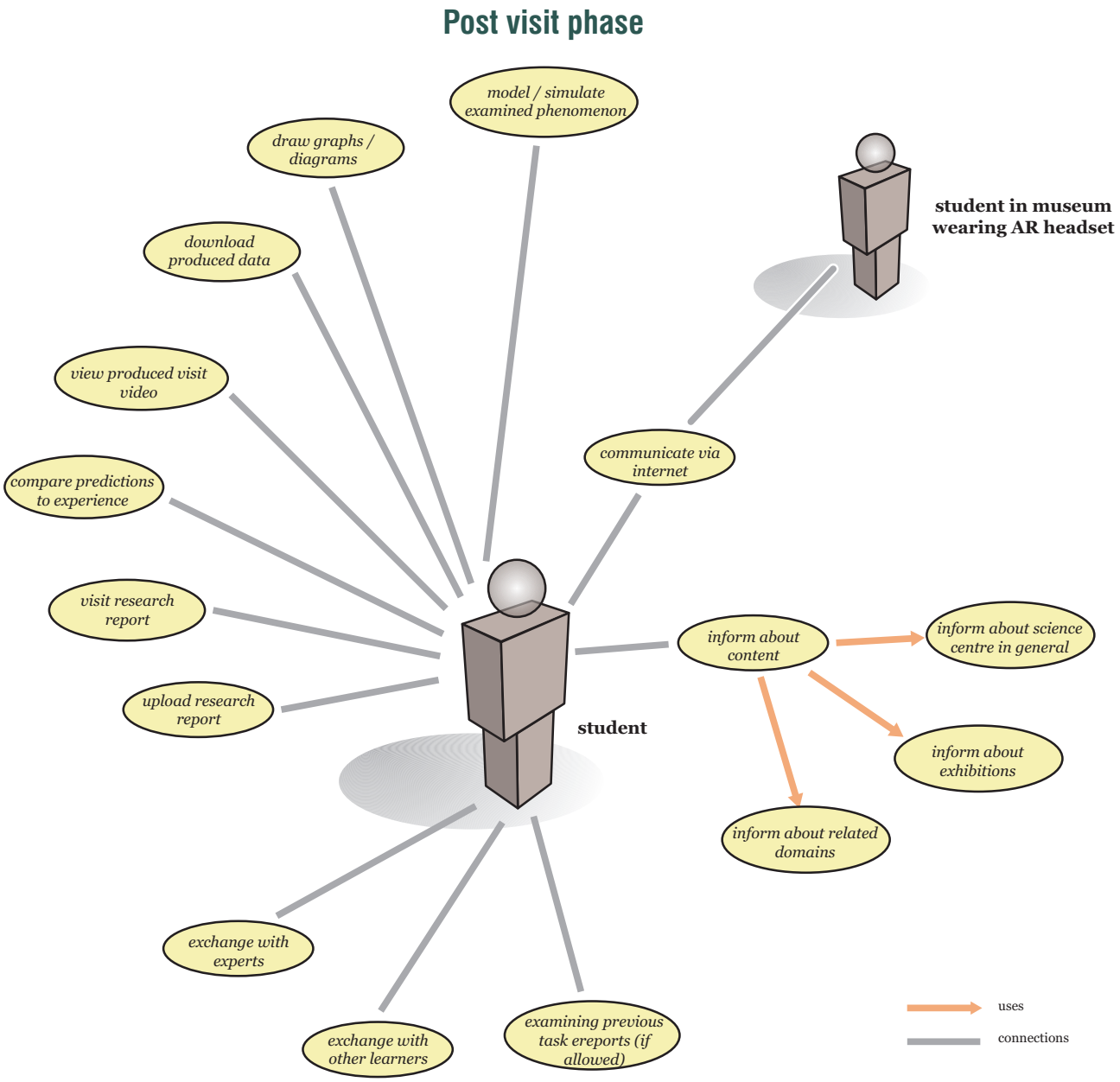


Figure 8: Use case diagram post-visit phase

3. Presentation of Technology

3.1 An Overview to the CONNECT System

The main objective of the CONNECT project is to connect informal with formal learning by exploiting the huge and concentrated knowledge stored in science museums, "break" the walls of the science park or the museum, and virtually transfer the science museum into the classroom and vice versa. Furthermore, the visit to a science museum will be more personalized to the exact profile, knowledge level and personal interests of the student. The above is achieved by the usage of innovative technologies which allow the real and the virtual student/visitor to a science museum to wonder around the exhibits enriching his/her learning experience with his/her own personal selections in an information rich environment.

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 system provides a fruitful environment for innovative use of educational technology and alsointerconnects 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 which facilitates pre-visit

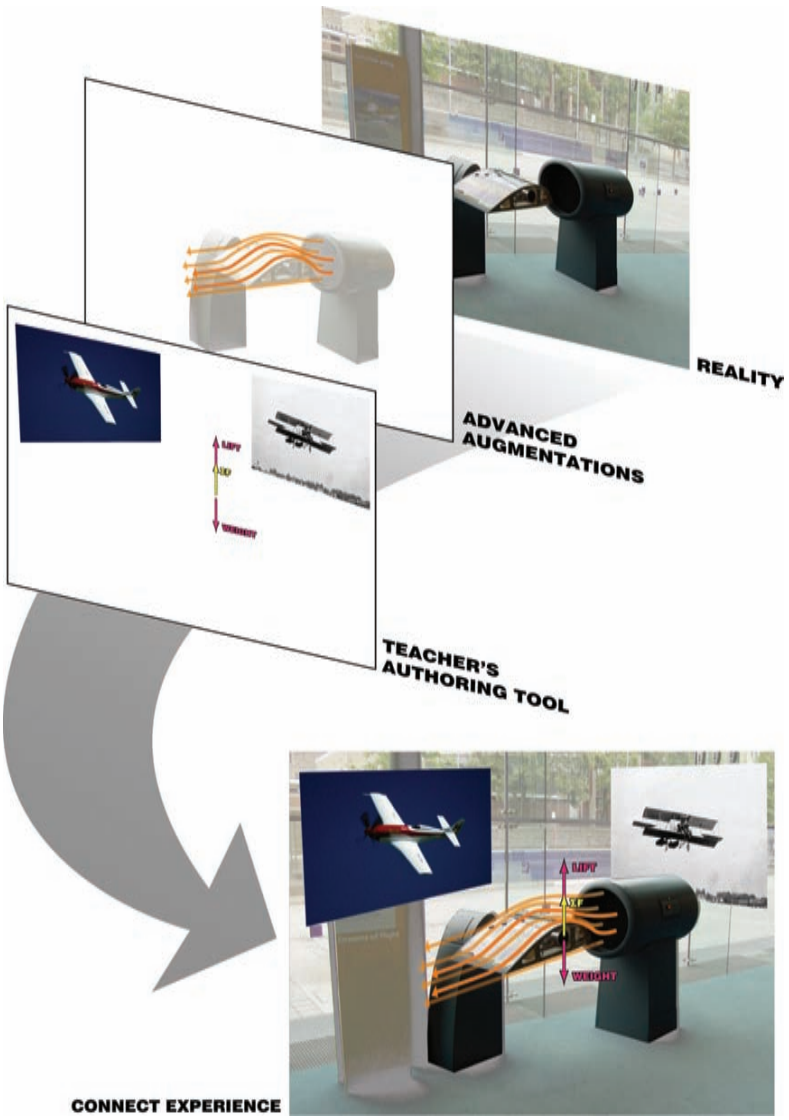
and post visit activities as well as the remote visits to the museums and science parks, and

(2) the mobile AR system which the student will wear during his/her visit (The mobile AR system is fully described in the next chapter of this guide).

The CONNECT platform 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 science parks, science museums and research centers. It distributes information and organizes educational activities. It coordinates teachers, students and museum staff in the use of the innovative technology. The CONNECT Platform supports the mobile's AR system specifications and functionalities as well as materializes the VSTP's requirements and procedures. The CONNECT Platform supports the management of educational pathways, the authoring tool (CONNECT Virtual Designer, CVD), the remote school visit pathways which allows the science museum to classroom communication and provides collaborative tools.

The integrated CONNECT system provides an ambient learning environment which functions in two distinct and equally important educational modes: the museum and the school mode (see Figure 10).

In the museum mode, a student sees the real exhibit as well as visual augmentations provided by the educator via theAR system. Through the school mode, students that do not have access to distant museums or science centres can share the experience of a visiting student via a 2-way audiovisual communication channel. The two groups of students can interact with each other via an audio connection.



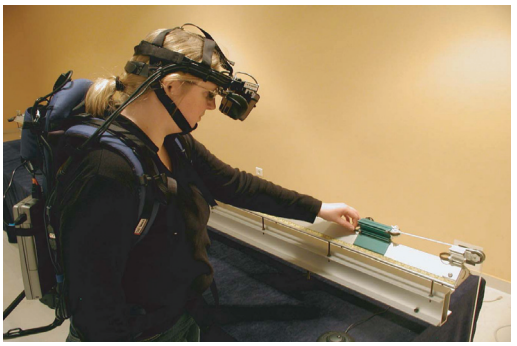


Figure 9: Visualising the invisible

The CONNECT experience could be realized by adding to the student's view a series of augmentations, advanced or simple. The advanced augmentations (E/M fields, molecular motions, air flow, microscopic view of the matter) are created by the CONNECT team. Through an authoring tool the teacher or the museum educator can upload additional simple content (text, graphs, symbols, video, sound) in order to create all the necessary links to the curriculum.

3.2 Description of the CONNECT Platform

Upon, log in the VSTP, the educator enters the CONNECT Platform (CP). The CP provides two types of facilities: the workspace and the toolbox. The workspace helps the educator to manage and guide through the educational processes. The toolbox is a collection of tools provided to facilitate the educational process. It contains tools for managing the students and their access rights, content search facilities, communication facilities (chat, forums and mail) and so on.

The educational process resembles a path and thus it is called Educational Pathway. Each Educational Pathway is separated into four phases: Preparatory, Pre-Visit, Visit and Post Visit. The educator's first task is to prepare the Educational Pathway, which occurs in the Preparatory Phase.

During the Preparatory Phase, the educator

- creates accounts for the students,
- assigns them to the specific Educational Pathway,
- uploads material for them
- sets up the upcoming phases.

During the preparatory phase, the educator also specifies the AR experience for his/her students before they go to the science museum. Therefore, the educator needs to know which exhibit at which science museum to use. The decision will be based on the information received from the VSTP. The CONNECT Visual Designer (CVD) provides the authoring tool for designing the AR experience.

The CVD is part of the CONNECT Platform. However, it represents a novel approach to the specification of augmented reality experiences and supplies a large amount of functionality, thus it is treated separately in this manual. The specification produced with this tool is transferred to the mobile AR unit, which will reproduce the experience during the visit of the student at the science museum.

The Pre-Visit Phase prepares the students for the visit. They can log in to the CONNECT Platform in order to communicate, share, explore and learn about the educational domain. Through research and communication, they can develop ideas about how the phenomena under study work. The platform serves as a medium to this purpose.

During the Visit Phase, the students visit the science museum. The technical museum staff (administrators) will load the educator's prepared material (AR Scenario) on the mobile AR unit. A student will wear the mobile AR unit and go to the exhibit. They interact with the exhibit and test their ideas about the examined phenomena. They collect measurements and pictures to substantiate their claims as well as communicate with students in remote locations. The CONNECT platform grants the ability to remote classrooms

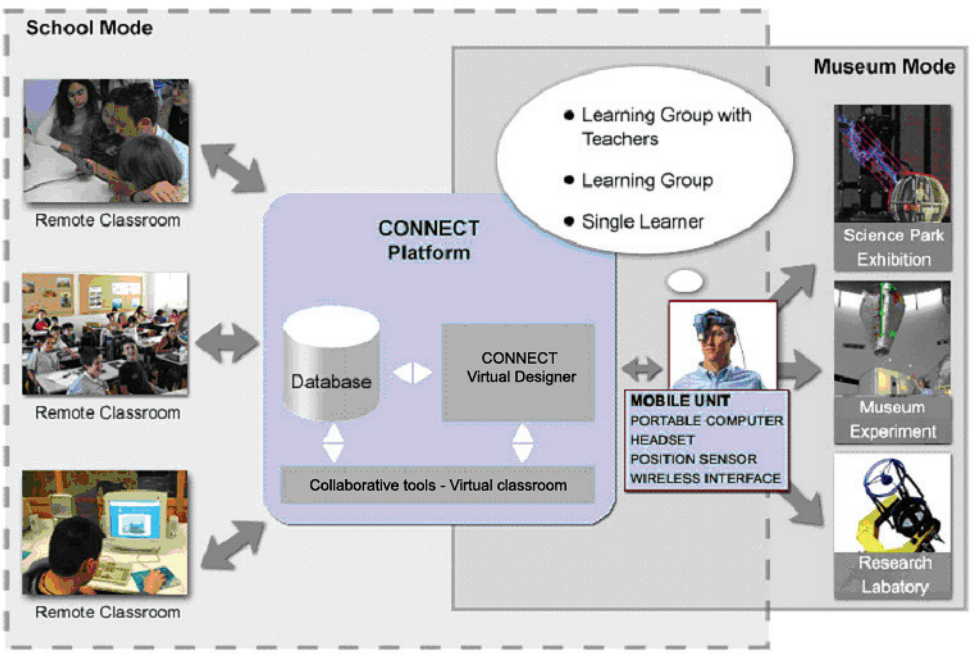


Figure 10: The system's architecture.

to communicate with the one wearing the mobile AR unit as well as see what they see.

For the Post-Visit phase, the CONNECT platform will make available the data collected during the visit to the classroom. The students can use them to draw conclusions about the phenomena under study.

The discussion so far has revolved around the main users of the CP: the educator and the student. The system however requires users responsible for the maintenance and proper operation of the system. This is especially needed since the CP is deployed in several locations which co-operated with each other. These users are the Administrators and their responsibilities include:

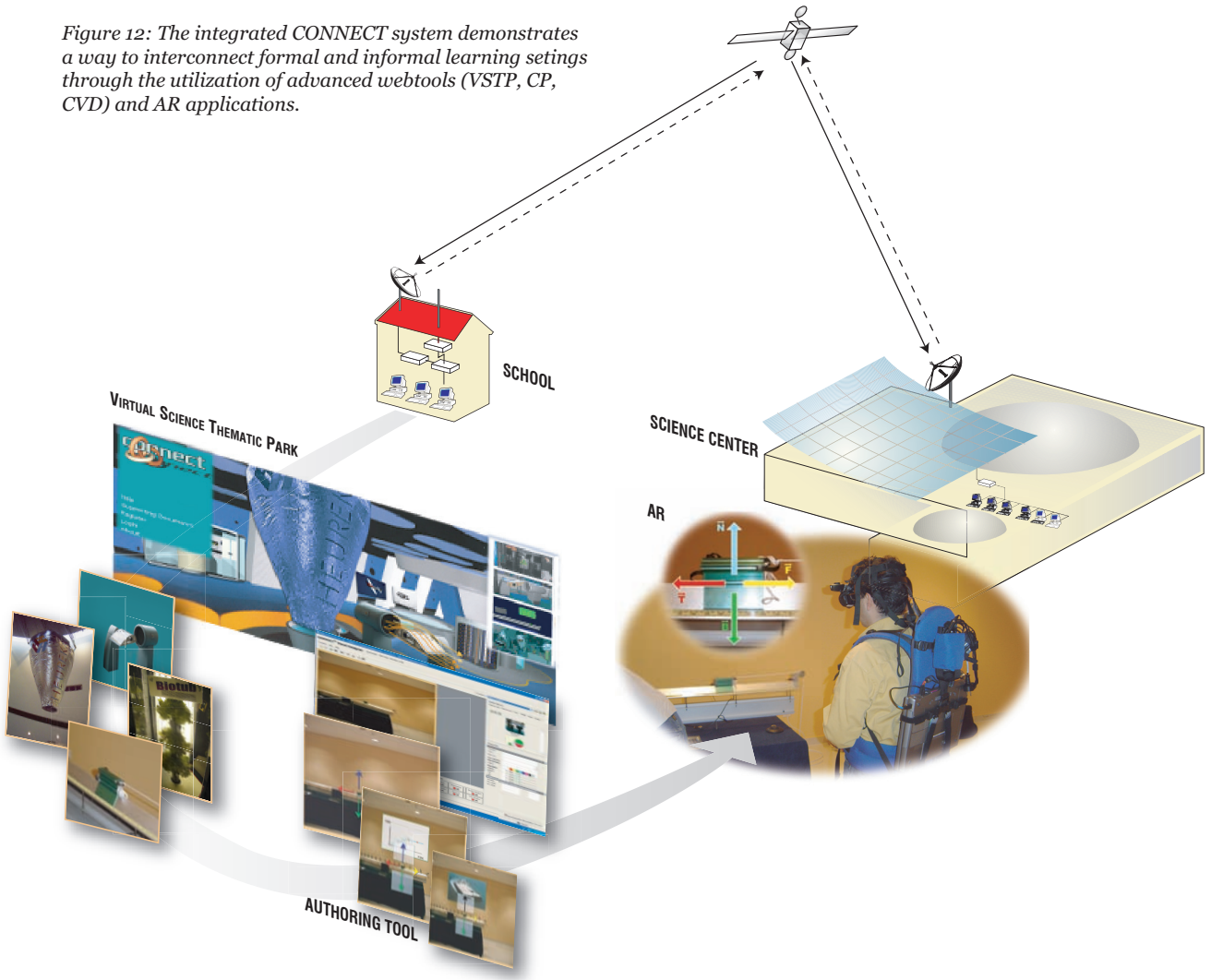
- Installation of the CP
- Educator account management and registration
- Making more exhibits available for AR Scenario authoring through the CVD
- Updating the CVD content
- Issuance and collection of the mobile AR unit at the science museums
- Upload of the captured data on to the platform
- And may be even content development

This document does not explain the CP features geared towards the administrator.



Figure 11: The artist's point of view of the interface of the Virtual Science Thematic Park, which is currently under development. The interface will be enriched with further 3D applications to represent a real science thematic park.

Figure 12: The integrated CONNECT system demonstrates a way to interconnect formal and informal learning setings through the utilization of advanced webtools (VSTP, CP, CVD) and AR applications.



3.3 The VSTP

The VSTP is in an eye-catching interface, which introduces the features of the project to perspective users. It is divided into 3 sections. The VSTP interface is presented in Figure 11.

The interface depicts the exhibits available for use in the CONNECT Platform. Clicking on any on the images will show information in the central area about the exhibit and the science museum that hosts it.

3.4 The CONNECT Platform Tutorial

The CP has been implemented to support the educator in setting up educational pathways. In particularly, the software is modelled around “standard educational pathway” and it is flexible in accommodating the “remote school visit pathway pattern”. This tutorial walks the educator through setting up a standard educational pathway.

We start with a brief introduction to the organization of the activities necessary to set up an educational pathway. It includes the explanation of concepts to aid understanding. Then, the steps of the procedure are described along with clarifying notes, cautions and warnings.

Pre-requisites

Before we begin, make sure your computer has Internet browser installed and has access to the internet. If your browser blocks pop-up windows, you will need to allow them when working with the CP. It is recommended that your display's resolution is adjusted to 1152x864. Basic familiarity with computers and how to browse the Internet will be adequate for completing this tutorial. However, it is strongly recommended you review the pedagogical reports accompanying this project and follow the recommendation therein.

Entering the CONNECT Platform

1. Make sure you are connected to the Internet.
2. Open Internet explorer.
3. Direct your browser to http://connect.iisa-innov.com/

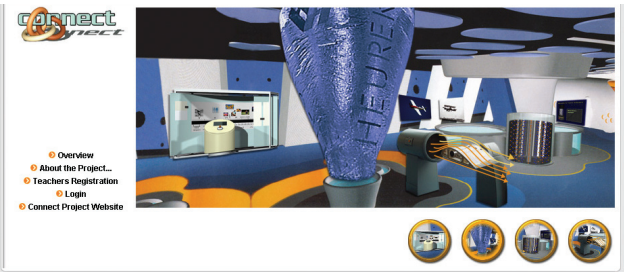


Figure 13: The Initial screen of the CP.

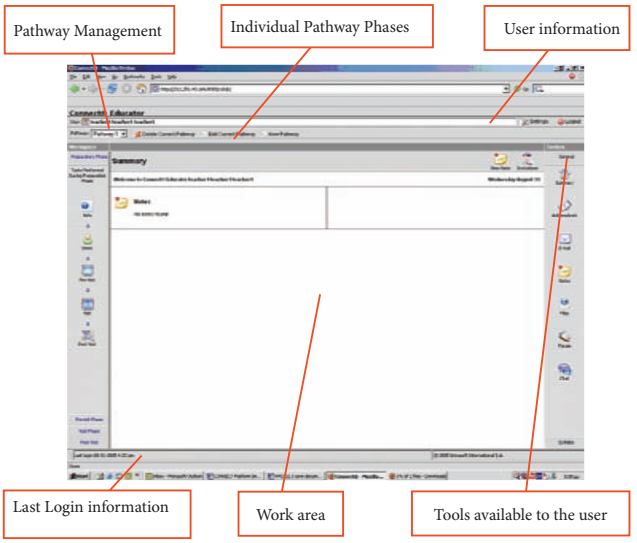
The browser should load the initial screen (Figure 13). A username and password will be provided to you upon request but for the purposes of this training exercise we will use a default account "teacher" with password "123" (remove the quotations when typing in the username and password).

Introduction to the CP Interface

After entering in CP, the first screen encountered is the following

Upon entering in the CP, the system provides the user with a number of status information.

- The "Title" field informs you in which mode the system is in. On the top left hand corner notice the label "Connect@ Educator" informing that the user that they have entered the system in a Teacher's role .In the line below, the platform informs the user of the account name with which they are currently entering the system.



- The "User Name" display is followed on the right by the Settings button, which allows the Teacher to personalize the tools and manage their own profile, password, look & feel, notations, email statistics.
- The users can logout of the CP by clicking the Logout button at the end of the same line.
- At the bottom left of the window the user can view the last time he/she logged. This information may help the user identify authorized access to the CP with their credentials.

Further down, the screen is divided into three sections. The middle area, which is by far the largest, serves as a work area, while the areas to the left and to the right provide access to tools. On the left, the user can find a workspace assisting to set up an educational pathway (see section 2.6). On the opposite side (on the right), the platform makes available communication, collaboration and AR scenario tools used in conducting the pathway, file management as well as information related to the augmented exhibits & their science centers or museums

Manage an Educational Pathway

Every time, you would like to create an educational experience through CONNECT, you will have to create an Educational Pathway. This concept is central in the CONNECT Platform because it organizes all information relating to the students' educational experience. For example, it is used to group multiple participating students as well as relevant educational material. An Educational Pathway consists of

four phases, which occur sequentially: Preparatory, Pre-Visit, Visit and Post-Visit Phase. An educator can have multiple Educational Pathways running concurrently at differing phases.

Now, we will discuss how to create, delete, edit and navigate Educational Pathways.

To create a new Educational Pathway simply click on the New Pathway button. The CP presents a series of the existing pathways for each exhibit. These pathways have been created from other users. For each pathway the scenario and the AR view are presented (Figure 14). You will be asked to enter the following information:

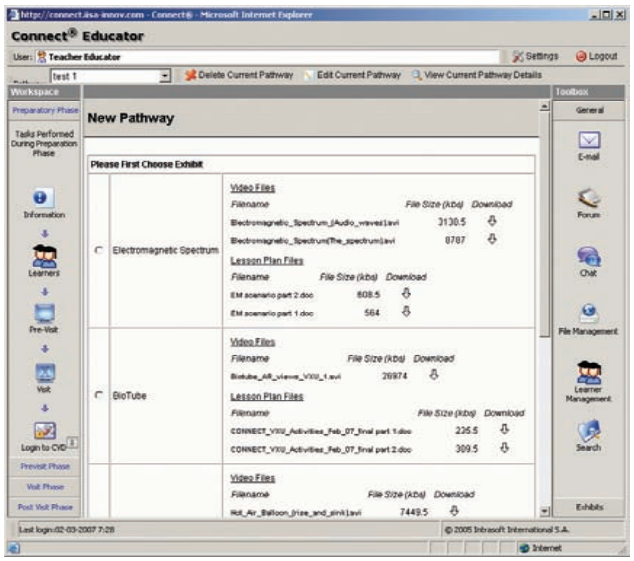


Figure 14: The CP database of existing scenarios for each exhibit.

1. Exhibit: You can choose the exhibit on which this Educational Pathway relates to.
2. Title: This is a simple pathway name.
3. Date of Visit: This is the date the students are expected to visit the science museum and have their AR experience.
4. Description: Here, a short description of the pathway is entered.

Note that you will have to know beforehand, which exhibit you will want use in the educational pathway and when the visit is to occur. The CP will assist you with the first task while arranging for a visit to the science museum is to be done entirely outside the platform. Of course, the platform allows for modifying both of those pieces of information at any time.

Also note, the CP is oblivious of the phase the pathway is on.

After entering the above information, click once on the Save button to save or the Close button to cancel the creation of the pathway. After saving the above information, click on the Close button to close the window.

To navigate an Educational Pathway, look at the Educational Pathway Management toolbar. The drop down arrow allows you to select from the pathways available the one to make active. The button View Current Pathway Details brings the pathway's summary.

Having selected an Educational Pathway, you can delete it by clicking on the Delete Current Pathway. The system will inform you when it is deleted.

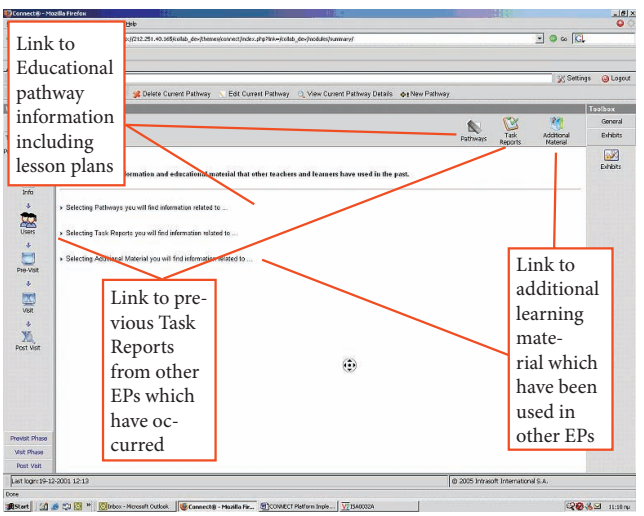
Selecting a pathway and then clicking on View Current Pathway's Details will generate a summary of rights and content per phase relating the selected pathway.

Finally, you can edit the pathway selected by clicking on Edit Current Pathways. This action will bring you to the same dialogue with the one presented during the new pathway creation process. The fields this time are populated and the information is editable. Pressing the Save button will save the changes while the close button will simply discarded them.

Preparatory Phase

Having created an Educational Pathway, you have taken the first step in establishing an educational pathway. Currently, you are at the preparatory phase of the Educational Pathway. In this phase, as the educator you will need to:

1. View prior lesson plans, task reports and learning material associated with this type of the Educational



Pathway. To do this navigate to the Workspace on the left and click on the Preparatory Phase bar to open it, if it is not already open. The first icon reads "Information", click on it.

During this stage for the Preparatory Phase, you are expected to research information from previous Educational Pathways, in order to develop a pathway fitting your students.

2. Having found an Educational Pathway and evaluated its appropriateness for your own students, you will have to assign the students who will be participating in your Educational Pathway. To do this click on the icon below the Info icon termed Users.As you can see there are two lists of users the "Learners" and the "Assigned Learners". The list of "Learners" contain all students you have created accounts for into platform. You can select them and using the ">>" and "<<" buttons you can assign them to the current Educational Pathway. To add a new student simply press the Add button. A dialogue will appear asking for the new students first and last name (Figure 16).

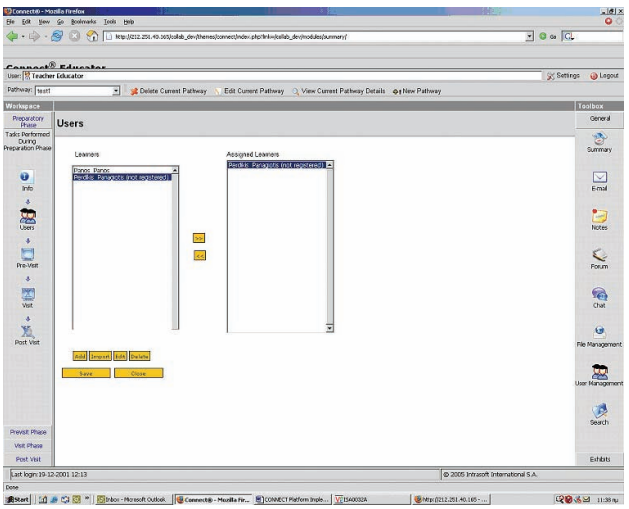


Figure 15: Screen for Preparatory Phase -> Users



Figure 16: Preparatory Phase-. Users-> Add User

When you type in their names press Add to add the user or Close to cancel the process. In case you have a number of students that you need to enter the system allows you to create them all at once by inputting in a text box with separated pairs of last and first names. You probably have noticed that some students' names are followed by a "(not registered)" label. These students have been typed into the platform but since they have not attempted to enter the platform they have not registered and their accounts have not been activated. In order to make any changes in the first or last name of a user you have just created, you only need to select their name form the "Learners" list and press the Edit button. An interface similar to the one in figure 15 will appear which will allow you to edit the user's names. To delete a learner, select them from the learner's list box and press the Delete button. You will be prompted for conformation, press Yes to delete and No to cancel. After, you have compiled the desired list of participants press Save to save your selections.

3. Now, it is time to prepare the Pre-Visit phase. Click on the icon below the Users icon called Pre-Visit. Figure 16 shows your current work area.

There are four activities which you can use to prepare the Pre-Visit phase.

1. Pre-Visit Introductory Text: Here, the platform makes available to you an editor where you enter and format text. This text will be presented to the students when entering the CP in the Pre-Visit Phase. You type in the message, you want them to see and save it pressing the Save button.

2. Uploaded Documents: The educator can add documents or files they want their students to see during

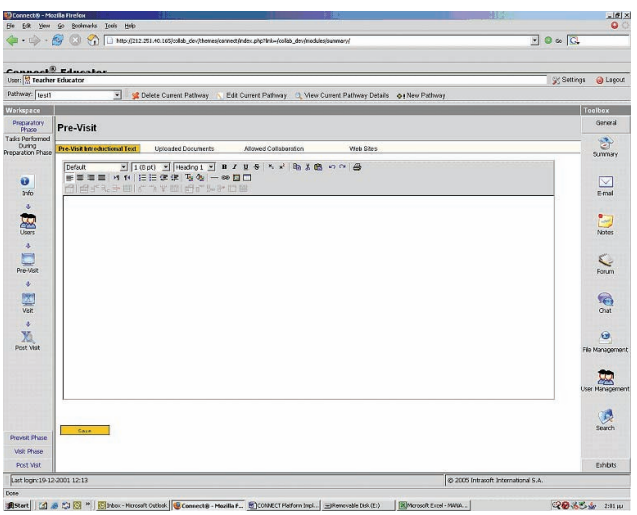


Figure 17: Screen for Preparatory Phase ->Pre-Visit

this phase. In the figure below, you can see the work area for this option. On the list box on the left, you can see the files uploaded on the CP and ready to be used. Selecting any of those files and using the ">>" and "<<" buttons will move them into the list box in the middle which shows the files selected to be shown to the students during the Pre-Visit phase. Selecting a file in these list boxes will show you its name, title and description on the right. If you want to include a file, which is not present in the list box in the left

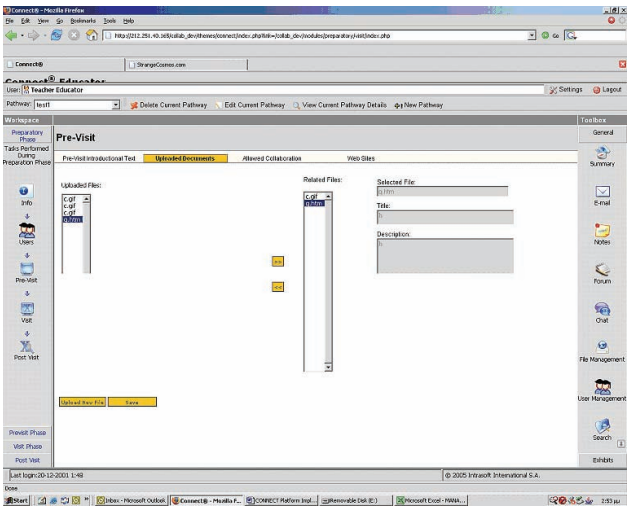


Figure 18: Preparatory ->Pre-Visit-> Uploaded Documents

(show files available on the platform), pressing the Upload New File button. It will bring up a dialogue box allowing you to associate a title and a description

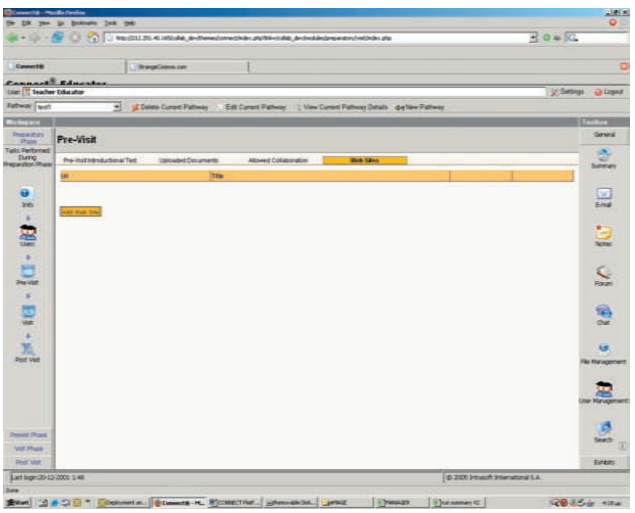


Figure 19: Preparatory -> Pre-Visit-> Web Sites

with a new file and upload it on the platform. Once, you have selected all appropriate files for this phase, you can save your choices through the Save button at the end of the page.

3. Allowed Collaboration: Provides a way for the educator to limit the students' communication options as well as sources of information. The scope of these limitations is bound to the current phase.

   The available communication options are:

   a. Task
   b. Chat
   c. Forums
   d. E-mail to Student
   e. E-mail to Teacher
   f. E-mail to Expert

   Check the options you would like to allow and press Save.

4. Web Sites: At this location, the educator can add links for his/her students to visit. The links added here will be presented to the students assigned to the current Educational Pathway when they enter this phase. In Figure 19 you can see the interface.

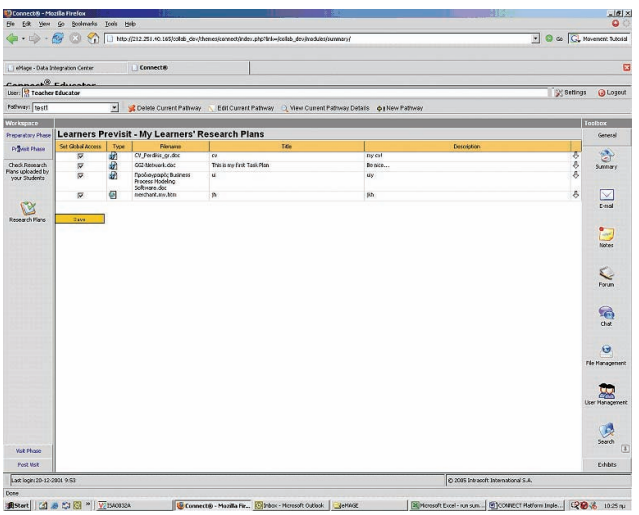


Figure 20: Pre-Visit Phase-> Research Plans

Pressing the Add Web Site will bring up a dialogue that will allow you to enter the URL, its title and save it. At this point, you have completed all tasks necessary in order to prepare the Pre-Visit phase of an Educational Pathway. To complete the preparation of the entire Educational Pathway, you will have to conclude the preparation for the remaining phases.

The activities and interfaces for following phases are the same with the above descriptions.

Pre-Visit Phase

The Preparation Phase for the pathway has been completed. You assigned the participating students and have informed them of their user names and passwords. The students take over. They start exchanging information, collaborating, researching, learning always working towards producing their research plan. They will be uploading versions of those documents plus other content on the CP as they progress towards a final idea of what they will have to do in front of the exhibit wearing the mobile AR unit.

The platform provides you with the uploaded files from each student for the current pathway available to you, the educator. Navigate to the workspace tool bar Pre-Visit Phase->Research Plans. Figure 20 shows the interface.

All content listed for you in the work area with the following information about them:

1. Set Global Access: For each piece of content you have the right to make it available for viewing to the remaining platform users, if you so choose.
2. Type: It informs you what type of file is the one uploaded.
3. Filename: Displays the filename of the document.
4. Title: Shows the title entered for the file.
5. Description: Presents the description entered for the file.
6. Arrows: The last column consists of arrows pointing downwards. Pressing on this arrow will initiate the download of the file to the computer you are working on.

The save button at the end of the page allows you to store the changes you may have affected on the "Set Global Access" column.

Visit Phase

The Pre-Visit was completed with the completion of Research Plans. It is time for the students to visit the exhibit at the science museum, wear the mobile AR unit and execute their plans. The educational activities continue at the science museum and off the platform. The educator and the remaining classroom can follow the students progress from the classroom as well as communicate with them.

Navigate to Visit Phase -> Monitor, to establish audio visual communication with student wearing the mobile AR unit.

Post Visit Phase

The student has returned from the science museum visit. They experimented and collected data. It is time to write a Research Report (RR). The students will upload images, videos, documents and other content in files of varying formats while trying to formulate their conclusions into the RR. The platform makes available these files plus the data collected during the science museum visit to the educator.

Navigate to Post-Visit Phase->Research Reports will present all the files students uploaded in this phase for the current Educational Pathaways. The interface is exactly the same as the one described in section for the Pre-Visit phase content.

The visit collected data are made available through the Experimental Data button.

Toolbox

The Toolbox is a series of tools available for the teacher to use at any point regardless of the stage any particular pathway. They are pretty much standard in their features, thus descriptions will be restricted to places where specialized features exist.

The tools are organized in two groups within the Toolbox:

1. General:

a. Summary & Notes: The first page educators encounter in their work area is a summary of their activities. The summary provides a consolidation of the latest information regarding the educator's use of the platform. Moreover, it integrates a notes management

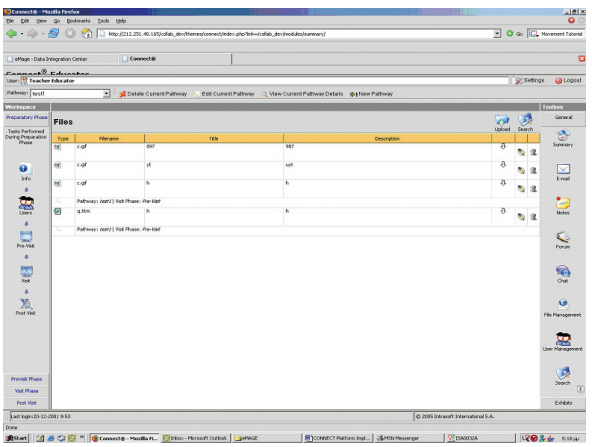


Figure 21: General-> File Management

system where you can create, update and delete notes relating to the tasks at hand.

You can create new notes either through the New Note button under summary or the Add button under Notes. In this case, the interface and method of adding new notes are the same to the one describe earlier. You enter its name, and its content. Pressing

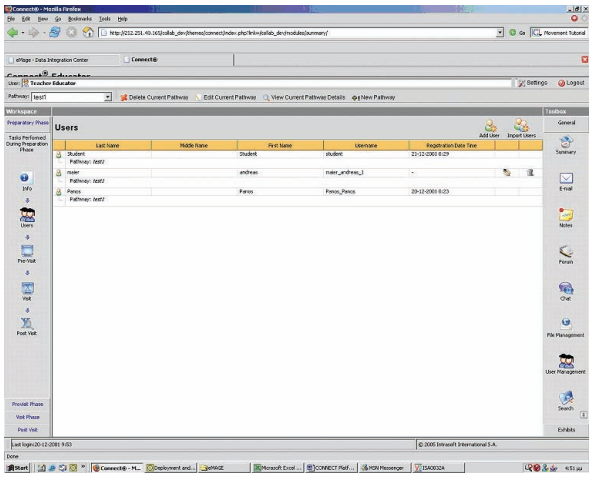


Figure 22: General-> User Management

Apply will add the note and maintain the same interface to add another note, while OK will add the note and return the user to the notes interface. A note can be removed via the trash icon bin , while selecting the name from the list will allow to editing it.

b. E-mail: The CP does not provide you with an e-mail system but rather with an interface to your existing mail. In order to set it up request assistance from your system administrator.

c. Forum & Chat: These tools are self explanatory and their functionality is standard. Any moderately experienced Internet user will not have difficulty navigating their functionality.

d. File management: The educator uploads a number of files containing content pertinent to the pathways they construct for their students. All these files are accumulated and presented collectively under the General->File Management. The interface used to show the files they have loaded is shown in Figure 21. Each file is associated with the pathway it was uploaded for. Through here, new files can be uploaded and old files can be searched using keywords.

e. User management: The educator enters students into the CP as part of the Preparatory Phase in order to assign them to Educational Pathways. All these students can be managed from this option. Clicking on User Management will introduce the interface in Figure 22.

It is should be noted that here are displayed all the users entered over time. Therefore the system displays the pathway they are assigned to.

f. Search: Clicking on the Search icon introduces a simple keyword search tool. It is enough to enter a number of key words into the text box, optionally select how they are connected and where to

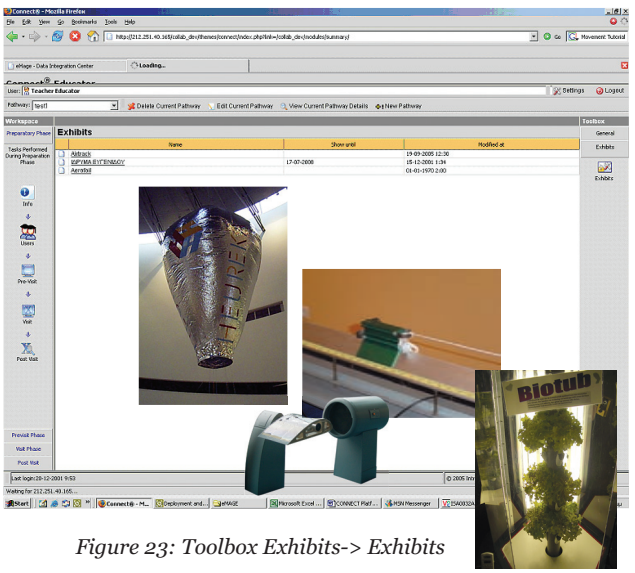


Figure 23: Toolbox Exhibits-> Exhibits

search in then press the Go button. The system return all documents containing the words you are searching by.

2. Exhibits: In this group currently, you have the option to see a list of available exhibits. Thus, under the Toolbox clicking on Exhibits will present the interface shown in Figure 23.

Selecting one of the exhibits will bring information regarding the exhibit and its science centre of museum. At the end of the description, you'll find a button 'Login to CVD'. By clikcking on it, you enter the CONNECT Visual Designer.


Τα κύματα της επικοινωνίας
Τι είναι ένα ηλεκτρο-μαγνητικό κύμα;
Waves of communication
What's an
gamma decay
γ- radiation: high-energy
Electromagnetic waves have a much higher propagation speed than sound waves. Whereas sound travels through air at about 340 metres per second, electromagnetic waves shoot through empty space at nearly 300,000 kilometres per second.
Electromagnetic waves are widely used in the field of telecommunications.
Ακτίνες γάμμα (γ)
Gamma rays (γ)
Ακτίνες X
X-rays
Υπεριώδεις ακτίνες (UV)
Ultraviolet
ΗΛΕΚΤΡΙΚΟ ΠΕΔΙΟ
ΠΗΓΗ
ΜΑΓΝΗΤΙΚΟ ΠΕΔΙΟ



Presentation of possible augmentations of the Electromagnetic Spectrum Exhibit. A long series of scenarios were designed for the teachers for the specific exhibit at the last stages of the project's implementation. The augmentations are presented when the user is focusing in the circular areas for more than 3 sec.

3.5 The CVD Tutorial

This section will walk the user through the design of an AR experience for a mobile AR unit wearer. After reading this tutorial, the user will be able to utilize the CONNECT Visual Designer to design such experiences.

We start with a brief introduction to the organization of the activities necessary to create an augmented reality experience. It will include the explanation of concepts to aid understanding. Then, the steps of the procedure will be described along with clarifying notes, cautions and warnings.

How to design an augmented reality experience

The CVD focuses in allowing the educator to specify the visual augmentations the student can see through the augmented reality view, effectively allowing the educator to configure the experience to the specific needs of the student.

The teacher specifies a collection of rules, which specify what will happen when a student performs one of a set of predefined actions. The student's actions indicate to the system when to react. The reactions are presentations of multimedia content, such as images, sound, video, text and 3D objects.

The experience design is organized around rules. A rule consists of four parts:

1. **When:** it identifies a student's direct or indirect action, which should be responded to. In other words, it identifies the time of appearance of an object. The definition of "when" is accomplished through conditional statements, for instance, "if the wing of the airfoil is between an angle 10 and 20 degrees". When this statement is true, the object associated with it will appear in the AR view. When the statement is false, it will disappear. Multiple conditional statements can be connected together with logical operators to form complex conditions. Apart from the increasing complexity of the statement, it is no different for the conditional statements described above. The complex conditions is evaluated to true or false and the content is shown or not accordingly. Multiple conditional statements can be simultaneously true. For example, the wing angle on the airfoil can be within an angle range (first event) and the fan can be on or off (second event). Possible conflicts are resolved in the following manner. Newer true conditional statements override older ones, even if they are still true.

2. **What:** it identifies what content should be presented to the AR view. The general term used in this document for a piece of content is object. There are three types of content:

   a. Simple Content: Static images, audio, video, text and 3D Shapes provided by educator during preparatory phase. They appear when a condition becomes true.

   b. Phenomena Representation: Dynamic 3D objects show what is happening while aspecific phenomen occurs. The specification of conditions is not required for them to respond to actions performed on the exhibit. Teachers have no control over them. The Mobile AR Unit allows the Students to turn them ON/OFF during the visit.

   c. Variable Representation: Objects representing the magnitude of physical quantities varying during the interaction with the exhibit. Variable representations can be arrows, cylinders or alphanumeric. They are already in the CVD but the teacher can modify their appearance.

3. **Where:** It specifies the location an object will appear as well as how it will be delivered to the student. It is otherwise known as delivery aim. These locations are predefined and the user cannot add, delete or edit their position. There are two types of locations:

   a. Placeholders: Placeholders are projection areas, which the Mobile AR Unit materializes as virtual billboards or backwall projections. They hold Simple Content 3D Shapes.

   b. Hotspots: Hot spots are points in space which serve as origin for 3D Shapes and Variable Representations.

4. **How:** Objects have properties, which affect their appearance. How refers to how content should be presented to the Student.

Entering the CVD

The Visual Designer's Entry Page should appear:

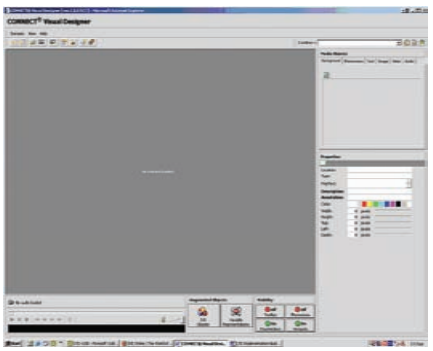


Figure 24: Entry page to the CVD

At this point, you have entered the tool.

Creating a new AR Scenario

When entering the CVD nothing is loaded into the tool. You can create a scenario from one of three different ways:

1. **To create a new AR Scenario** (Scenario -> New -> Templates). This is an empty Scenario, which can be used to create an AR experience for the student.

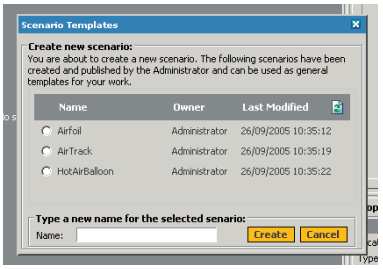


Figure 25: Create new scenario

Upon selecting this option the dialogue above will appear. In this dialogue, you can choose from the exhibit scenarios, which can be created for this science museum. Then, you enter the name of your new AR Scenario and press Create to proceed with the design effort.

2. **To open a Published AR Scenario** (Scenario -> New -> Published). This is an AR Scenario previously created and made available to others for use. When opening a Published AR Scenario, you are taking a ready made AR Scenario which then you will modify and tailor to your needs.

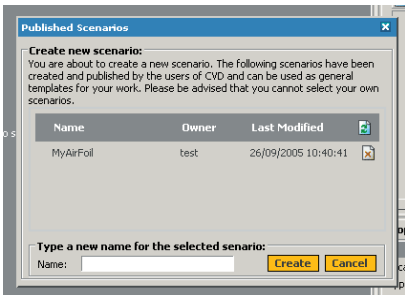


Figure 26: Open a Published scenario

Upon selecting this option the dialogue above will appear. In this dialogue, you can choose from the AR scenarios, which have been created published by another creator for this exhibit. You cannot choose from your own published AR Scenarios here. Your own published scenarios are available when opening your own AR Scenarios (see below). After, you select the scenario, you enter the name of your new AR Scenario and press Create to proceed with the design effort.

3. **To open your own AR Scenario** (Scenario -> Open). This is one of your own AR Scenarios, which was previously saved and you want to retrieve it in order to continue working on it.

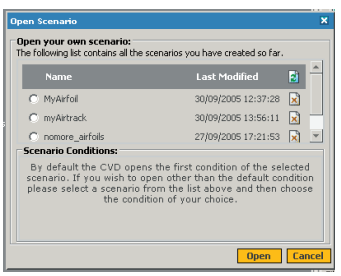


Figure 27: Open your own AR Scenario

Upon selecting this option the dialogue above will appear. In this dialogue, you can choose from your own saved AR scenarios, even the ones you have published. After you select the scenario, select the specific condition in which you want to enter and then press Open to proceed with the design effort.

In all options, you are given the opportunity to abort the process of opening an AR Scenario by pressing the Cancel button. Moreover, failure to select an AR Scenario or entering a name will result in a warning, which will inform you of the lack of input and prohibit you from going further until all information is entered. All options above follow the same design steps. For the sake of simplicity, we will create a new AR Scenario by choosing the first option.

The first step of creating a new AR scenario is to build a new

condition.

In the next section, we will start building conditions.

Building a Condition

A condition is a statement, which can be true or false. This is the when part of a rule as described in the relevant section. When, a condition is true the mobile AR unit will present to its user the AR content you want them to experience. You build a condition in the dialogue box in Figure 31. The dialogue box itself guides you in building the condition incrementally. The process is very similar to constructing the first part of a conditional statement in English. In more detail this is done in the following way:

1. Start form the first cell in Figure 28. This will allow you to select a variable on which to base your condition. In grammatical terms this is the subject and verb of the part of the conditional statement you construct. Choose "the item's weight" from the drop down list.

2. Immediately the system pops up a message that informs you of the values the following boxes can take for the selected variable. Note that there is no explicit error checking at this point and therefore the system depends on you to follow this guideline. Click OK for the message to go away. Element number 2 in will present you with this message again in the event you need.

3. In element number 3 select "is"

4. In element number 4 enter 1

5. In element number 5 select "and"

6. In element number 6 enter 2

7. Having constructed the statement, it is possible to choose its negation by selecting "Not" in element number 1. The content will be present to the mobile AR user when the statement is false.

Now you have completed the definition of a condition. You can string multiple conditions together, if you change the last drop down to AND or OR and then press "Expand Condition". This will add an additional row, which can be used to define another condition. The content is now going to presented to the wearer of the mobile AR unit when both statements are true in the event they are connected with an AND or when one of the statements are true in the event the two conditions are connected with an OR. To remove a statement, you just press the X button at the end of each condition. Finally, the condition is submitted when you press the Apply button. The system warns you that just because the condition was created it is not saved and that you will have to do manually by going to Scenario -> Save Condition or using the shortcut Ctrl-S.

The system will prohibit you for creating another condition or deleting the current one. When attempting either of the above, a message pops up informing you that you are in a new condition state and cannot proceed. You will only be able to edit the condition you have just entered until you save it. At which point attempting to create a new condition will be greeted by a confirmation request.

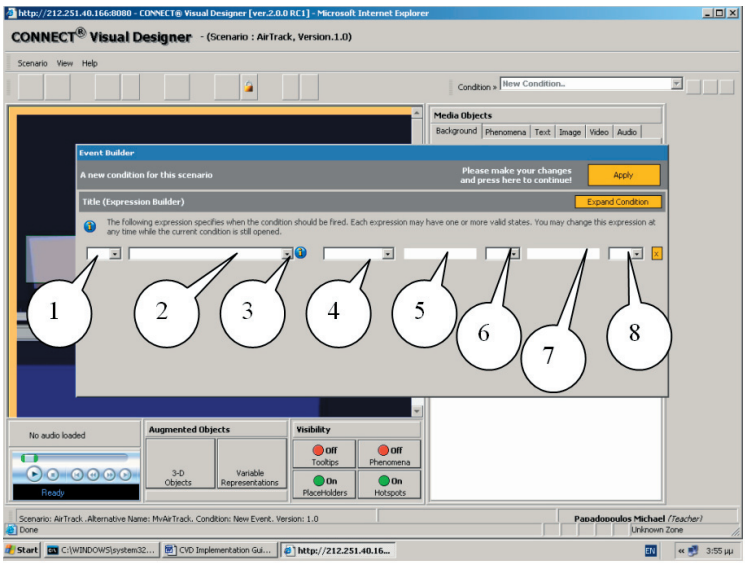


Figure 28:
Condition Builder. Elements are referenced by their position from left to right.

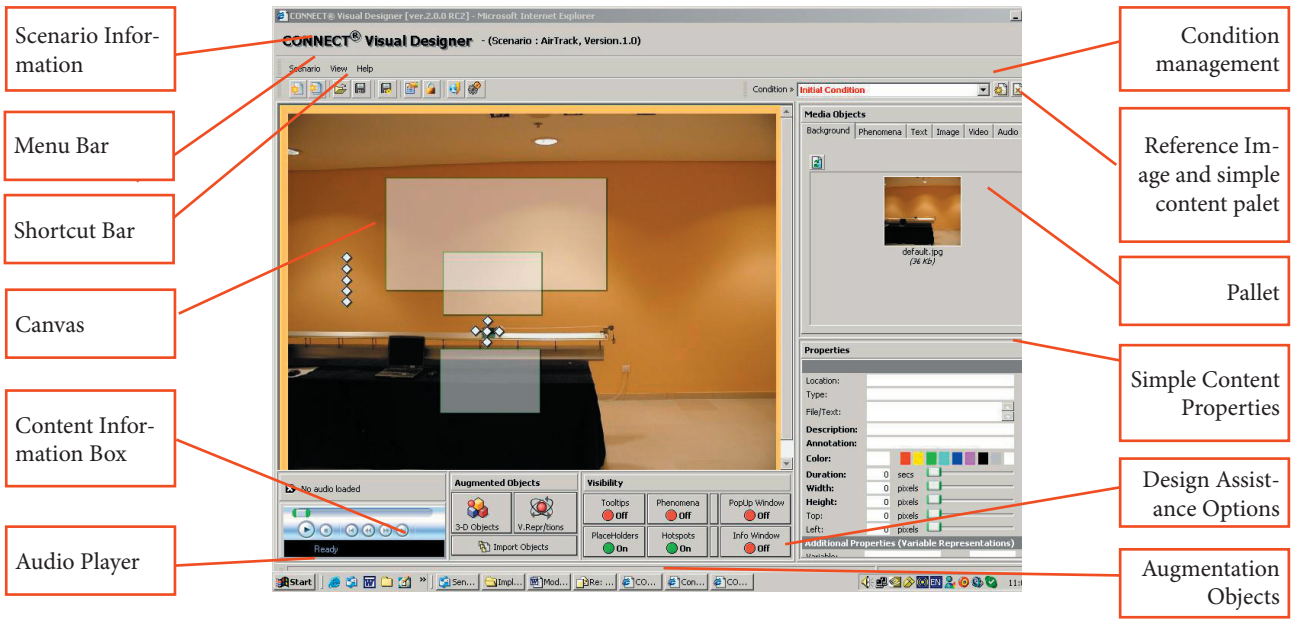


Figure 29:Annotated image of the CVD for the Airtrack scenario.

CVD Design Interface

Before, we proceed with the remainder of rule construction; we will explain how the tool interface is organized. To facilitate the discussion, an annotated image of the interface below is introduced.

The first step in constructing a rule is to build a condition.

Conditions are central to the procedure because all information is organized and stored according to them. In the previous section, we showed you how to build a condition. On the top right of Figure 29, there is a drop down box, which shows the current condition being worked on. From there, you can select which condition you want to work on. The buttons on the right of the drop down box allow creating, deleting and editing a condition respectively. Delete and edit are applied on the condition selected in the drop down box.

Reference Images accompany conditions. These are images that depict the exhibit as it would be, if the condition were true. Each condition has associated with it a default Reference Image. However, the user can change the Reference Image to an image they feel more appropriately reflects the condition they have formulated. To learn how to change the Reference Image for the condition you have defined read “Changing Reference Images”.

Having built the condition, it is time to choose the content, which will appear during the event. The content is equivalent to the what while the placement of content is specifies to the where component of a Rule as explained earlier. There are 3 types of content: Simple Content, Variable Representations and Phenomena Representations.

Phenomena Representations are included in all AR Scenarios by default. The mobile AR user can make them appear or disappear from their view during visit time via a menu selection. The CVD provides a collection of design assistance tools to the educator. There the educator is able to view the phenomena representations applicable to the Reference Image used in order to have a better idea how to place other types of content. To find out how view phenomena representation and how to exploit other design assistance options read “CVD Design Assistance”.

Variable Representations show the magnitude of physical quantities relevant to the exhibit and the exhibit’s educational domain; hence they are specific to the exhibit. There are different types of Variable Representations available for each quantity. The educator can choose which representations to include in the AR experience. He/she also can affect the way they appear in the AR view. To find out how to specify a variable representation read “Selection and Placement of Variable Representations”.

Simple Content is standard multimedia content. With the exception of 3D Static objects, the educator uploads them into the tool. They create 3D Static objects via the CVD in-

terface. The process is very similar to the one described for Variable Representations. All Simple content objects have properties, which can be used to adjust their appearance during the AR experience. Objects, which have been widely used in scenarios for a particular exhibit, are loaded as default objects. The CVD operators cannot remove them but can use them to create AR experiences faster. To learn more about how to add content, please go to "Selection and Placement Simple Content".

At this point a rule has been created. In order to add a new one, the educator needs to create a new condition as we have described above. Before creating a new condition you need to save or close the current on. This can be done via Scenario-> Save Condition or Close Condition respectively. It is imperative that the work performed underneath each condition is saved, in order to be able to retrieve it later on. Once all rules have been crafted, the AR Scenario is complete.

Changing Reference Images

To change the Reference Image means to change the background image in the canvas window. In order to accomplish this:

1. Navigate to the right side of the window in the Media Objects group.
2. Choose the background tab if it is not already chosen.
3. You see a pallet of available Reference Images. Press the refress button on the right of the pallet of images to make sure you have most recent collection.
4. View the images available and choose the one that best fits the condition you have described.
5. Drag and drop your choice on the canvas window. This will update the Reference Image to the one you chose.

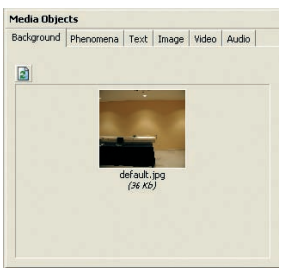


Figure 30:Media Objects group

CVD Design Assistance

The CVD provides the teacher with four functions, which aim at delivering a better sense of the environment the AR Scenario, will be experienced in. These four functions are placed together under the group Visibility at the bottom of the CVD as shown in Figure 31.

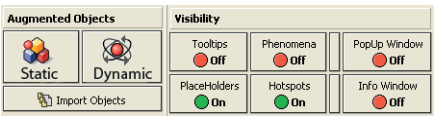


Figure 31: Augmented Objects and Visibility group

In the four buttons in the Visibility group are:

1. **Tooltips:** When it is on, it reveals extensive attributes (information) of objects, everytime the cursor goes over it.
2. **Phenomena:** You can remove or place on the canvas all available phenomena representations. The image showing the Phenomena Representations can be chosen from the Media Objects group from the tab called phenomena by dragging and dropping the image on the canvas window. A default is always associated with the Reference Image used.
3. **Hotspots:** You can activate or deactivate the appearence of all hotspots on the canvas. The content associated with hotspots remains on the canvas.
4. **Placeholders:** You can remove or place on the canvas all placeholders even if they are populated. They show media objects that are dragged and dropped to them. They are " world related" which means that they are visible only at specific view ports of the student.
5. **Pop Up Window:** You can add a message for the student. It covers 95% of the student's view and it is "view releted" which means it is visible at all times.
6. **Info Window:** You can add a message for the student. It covers 1/3 of the student's view and it is also "view releted".

The above buttons are green when active and red when they are deactivated.

Selection and Placement of Variable Representations

To add a Variable Representation to an AR experience, you need to:

1. Navigate to the Canvas window and locate a suitable hotspot. They are blinking rhombuses. Single click on the desired rhombus selecting it as the locations on which the object will be placed. A red dashed square will appear around it.

2. Then, navigate to the bottom of the CVD at the Augmented Objects group (see Figure 32). The two (2) buttons allow access to 3D static objects and Variable Representations. Clicking on the Variable Representations button.

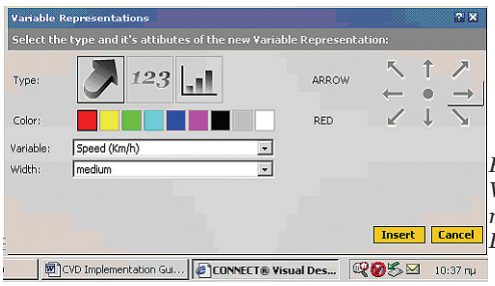


Figure 32: Variable Representations Dialogue box

3. The above dialogue box appears. Here, you can specify the properties of the variable representation. As soon as, you click Insert, the variable representation will appear in the canvas window at the hotspot selected.

4. The properties which can be modified are:

   a. Type: There are three types of Variable Representations:

      i.Vectors: They are arrows whose direction you can choose. Their length varies with the value of the variable they are associated with.

      ii.Alphanumeric: This is a label whose direction is always horizontal. The numbers change according to value of the variable they are associated with.

      iii.Diagrammatic: They are plots of pairs of variables changing together. They have one orientation as well.

   b. Colour: You can choose the colour for the Vectors, Alphanumeric and lines in diagrams.

   c. Variable: You can choose with which variable each representation will be associated.

   d. Width: Finally, you can choose the width of the representation.

3D Objects are simple content the placement of whichfollow the same procedure as described for the Variable Representations. Hence, we do not provide another design description. Instead, we point out their major difference. 3D Objects are static whereas Variable Represent, actions are dynamic. Therefore, 3D Shapes are not associated with any variables and their height is strictly specified.

Selection and Placement of Simple Content

You can add simple content such as text, images and video. The steps below are targeted for images but they are the same for text and video:

1. First select the placeholder the image should appear during the AR experience.

2. Navigate to the Media Objects group.

3. Clicking on any of the tabs images. You will see the images (or videos) available on the system for your use in the pallet as shown in Figure 33.

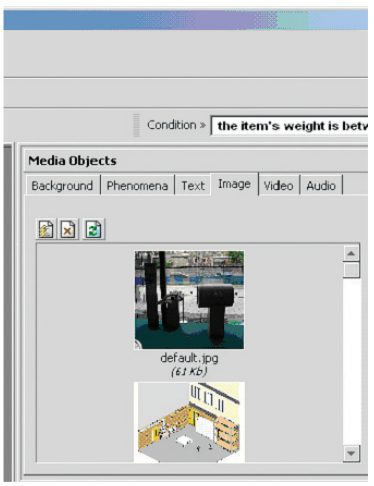


Figure 33: Media Objects group, Images Tab, available images pallet.

4. If the existing images are insufficient for your design goals, you can add an image by clicking on the first button from the left. In the dialog, which will follow, use the browse button to find the image and press the Upload button to make the image available.

5. A message will inform you that the image was uploaded successfully.

6. Click on the refresh button above the pallet if you do not see the file you uploaded.

7. Finally, you can remove it from the pallet by selecting the image and clicking the remove button above the pallet. The remove button is the second button from the left.

8. Dragging and dropping an image on to a placeholder will place the content on the canvas.

9. To remove content from a placeholder, select the placeholder and click on the X button that appears in it. A confirmation message will appear where you can cancel or confirm the action.

Images and text can be previewed directly in the placeholder they are placed in. Furthermore, double-clicking on the icon, which appears in the placeholder, can be used to preview videos. A video player will appear in a new window which will show the video.

Audio is handled differently because there can be only one audio file that can be associated with every condition. The audio player is set on the lower left corner of the CVD as shown in the Figure 34.

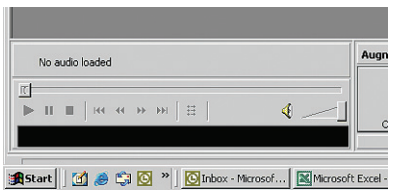


Figure 34:The Audio player

It can be removed by clicking on the X button above the audio player or replaced by dragging and dropping a new audio file from the pallet.

For each type of content, you can adjust its properties and thus affect its appearance. As shown in Figure 35, the properties that cannot be changed are greyed out while the remaining properties are variable. The most interesting of all is Depth because it gives access to the Z component, which is not accessible in the 2D environment of a browser. Increasing the depth value, brings the component closer to the user and decreasing it takes it further away.

When been defined, It is time to save the AR Scenario. To do this, navigate to Scenario->Save As. The system will request for a name. Clicking on Save will save the AR Scenario.

Publishing an AR Scenario and setting its Properties

An AR Scenario is published through the Publish button in the Scenario menu. Before publishing the CVD will give the educator the option to describe the AR Scenario by answering a number of questions in the form or properties. These properties allow other educators to identify a published AR Scenarios, which may be useful to them. These properties are also accessible from Scenario->Properties as well.

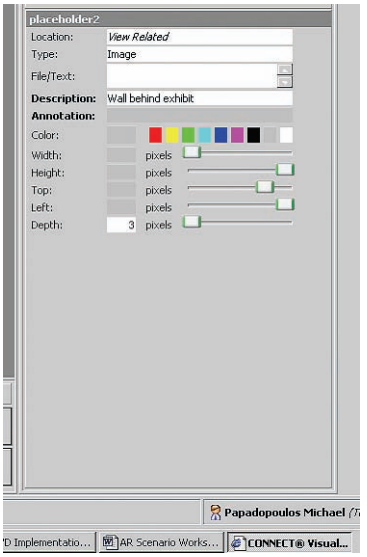


Figure 35: Properties dialogue

3.6 The mobile AR System

The mobile Augmented Reality (AR) system allows the student to experience the exhibits at the science centres and museums with advanced augmentations. To deliver the Augmented Reality experience to the learner, the following functionalities have to be performed by the mobile AR system:

- Determining the visitor's head position and orientation through head tracking,
- Presenting the real view with video augmentation captured by a camera,
- Presenting virtual objects in the display that augment visualisation of exhibits,
- Supporting interaction with the scenarios through menus,
- Recording the visitor's view for use in the post-visit phase (Video Capturing),
- Streaming the learner's view to a server, to transmit the video (stream) to remote classrooms,



Figure 36: Learner wearing the mobile AR system.

- Operating a bidirectional audio communication line between visitor and remote classrooms,
- Transferring the scenario specified in the CVD into an interactive AR scenario description.

The mobile AR system has three principal high-level user requirements that have been identified implying the following design decisions:

- Advanced visual augmentations of exhibits by complex virtual objects - Simple 3D objects, complex 3D phenomena representations, images, audio, video, and text are to be displayed.
- Mobility - The student should be able to move freely inside the museum. Wired connections to fixed points in the museum are not possible.
- Scalability - Many studentss should be able to use the distributed mobile AR system independently from each other.

In addition, the augmented exhibits offer specific functionalities, such as

- Determining the position and/or orientation of exhibit's parts, e.g. the rotation of the Aerofoil, the position of the glider on the Airtrack, the Hot Air Balloon height.
- Acquiring data measured by sensors (e.g. temperatures inside and outside of the Hot Air Balloon, CO_2 concentration within BioTube)
- Control specific variables of the environment (e.g. switching on/off neon lights in the BioTube)

The functionalities of the mobile AR system are provided by the hardware and software components running on a mobile unit. The mobile AR system components are grouped into three modules (see Figure 37):

- a headset with display and tracking hardware
- either a backpack with laptop or a beltpack with wearable computer
- a wireless mouse

Usually the backpack unit consists of a stripped baby carrier mounted by a high-end laptop with stereo graphics capabilities . All software components are run on this system and all other hardware components are connected to it. It is the heart of the system. A small bag fixed at the carrier is used to hold all the wires and an additional battery pack to supply the display with power. As an alternative to the laptop



Figure 37: The full AR system: backpack with laptop, Headset with video see-through display and tracking hardware,and wireless mouse

at the backpack, used at three sites, a wearable computer is used at the forth site, worn on the belt.

The headset comprises either a binocular video see-through stereo display or a monocular optical see-through display (see Figure 37). In the first case the real world is captured by a webcam attached to the front of the display (see Figure 38, right) and displayed within a non see-through display. In the latter case the real world is perceived directly (see Figure 36). In both cases the webcam mentioned above is required for capturing the real world view to be sent to the remote classroom that is attending the feel trip over distance.

Also the headset has an inertial tracking sensor for tracking head rotation and a second webcam for tracking head position. This second webcam is detecting black and white patterns printed on paper and scattered around the exhibits (see Figure 39). As the pattern positions are known to the system, it can determine the head's position.

As a consequence the student is restricted to an area around or in front of the exhibit. As long as the tracking camera finds patterns, the position is tracked. Opposed to that, the orientation is always tracked. Thus the student can look in directions with the camera seeing no markers without a problem as long as the student does not change position.

However, if the student moves without seeing the marker, she/he has to bring them into sight of the tracking camera to update the head position.

The wireless mouse is used to interact with a virtual menu displayed within the view. Only the buttons and the mouse wheel are used; a cursor controlled by the mouse is not required.



Figure 38: The monocular optical see-through display of the Mobile AR system

3.7 Putting on the mobile AR system

The museum staff will help the student to put on the mobile AR system in the following four steps:

a) To put on the backpack, it has to be adjusted to the student's back dimensions. A ladder system allows adjusting the height according to the student's back length. The four lengths S, M, L and XL are available.

b) After putting on the backpack the shoulder straps should be fastened so that the waist belt is slightly above the hip. Attention: Make sure to close and fasten tight the waist belt so that all the weight (approx. 4.5 kilograms) is resting on the hip instead of on the shoulders of the student.

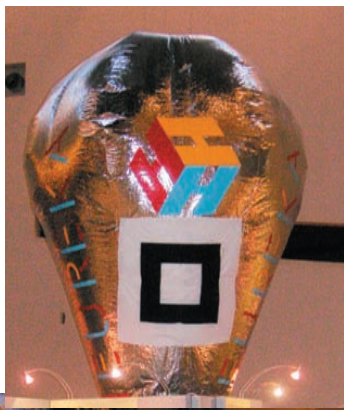




Figure 39: Patterns on the Hot Air Ballon for head position tracking in HEUREKA science centre in Finland.



Figure 40: Fixing the horizontal strap of the binocular headset.



Figure 41: Using the wireless mouse with the thumb.

c) The headset, held by museum staff so far, is handed to the student who takes it with both hands and puts it on her head. The student has to move it until the full video image is clearly visible within the display(s). In case of the binocular display the horizontal strap at the back of the headset should be fastened as tight as possible so that the headset does not slide forward. In case of the monocular displays the knob at the back of the headset has to be turned accordingly.

d) The wireless mouse is handed to the student. It should be held such that the wheel and buttons can be operated with the thumb (see Figure 41).

Equipped with the mobile AR system the student can now freely walk through the science centre and experience the exhibits. The view of the museum and the real parts of the exhibits are visible inside the display. Although the glasses allow only a very reduced field of view (20° - 25 ° horizontally), the peripheral view passing besides the glasses can complete the view to the usual field of view.

3.8 Interacting with the exhibits

Virtual objects are augmented onto the real parts of the exhibits, on the walls around the exhibit or in free space near to them. They represent the following types of content:

- phenomenon representation
- variable representation (textual and graphical)
- variable graph
- simple content: text, image, video, audio, 3D element (arrows, cylinder)

What objects are visible can depend on a variety of conditions:

- the current value of an experiment variable is within a certain range
- the current state of the experiment
- the student's distance to a certain part of the exhibit is within a specific range
- a specific object which is in the focus of view
- the student switches an object on or off through the menu

The actual behaviour of virtual objects is specified by the teacher in the CONNECT Visual Designer in the preparatory phase. During the visit the student can interact according to this specification in several ways.

Experiment variables and states

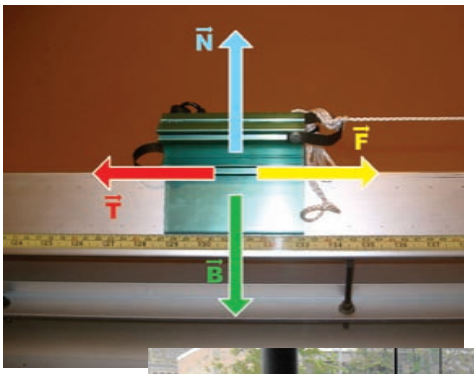
By interacting with the real parts of the exhibit, the visitor can directly or indirectly influence the predefined experiment variables, which themselves influence the different experiment state variables. If they change, depending variable representations, variable graphs and phenomenon representations are updated. Examples are:

- the height of the hot air balloon for an experiment variable and
- the motion state of the balloon, which can be down, rising, up or sinking for a state variable.

Possible actions besides the visual representation of these variables could be to show images or diagrams related to these values.

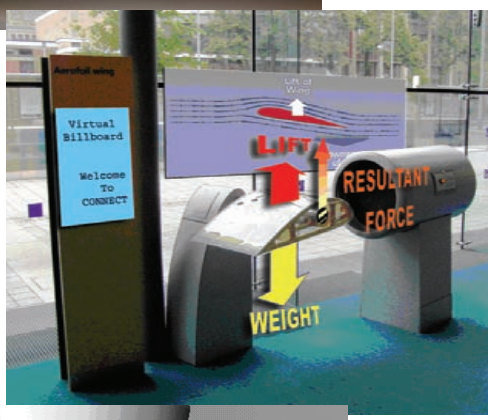
Distance to exhibit parts

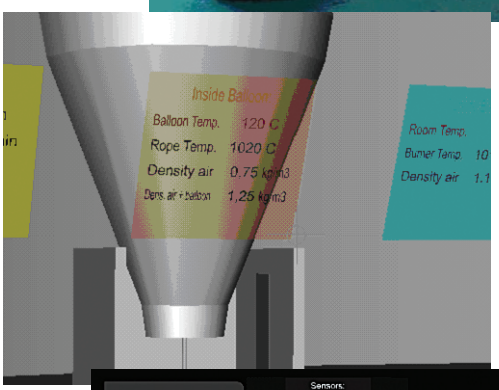
When the student is moving around the exhibit and/or approaching different real or virtual parts, different content can be made visible. Also different levels of detail could be presented depending on the distance.



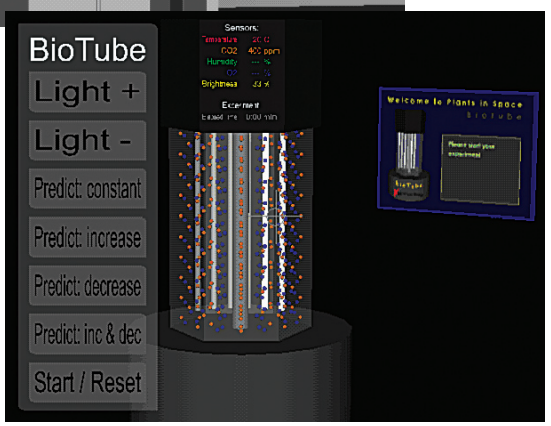
The concept of friction

Why do planes fly?

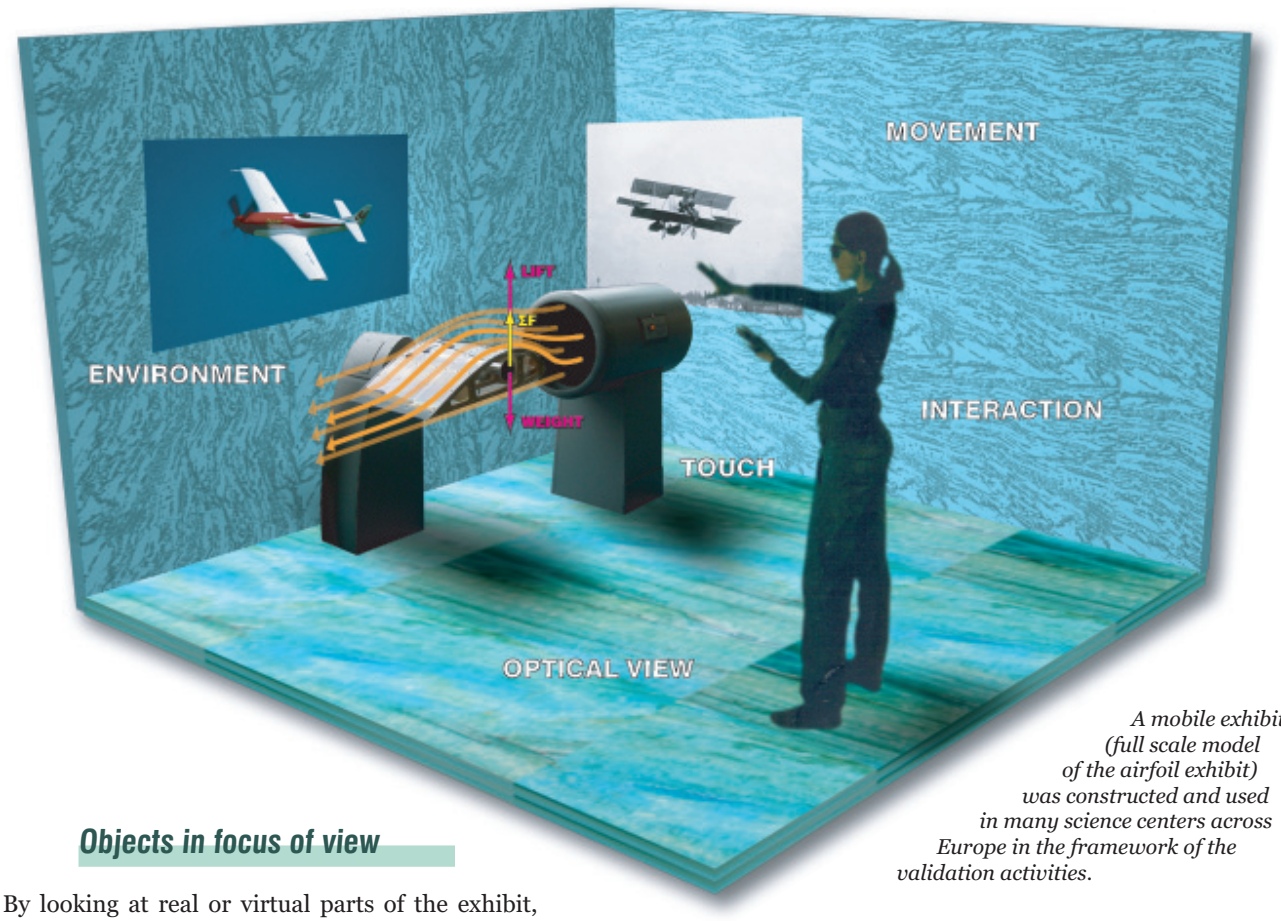




The hot air baloon



Photosynthesis



A mobile exhibit (full scale model of the airfoil exhibit) was constructed and used in many science centers across Europe in the framework of the validation activities.

Objects in focus of view

By looking at real or virtual parts of the exhibit, special content could be shown that is related to the specific part. A crosshair in the middle of the display could then be used to aim at parts. This interaction technique is called head pointer.

Choice from menu

The explicit choice of content can be performed through items presented in the head up menu in the view of the student. This same menu is also used for many other activities.

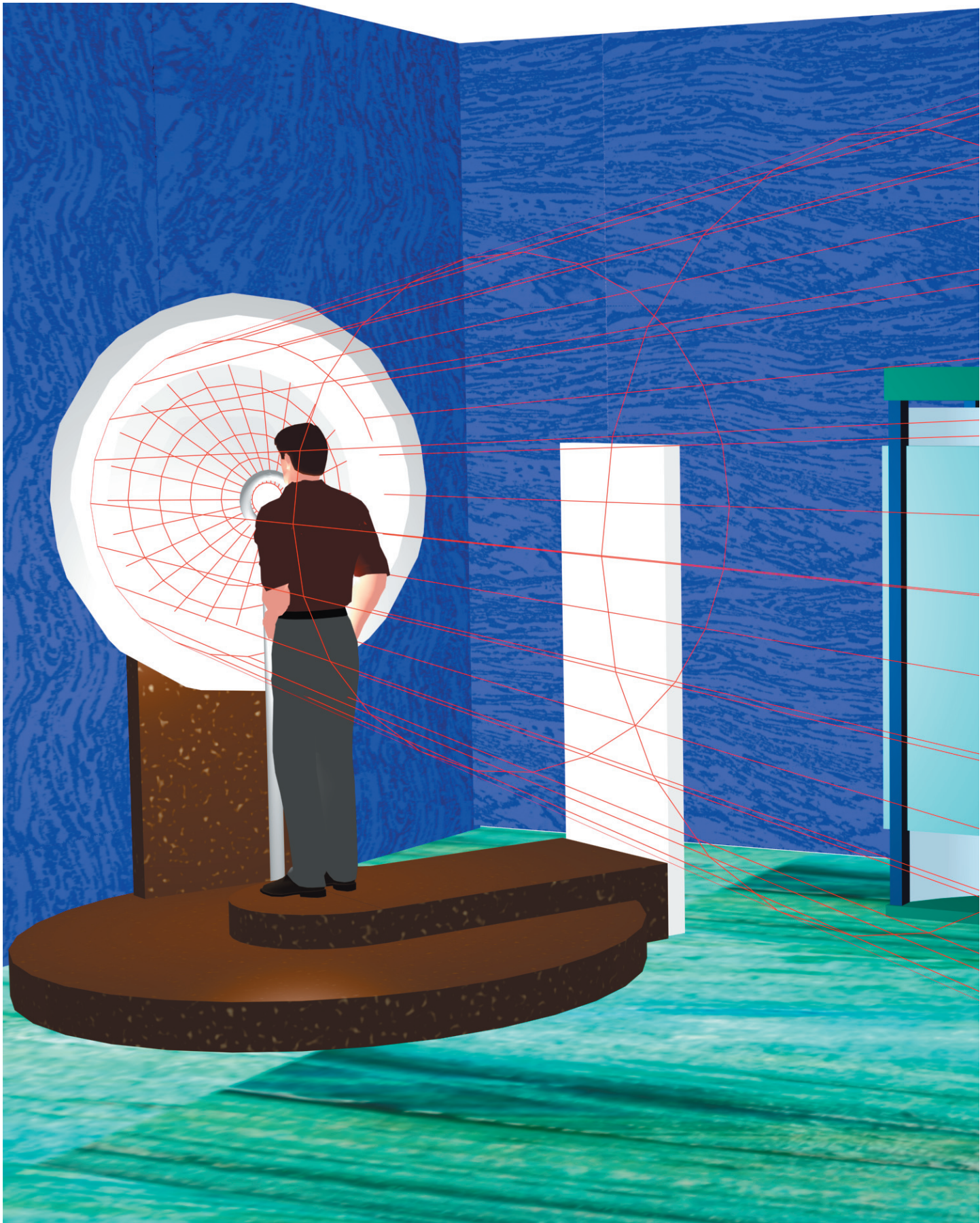
The head-up menu is located at fixed position in the view at the left side of the view. It's a hierarchical menu of two levels: The main menu (level 1) contains up to 7 submenus or entries. Each submenu (level 2) contains up to 7 entries. Each entry is related to a specific action. All menus have a title: the main menu that of the exhibit, the submenu its name.

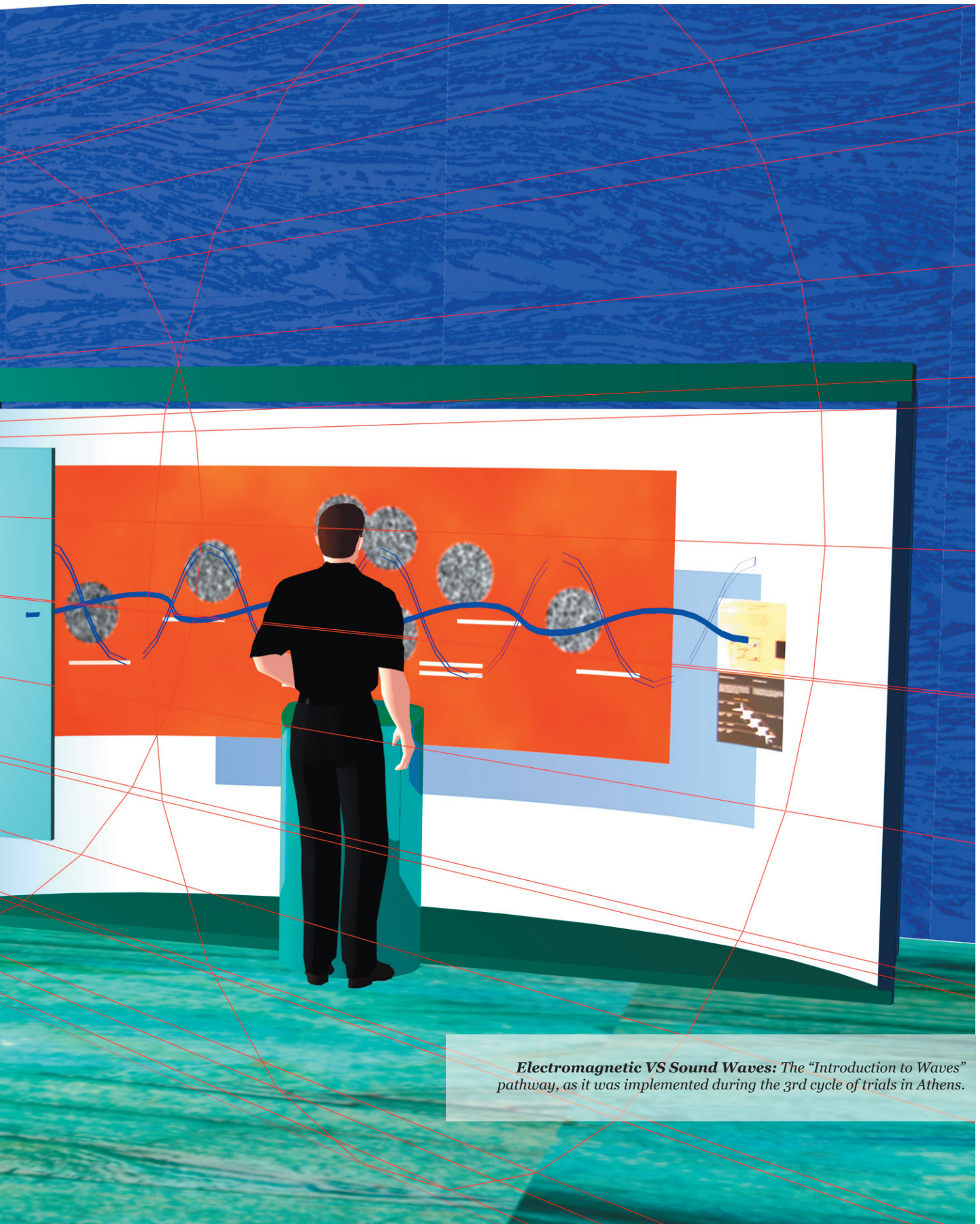
There is a fixed menu structure common to all exhibits. Its content may vary depending on the exhibit (and later on the scenario definition in the CVD). Here is the example of the current structure of the AirTrack exhibit, which may be subject to change.

The Main menu consists of 6 submenus.

- The Capture submenu contains all functionality for capturing data and video images or stills for the post visit phase. Data, i.e. variable values and a time stamp, can be captured either once (Data Now) or repeatedly at a scenario specific rate (Start Data, Stop Data). Screenshots can be taken (Screen now) and a video can be recorded (Start Video, Stop Video).

- The Control sub-menu contains two types of entries. They allow to directly control real parts of the exhibit (e.g. switching on the lights in the BioTube). They provide the means to tell the AR systems what changes have alternatively been applied to the real exhibit, which cannot be detected by the system themselves. For example, in case the airflow is switched on, the user has to tell it to the AR system explicitly.





Electromagnetic VS Sound Waves: *The "Introduction to Waves" pathway, as it was implemented during the 3rd cycle of trials in Athens.*

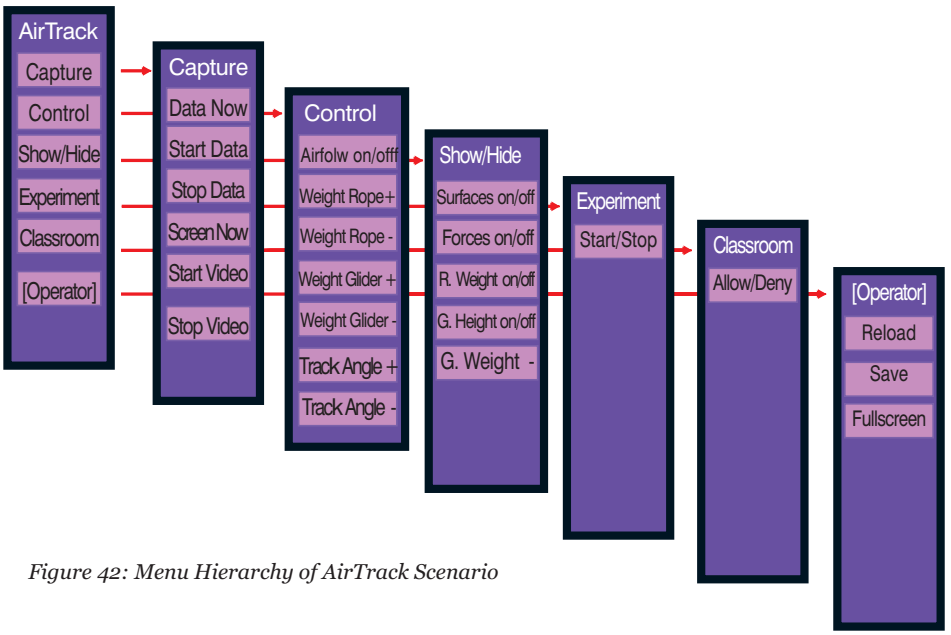


Figure 42: Menu Hierarchy of AirTrack Scenario

- In contrast to the above, the Show/Hide sub-menu allows to switch on or off the visualization (only) of content.

- The Experiment sub-menu holds all entries related to the experiment. Here the Exhibit timer can be started and reset. The latter also implies the storage of the data captured.

- In the Classroom sub-menu the student can allow or disallow connections from a classroom. As the connection is made from the classroom to the student, she cannot initiate but only allow or deny the connection.

- The [Operator] sub-menu should not be used by the student. Instead it holds functionality to control the operation of the AR systems for the technical museum staff. These are reloading (Reload), saving (Save) and toggling between fullscreen and non-fullscreen (Fullscreen) mode to reach windows of other applications running on the machine.

The head-up menu is operated using the wheel and buttons of a wireless mouse (see Figure 43). The menu is activated, i.e. made visible by pressing the wheel button. By turning the wheel, the student can navigate through the list; the current entry is highlighted by a white frame. An entry is selected by pressing the left button. When selecting a submenu it replaces the main menu. After selecting a (sub-) menu entry its highlight is reinforced as long as the button is pressed. After selecting an entry that is not a sub-menu, the menu is deactivated. When activated again the same (sub-) menu becomes visible. To navigate from a submenu into the main menu the right button has to be pressed. In the main menu this deactivates the menu. Pressing the wheel button deactivates the menu at the current level.

This means: The left button is used to descend into the second level of the menu hierarchy. The right button is used to move up again to the main menu. And the wheel button is used to stay at the current level. The fact that activating the menu leads to the same (sub-) menu that was active at last, allows fast access to the same group of functions. This allows capturing a series of screenshots without having to navigate through the main menu into the specific capture menu again and again.

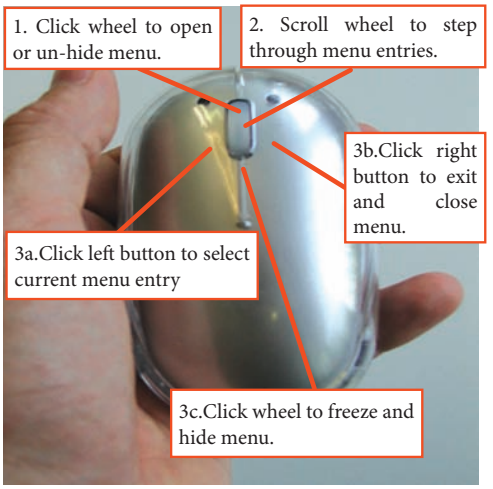


Figure 43: Operating the head-up menu with the wireless mouse

Component	Sub parts	Mounting location	Dimensions h x w x d [cm]	Weight [grams]
Mouse		Handheld	3 x 6 x 11	**100**
Headset		Head	11 x 17 x 10	**650**
	Cables	Back		400
	Battery pack	Back		150
Laptop		Back	4 x 36 x 27	2300
	Battery packs	Back		850
Backpack		Back	68 x 37 x 22	1650
		Total on Back		**5350**
		Total		**6100**

Table 1: The dimensions and the weight of the CONNECT mobile AR system.

3.9 Dimensions and Weight

The dimensions and the weight of the CONNECT mobile AR system is shown in Table 1



Figure 44: University of Birmingham's foutrh generation wearable computer: x4

3.10 Iterative Developments

Several refinements and upgrades are in progress to the presented CONNECT mobile AR system. The following paragpahs are presenting the most promising ones.

Wearable computer: x4

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 may be tested. 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 laptop solution which is 2300g, Table 2) plus each battery pack, 190 grams each. One battery pack is required, two improves longevity and therefore reliability to the user, and significantly lighter than the 850g of the 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 implementation guide to elaborate on the posture assessments. The power consumption of the x4 is low and of very high performance, of similar graphics and processing capabilities to the laptop. Regarding its processing power, initial trials for the CONNECT project suggest that is more than sufficient for the task.

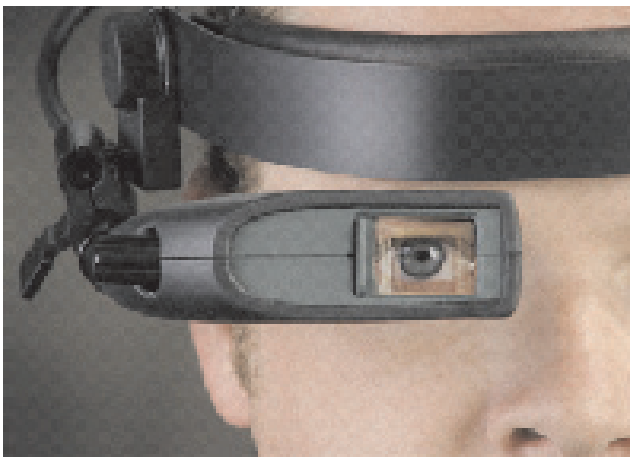




Figure 45: (Left) Shimadzu optical display (Right) Liteye optical viewer (image from Liteye website)

Optical HMD

Following symptoms of visual discomfort experienced using the i-glasses SVGA Pro 3D, highlighted during the human factors evaluation, the next design will investigate using a monocular optical see-through display solutions using the Shimadzu Data Glass 2/A and Liteye LE 500.

In this instance the real world is perceived directly within the users natural FOV, and not via a mediation webcam stream (see Figure 45).

4. Designing the CONNECT educational Pathways

4.1 Activities of the Educational Pathways

Part of designing an educational pathway is to describe the activities that will take place. The 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.

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 the following tasks:

- administrate the visit, e.g. arrange dates, number of visit ing pupils, etc.
- configure the platform in general (e.g. are the students allowed to view previous research reports of other students?)
- 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 personalise 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 one that designs the learning scenario, 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')

- Question 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. A teachers' authoring tool has been built especially for this reason: The CONNECT Visual Designer (CVD, see next chapter). 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 to the table tennis balls in 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.

A typical educational pathway has three phases: the pre-visit, the visit and the post-visit phase. The pre-visit phase is realised 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. A research plan could include:

- a description of the phenomenon they want to do research on
- a predictive explanation about the phenomenon
- a selection of exhibits they want to examine
- Concrete examination plans explaining how to proceed for each exhibit. Figure 1 shows the different phases and the data flow that has to be supported by the system.

Dependent on the individual class (even students) situation the teacher has to adjust the scaffolding level (by work sheets, pre selections, etc).

The CONNECT platform supports the students' work in this phase by:

- Delivering easy access to information about the science centre in general, its exhibits and the phenomena research can be done on.
- Enable the students (synchronous and asynchronous) communication with other learners, experts and even current science centre visitors
- Providing a data repository where the student can store the files used or created during his research preparation
- Providing an upload possibility for information needed during the visit phase (like the research plan)
- Access a research report data base of former visits of other schools (if allowed by the teacher)

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 visualisations through the AR technology introduces a 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 visualisation 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. Figure 1 shows an overview of the sequence of the three different phases (green boxes), performed activities (within the green boxes) and the learning objects (yellow boxes) that are produced (grey lines) and/or used (orange lines) during the different phases.To conclude, we are presenting the general structure of the CONNECT educational pathways. The high level elements of this structure are the phases presented above. The activities of each phase provide particular ideas for what could happen during the CONNECT Test Runs as well as details regarding the scientific content under investigation. Thus, the General Structure of Educational Pathways for

each exhibit is presented in Table 2.

Learning Scenarios for CONNECT

Bearing in mind that there are four different science centres and museums involved in the CONNECT project, the General Structure of Educational Pathways aims to be the ground for describing the particular learning scenarios of each exhibit. The learning scenario refers to the activities of the learner during the visit to the science centre, with or without the teacher. A learning scenario is a description of student's interactions with the exhibit with the aid of the CONNECT technology. They have been delineated to facilitate the design of augmented exhibit activities, which is the main focus of the CONNECT project. Each scenario deals with a different exhibit. In the next section, four learning scenarios are proposed. Each one comes into being through different educational pathways. The teacher can choose what he/she prefers: which scenario to use (e.g. the Aerofoil scenario) and which educational pathway to follow (e.g. the remote-visit pathway) resulting in a unique experience for each teacher and his/her students.

Preparatory Phase	**Pre-Visit phase**
Scientific Content	Communicating concepts under investigation (by the teacher)
Relevance to Curriculum	Formulating Inquiry Questions
Exhibit Description	Suggestions for Hands-on Activities
Focal Research Questions	Preparing the Visit to the Museum according to class profile and visit agenda
Common Student Misconceptions	Filling in Evaluation Questionnaires
Possible AR Realizations	
Visit phase	**Post-Visit phase**
Carrying out experiments	Reflecting and processing the visit
Suggestions for additional activities	Further investigate the examined phenomena & applications to everyday life
Visiting (non-augmented) related exhibits	Suggestions for hands-on activities and/or working with educational applets
Filling in Evaluation questionnaires	Filling in Evaluation Questionnaires

Table 2: The General Structure of Educational Pathways.

A matrix was defined to classify these and future scenarios based on the exhibits. Along with a task analysis, scenarios and other descriptions of exhibit related information, the Exhibit Criteria aim to break down information needed to integrate as well as further develop CONNECT Exhibit activities. The purpose of the matrix is to classify chosen exhibits within CONNECT in terms of

- Curricular Criteria
- Pedagogical Criteria (supported science skills and learning strategies)
- Real Exhibit Criteria
- Augmented Exhibit Criteria

These criteria are part of a specific description for each exhibit. The Curricular as well as Pedagogical Criteria can be a foundation for teachers, museum staff and others to decide whether exhibit related activities could be integrated into a unit, lesson plan, curriculum objectives or existing museum theme. The Real and Augmented Exhibit Criteria offer possibilities for museums to estimate costs and efforts. Besides the public use Exhibit Criteria, the matrix is used internally for exhibit comparison and overview.

The Matrix classification is used to more richly describe in what ways exhibits aim to meet various pedagogical criteria such as relevance to curriculum, science skills and learning strategies.

The four exhibits for the first run touch specific science topics in the subject matter of Chemistry, Physics and Biology. Some exhibits combine the investigation of properties and behaviour of matter with the focus of matter on molecular level. Every exhibit contains curriculum relevant topics but also tries to teach scientific phenomena not only on a school level. The aim is to make laws and concepts in nature tangible for students. For example the AirTrack exhibit aims to explain the resistive force (friction) that occurs when two objects are pressed together while travelling along each other. Thus the exhibit tries to impart also conceptual knowledge. Besides curriculum relevant concepts being taught, the exhibits also aim to teach methods that underlie current scientific practice. The scientific method is curriculum relevant in all countries involved in the CONNECT project to some extent. Especially Finland, Sweden and Great Britain integrate methods of scientific inquiry within their science curriculum. The application of scientific inquiry methods is strongly emphasised in all of the exhibits. We see scientific inquiry as a significant part of science skills that we aim to support with CONNECT exhibits. A list of types of science skills is defined within the pedagogical criteria that should be satisfied. The skill of investigating a scientific phenom-

Aerofoil: An interactive exhibit that uses a simple fan that is operated with an illuminated push button. The fan goes on for approximately 30 seconds and blows air across the wing. The wing pivots on a horizontal tube that can be tilted by the operator at a steep or narrow angle to the airflow that is blowing across it. Table tennis balls are encased in the wing - which is made of clear Perspex. The independent variable manipulated by the user is the wing and the dependent variable is the lift generated at each angle of the wing, represented by the position of the ping-pong balls, aiming to demonstrate Bernoulli's principle of lift.

The Aerofoil is an exhibit from Explore@Bristol, Bristol, England.



Figure 46: Aerofoil

Airtrack: An interactive exhibit that demonstrates a precision cart gliding upon a cushion of air back and forth on a horizontal track. The precision cart accommodates accessories such as additional mass for use in the experimental design, while the airflow can be regulated by a variable airflow. Located at either end of the 4.5metre track are soft bumpers designed to reduce energy loss as the cart moves back and forth. By varying the independent variables of mass and airflow (e.g. on – which minimises friction; or off) the user can measure the dependent variable of the distance traveled by the cart when a standardised horizontal force is applied. The exhibit aims to demonstrate Newton's laws and basic principle of friction.

The Airtrack is an exhibit from Eugenides Foundation, Athens, Greece.



Figure 47: Airtrack

Biotube: The Biotube is an enclosed plant-growth system that uses artificial lights (fluorescent tubes), hydroponics nutrient and water delivery. The central tube rotates 60 degrees every 5 minutes in order to provide even light distribution to the plants. The nutrients are absorbed in water and this "nutrient solution" is delivered to the plants from the inside of a vertical tube. Students The teacher explains the role of visit.can manipulate the growth conditions by changing light intensity as well as water delivery, displays are showing the current CO_2 and O_2 concentration in order to allow measuring the photosynthesis rate of the plants. A pan and tilt web cam, connected to a computer, is attached to the exhibit and it can be controlled via the web.



Figure 48: Biotube

This device allows taking time-lapse photos of the Biotube plants that can be viewed on the WWW.

The Biotube is an exhibit from Xperiment Huset, Växjö, Sweden

Hot air balloon: A closed system exhibit that presents a Balloon rising when the air is heated, and falls as the temperature of the air cools. The air is repeatedly heated by an electric heater when the balloon is at its resting position within the base station. Additional information is located on the base station in the form of a temperature gauge that indicates the temperature of the air inside the balloon. This observational experiment can be used to enable research in a way it is done on natural phenomena such as astronomy, and students can measure data and work on possible dependencies like temperature, weight.

The Balloon is an exhibit from Heureka, Vantaa, Finland.



Figure 49: Hot air balloon

Electromagnetic Spwectrum: In the framework of the CONNECT project, a new scenario to support the understanding of the concept of Electromagnetic Spectrum and focusing properties of parabolic reflectors is proposed through the present document. The Augmented Reality technology tools are used to provide visualization of sound waves and of Electromagnetic Spectrum properties at various frequency bands. The new AR pathway scenario uses a combination of two existing exhibits (Electromagnetic spectrum and parabolic reflector of the Eugenides Foundation science centre) and provides an excellent opportunity to the Greek CONNECT team to present to the students of the 3rd class of Lyceum a variety of phenomena related with the nature of electromagnetic and acoustic waves and their applications. Some of these phenomena and laws that will be investigated are the following:

- The nature of the Electromagnetic waves and their generating mechanism
- The nature of the acoustic waves and their generating mechanism
- The basic differences between the above two described mechanisms
- The nature of light and its propagation characteristics through various mediums
- The various sub-areas of the EM spectrum, their characteristics and their basic applications.

All of the above phenomena, laws and basic concepts that according to the Greek curricula cover a significant part of the wave theory that is being taught in the 3rd class of Lyceum, can or already have been investigated in the classroom during the pre-visit phase.



Figure 50: Electromagnetic Spectrum

enon effectively is emphasised by giving students possibility to pose predictions and to systematically plan and conduct experiments. The exhibits allow visitors to observe changes and to use made observations as evidence to support or reject their predictions. For example students interacting with the Hot Air Balloon exhibit will be able to observe changes of temperature along with change of height of the balloon. Students have then the opportunity to make inferences and to reason about the underlying principles of air and air expansion. Within this process students can practice activities as predicting, observing and experimenting. Other science skills that require in depth analysis of science concepts are: investigating, problem solving and reasoning. To impart these skills time is required before and after the museum visit to give students the opportunity to focus on science concepts. In the post-visit activities that will take place in the classroom students can work with the Internet and other recourses to conduct in-depth investigations to answer research questions. For example students who visited the Airfoil exhibit can employ some investigations afterwards to find out for example which Newton's laws apply. These investigations are guided by questions and the information they find can be used as evidence to support broader research questions or scientific records developed in the museum visit phase. Especially reasoning skills and predicting outcomes are skills that are required to develop problem-solving skills. Therefore the CONNECT scenarios aim to encourage students to engage in activities such as reasoning, hypothesising etc.



The use of learning strategies especially in free-choice learning settings is essential to support discovering of scientific phenomena and problem solving activities. One way for CONNECT scenarios to foster the use of learning strategies is to offer techniques to keep track of the own learning process. Students are encouraged to take notes and systematize their experimentation process. Students who are visiting the Biotube exhibit will learn to develop methods of conducting scientific experiments systematically. They follow the method of scientific inquiry as real scientists do, to not become overwhelmed by the complexity of the task. As in the other CONNECT exhibits, students can take notes and develop research journals that serve as records of their learning process. In all CONNECT exhibits it is planned to store these records within the CONNECT platform so they can be retrieved easily at later stages in the learning process. The also serve as learning objects that allow students to collaboratively produce, change and reuse scientific material created by themselves. These objects can be shared in all 3 phases of the CONNECT scenario.

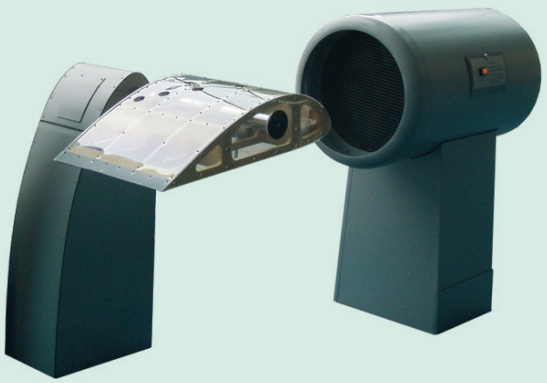
Augmentations for CONNECT exhibits range from location independent virtual objects to virtual objects that are fused with real objects. Virtual objects fused with real objects are for example visualized gases (Biotube and Hot air balloon). Some augmentations can also serve as annotations to physical objects. All 4 exhibits use arrows as virtual augmentations to indicate physical forces and gas flows. Virtual zooms into structures are used for the Biotube and Airtrack. These virtual objects can be given an added value to more specifically describe purpose etc. For example in place annotations to specific objects and display of current status or system properties are annotations that will be added to all of the CONNECT exhibits. The actual properties of the augmented virtual objects differ from shape complexity, colour use, dimension and grade of animation. All four CONNECT exhibits will be augmented with coloured objects. Furthermore the level of interactivity that can be established through the AR system is varying. For example the Airtrack has no real parts of the exhibit that are controlled (except the angle of the wing), however the weight force can be switched on and off using the AR system. For the Airfoil different variables can be selected via AR system. The Biotube uses the AR Menu system to allow choosing between different kinds of trend lines to predict the outcome of a planned experiment. The Temperature rate of the Hot air balloon exhibit can be selected and made observable through the AR system.

A range of augmentation opportunities has been highlighted in order to enrich the experimental environment of the learner, a number of these are common to all while some are specific to a single exhibit. The following have been identified for the initial CONNECT test runs which centre upon making the relative invisible phenomena visible; 3D object arrows illustrating the magnitude and direction of forces (such as weight, lift, airflow etc.) are common to all exhibits, 3D particles used to illustrate air density or flow are used only for the Balloon and BioTube exhibits.

Furthermore, a proposed augmentation opportunity exists in the ability to "zoom-in" to observe the microstructure of an object. This is realised within the Airtrack scenario.

Why do planes fly? The Aerofoil from Explore-At-Bristol, Bristol, United Kindom

Preparation phase



Scientific Content: The exhibit demonstrates the forces acting on an airplane wing and their effects on it. Airplane wings are designed so that the air speed above the wing is greater than that below the wing. Additionally, the wing has a slight upward tilt that causes air molecules striking its bottom to be deflected downwards. This deflection means that the wing is exerting a downward force on the air. According to Newton's third law, the air must exert an equal and opposite force on the wing that is lift. Finally turbulence also has an effect. If the wing is tilted too much, the flow of air across the upper surface becomes turbulent and the pressure difference across the wing is not as great.

Relevance to Curriculum: Concepts that relate to the curriculum are: Forces and motion (Newton's first and third law, quantitative relationship between force area and pressure, air resistance, drag,) air pressure and density.

Age Level: 10-16

Exhibit Description: The Aerofoil is an interactive exhibit using a simple fan that is operated with an illuminated push button and blows air across an experimental wing. The fan goes on for approximately 30 seconds and blows air across the wing. The wing pivots on a horizontal tube that can be tilted by the operator at a steep or narrow angle to the airflow that is blowing across it. Table tennis balls are encased in the wing - which is made of clear Perspex. The independent variable manipulated by the user is the wing and the dependent variable is the lift generated at each angle of the wing, represented by the position of the ping-pong balls. The Aerofoil is an exhibit from Explore-At-Bristol, Bristol, England.



Focal Research Questions: Examples of research questions are: How do airplanes fly? What factors influence lift? How does lift depend on these? Why do the ping-pong balls in the exhibit move up and down?

Common Student Misconceptions: A common misconception is that lift is created due to Bernoulli's effect. There is nothing wrong with Bernouli effect, but it is not complete. There are also problems regarding the invisible nature of the phenomenon. In particular, students often:

- neglect the effect of air movement on an airplane's lift,
- are unaware of the presence of air pressure, especially when air is not moving
- don't analyze the lift of an airplane's wing in terms of forces.

Theories of flight however are not in the curriculum at this stage so most students haven't thought about flight.

Possible AR Realizations: In order to "make the invisible visible," dynamic representations of air movement and the resultant forces can be created. It will also be possible to plot the wing's attack angles vs. lift force.

Pre-Visit Phase

Communicating concepts under investigation: The teacher can discuss about flight with students and explain the objectives of lesson. The students should be engaged in this discussion. Such discussion can reveal students' ideas and prior knowledge about flight. The teacher could also discuss the history of flight with the students. They would realise that flying is not easy for humans and it was difficult to explore and develop. This activity can make use of At-Bristol/CONNECT website, and other video files of websites.

A classroom investigation on the factors effecting wing flight could take place. The teacher, at this stage, does not provide the "right" answers. The teacher may ask students to make predictions of the suggested variables and prompt them to think of a rationale which may explain their predictions. A full explanation of the relevant information may be obtained on At-Bristol/CONNECT website (images, videos, including definitions of forces, pressure, lift, drag, gravity). The teacher may restrict access to this website for students prior to the visit and may make it available to students during the post visit activities.

Formulating Inquiry Questions: The teacher could prompt students to make concrete predictions about the exhibit's:

- Physical changes: What will happen to the ping-pong balls, as a function of the angle of the wing? How many will rise up? How high will they go? Why?
- Augmented changes: What happens when the wing surface changes? Possibilities involving friction and surface materials include smooth (metal), rough (sand), "organic" (feathers)
- Augmented variables: wind speed, shape of wing.

Suggestions for hands-on activity: The students could create paper airplanes of different sizes, using the same design, but starting from different-sized paper. Students will then fly these airplanes and will measure flight time, with the aid of a stopwatch. The teacher may facilitate a discussion, focusing on issues relating to forces on flight.

Preparing the visit to the science museum: The teacher explains the objectives of the visit to students. Students could view the overall exhibition, a video of the wing and other surrounding exhibits, in order to reduce "the novelty effect". If possible, students will be provided with an introduction to the AR headset, in order to allow them to explore its functionality.

The teacher should have communicated with the museum staff to arrange the difficulty and complexity levels required by the class. She would also need to select the ways different factors will be visualised. Additionally, the teacher needs to arrange the groups of students to visit the science centre and those to stay in the remote classroom. The visiting students should be informed of time limits, and self-regulate their procedures during the visit.

Evaluation Questionnaires: Identification of previous knowledge and misconceptions was done by administration of a diagnostic assessment tool, and through discussions in which the students can externalize and express

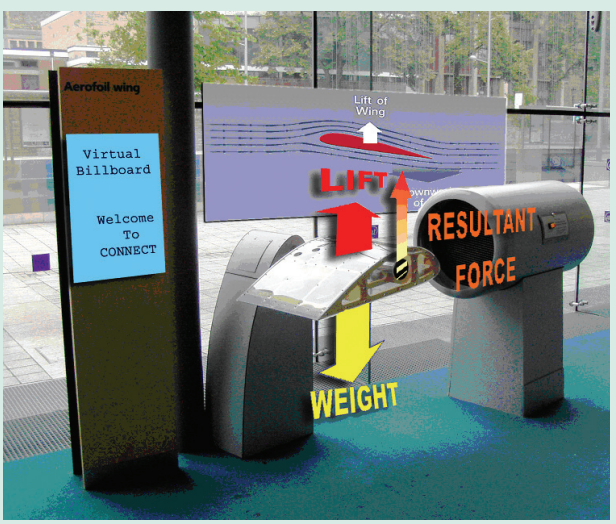


Figure 51: the Aerofoil exhibit showing visual augmentations.

their alternative beliefs and explanations about forces and flight.

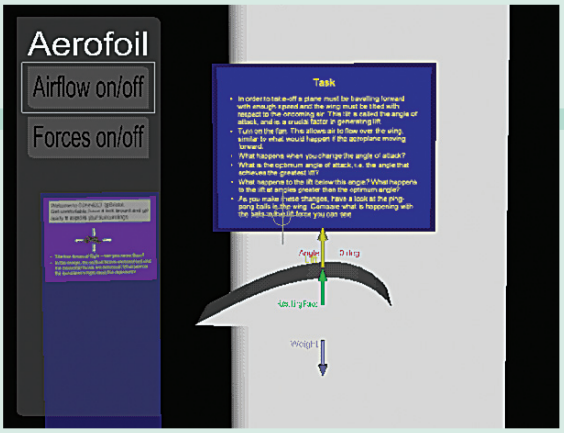


Figure 52: a snapshot of the Aerofoil AR view

Visit phase

Carrying out experiments: Students in groups of 5 take turns at Aerofoil exhibit and visiting other exhibits. From those visiting the Aerofoil exhibit, one student wears the headset and the rest watch the video of the AR system on the monitor. This phase last approximately 20 minutes. At the end of the trial, the students will be given a questionnaire for evaluation of their experience.

The Aerofoil exhibit can be turned manually. By doing so, the augmented visual representations of lift force (yellow arrow) and resulting force (green arrow) are changing. The weight of the aerofoil represented by the blue arrow is not changing. Also the representation of the airflow is affected but it is not shown. By pressing the 'Airflow on/off' entry in the 'Control' sub-menu the airflow representation can be switched on/off respectively. By pressing the 'Forces on/off' entry in the 'Show/Hide' sub-menu the force representations can be switched on/off respectively. There are two placeholders which can show additional information chosen by the teacher relevant to the phenomenon under study.

The students test their own predictions and those of remote students, e.g. altering angle of wing. They measure and record the discrete pre-set data points, they plot graphs or charts using AR. When applicable, the students apply formulae. The student using the headset could be challenged by his classmates to achieve different examples of lift and drag, by choosing the appropriate wing shapes and their inclinations. When the student has difficulties, the classmates offer their suggestions, which the student tries out. During students' activity the teacher role focuses mainly on group organisation, and prompting students with questions.

The AR visualization shows red lines representing air flow on the student's glasses. These airflow lines are superimposed on the top and the bottom of the real wing in the exhibit. As these airflow lines move above and below the wing (via the AR system), red lines appear above and below the wings, representing the resultant air pressure (also via the AR system). Therefore, the students will visualise air flow, drag, forces up/down, pressure then link these together.

Suggestions for additional activities: Visiting related (non-augmented) exhibits: Toward the end of the visit period, the students using the headset are directed to look at photographs of a bird in flight. These photographs clearly show the cross-section of the bird's wing at different points in the flight, with the accompanying black lines (showing air flow) and red lines (showing air pressure). The students – with advice from their classmates – now try to find the "airplane wing analogues" of each of the photographs of the bird in flight.

Filling in Evaluation Questionnaire: At the end of the trial, the students were given questionnaires for evaluating their motivation during the trial and the usability of the technology.

Post visit phase

Reflecting and processing the visit: After the visit and while in the classroom the teacher and students can reflect on the visit overall and discuss their feelings, the challenges, the strengths and weaknesses of their experiences.

They could watch and analyse the video of their experience and analyse data records that are preset and others that were recorded in real time. They could explore remaining predictions e.g. about forces and air flow.

Investigating further the examined phenomena: Additional activities could include plotting graphs or charts

using AR, applying formulae and comparing their results with their predictions., comparing their results with those of other groups, viewing video of scientists offering alternative explanations, viewing video of examples of bird/plane flight, drawing conclusions, presenting project to teacher/class, work on class project for CONNECT website. Optional simulated experiments could also be conducted testing air speed, wing covering, wing size/shape.

Filling in Evaluation Questionnaires: The students were given an evaluation exercise to record their learning outcome.

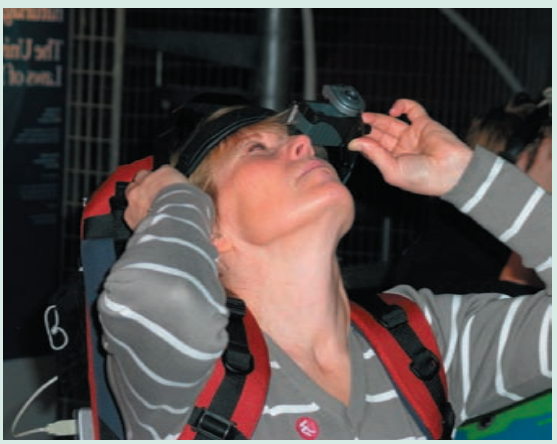
What keeps a balloon moving up and down? The Hot Air Balloon from Heureka, Vantaa, Finland

Preparation phase

Scientific Content: The exhibit demonstrates that the force of air pressure depends upon the rate of the collisions of the molecules in the air and the force of their impact. If these particles hit an object with greater force, more energy is transferred to it. Increasing the speed of these particles will also increase the force of their impact. All forces being equal, air particles will disperse evenly in an area, resulting in equal air density at every point. As air (or any other gas) has mass, it is influenced by gravity. The downward force of gravity "pulls" on all air particles in the atmosphere. But air pressure creates an upward force, which opposes gravity's pull. Air pressure level is highest right at the surface of the Earth. As one moves up, through the atmosphere, the air has less air mass above it, and so the balancing pressure decreases. This difference in air pressure causes an upward buoyant force in the air all around us. The atmosphere's buoyant force will only lift an object with a force equal to the weight of air an object displaces. So, for buoyancy to push up an object in the air, the object must be lighter than an equal volume of the air around it. Thus, in order for the balloon to rise, the air inside it must decrease in density, while keeping the same air pressure. So, to lower air density in the balloon, without changing air pressure, we simply need to increase the speed of the air particles, which will cause some air particles to leave the balloon; this can be done by heating the air inside the balloon, causing the balloon to rise. In order for the balloon to fall, the opposite process must take place: we can increase the air density inside the balloon, without changing the air pressure, by decreasing the speed of the air particles, which causes other air particles to enter the balloon; this can be done by letting the air cool inside the balloon, causing the balloon to fall.



Figure 53: The Hot Air Baloon



Relevance to Curriculum: The Hot Air Balloon exhibit allows students to learn about a variety of scientific concepts: Forces (Buoyancy and Gravity), Air Pressure, molecular nature of air, the relationship between pressure, volume, and temperature. Age Level: 11-13

Exhibit Description: The Hot Air Baloon exhibit shows a bal-

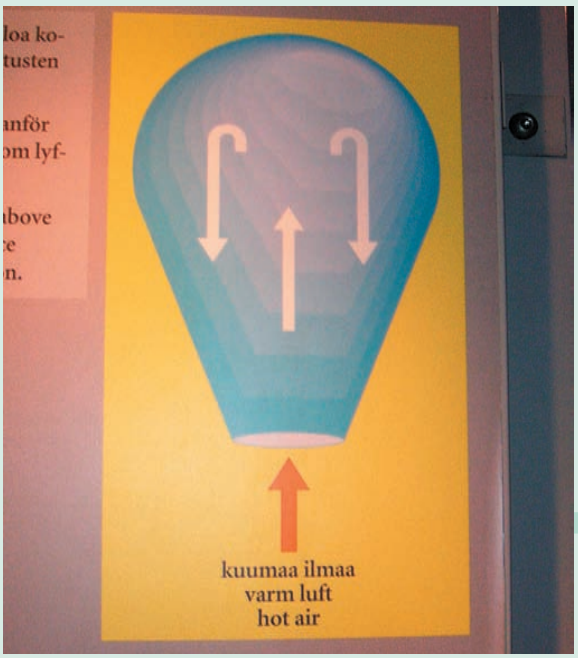
loon that uses heated air to provide buoyancy and thus rise. Warm air is less dense and thus lighter since it has expanded and occupies more space than cool air. Therefore, the difference between the weight of the hot air and of the cold air that it displaced, is what pushes the balloon up. The air is repeatedly heated by an electric heater when the balloon is at its resting position within the base station. The exhibit has been designed to allow no direct hands-on manipulation but works automatically; the visitor is expected to make observations. The visitor can see a thermometer showing the room temperature (approximately 21 oC). After the balloon starts to go upwards, another thermometer appears showing the temperature inside the ball (80-130 Celsius). The visitors typically see the exhibit from the distance, come closer, stop ("attractive power") to the exhibit, and then start to observe it typically 2-5 minutes ("holding power") depending on their background, motivation, and especially social context, which is with whom they come to exhibition. Very often the visitors are coming again to the exhibit with other people after they have discovered it first by themselves.



The Hot Air Balloon is an exhibit from Heureka, Vantaa, Finland.

Focal Research Questions: Why does the Hot Air Balloon rise? Why does it stay up in the air? Why does it come down again? What is the relationship between the temperature inside the balloon and these movements?

Common Student Misconceptions: Some students have a "non-particle view of air," i.e., they perceive air as being empty ("There is nothing there"). Some students have the notion that air is a matter but they have wrong models regarding the molecular structure of the gaseous state. In addition, some students believe that hot things expand because the molecules or atoms get bigger as they heat up. They also believe that heating something makes it lighter. Finally, students have difficulty integrating many scientific concepts, which usually are been taught separately, i.e., the molecular theory of gases, air pressure, buoyancy, and forces acting on an object. Another common misunderstanding AirBaloon-specific is that the cylinder is blowing the air, although it is warming the air.



Possible AR Realizations: In order to "make the invisible visible," the dynamic visualization of the density of the air molecules inside the balloon have been created, with representations of the number of molecules and molecular speed. Likewise, arrows coloured in blue and red could represent the movements of hot and cold air layers, if the teacher wants. Variables such as room temperature, balloon temperature, balloon height and time elapsed can be recorded and displayed. Such data can be used later to plot graphs that demonstrate the correlation of different variables, e.g., balloon height vs. balloon temperature and density of air molecules vs. balloon temperature.

Pre-Visit Phase

Communicating concepts under investigation:

The kinetic theory of gases: Air or any gas is not vacuum (emptiness). Gas consists of a large amount of small moving parti-

cles (molecules), the distances between particles are fairly large. The ideal gas's law describes the relationship between the different properties of volume, pressure, temperature and weight. A useful link to demonstrate these relationships is: http://mc2.cchem.berkeley.edu

Density of gases: Density is defined as Mass/Volume. Students have a notion of those concepts from daily experience, especially regarding solids and liquids. For example: Some objects are heavier than others, even though they have the same size: a brick and a loaf of bread; same volumes of iron and aluminium – Iron is heavier. Oil floats over water.

It will be useful to make specific links of these concepts to the gaseous state. It is important to emphasize that in liquids and solids density remains fairly constant (volume changes are neglectable). However in the gaseous state changes of density are mainly due changes of volume. Each demonstration should be followed by a discussion.

Formulating inquiry questions: In a classroom lesson, students could be challenged to investigate a guiding question: "How do hot air balloons fly?" The students are invited to investigate this question by reading their science text, using the Internet and talking to a practicing pilot.

Buoyancy and Archimedes law are easy to approach by linking them to daily experiences of the students. Archimedes law: the weight of the displaced air is greater than the air inside the balloon. For example, discuss about floating and sinking objects – what makes them different? Ask why is it easier to lift something when it is in water. Discuss about metals: even if they are denser ("heavier") than water – how do boats and ships float? After discussing these topics about the liquid state link them to gases since gas behaviour can be considered as a fluid behaviour, in this context.

Suggestions for hands-on activities: Students can design and build a small hot air balloon using plastic film bags, paper clips, and a heat source like a camp stove. Alternative examples are: An egg can be used for a simple demonstration that promotes thinking. Put an egg in a flask containing sweet water (drinking water). Then put the egg in the same volume of water, but this time uses salty water. Observe the differences in egg's position, and try to explain them. Our suggestion is that after discussing these topics in the liquid state, to connect them to gases. Gas behaviour can also be considered as a fluid behaviour, in this context.

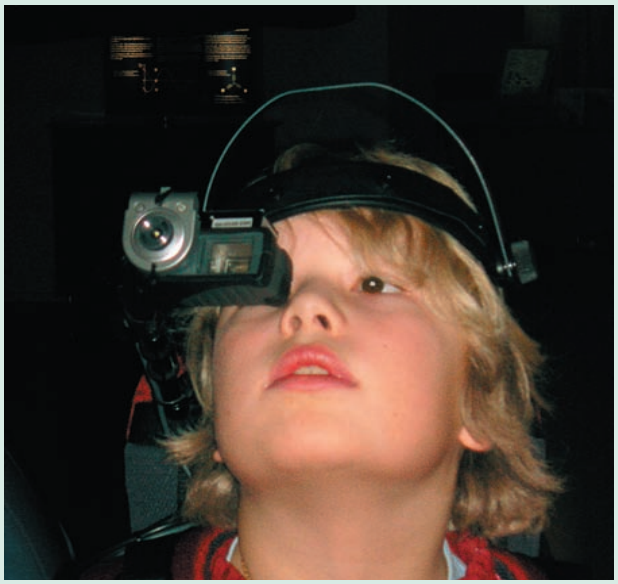


Different gases – different densities (same temperature): Take three balloons of the same volumes (Aluminum foil balloons are preferable, but rubber balloon work too) filled with different gases: Helium, CO_2 and air. The balloons will float in different positions in the room: CO_2: close to ground; air – about the middle of the rooms' height and Helium – up to the ceiling. Discuss the cause for the density differences in this case.

Heating a constant mass of gas: Put a simple rubber balloon on the neck of a glass flask (Glass bottle, Erlenmeyer). Describe the condition of the balloon (empty and crinkly). Put a burner below the glass flask and watch the changes in the balloon's shape (full with air). Discuss the observation and try to explain them. Relate the change of volume to the concepts density and pressure.

Cooling air: Take two identical rubber balloons and fill them with air (preferable – by a pump that can obtain a constant amount of air). The volume of the two balloons should seem similar. Place one balloon in the freezer for at least 6 hours. Leave the other balloon at room temperature. Observe the differences between the balloons and try to explain them.

Planning the visit to the science museum: The teach-



er in cooperation with the students organizes the visit to Heureka. The students can view the overall exhibition, a video of the HotAirBaloon and other surrounding exhibits, in order to reduce "the novelty effect". If possible, students will be provided with an introduction to the AR headset, in order to allow them to explore its functionality. The teacher should have communicated with the museum staff to arrange the difficulty and complexity levels required by the class. She would also need to select the ways different factors will be visualised.

Evaluation Questionnaires: Identification of previous knowledge and misconceptions were done by administration of a questionnaire, and through discussions in which the students can externalize and express their alternative beliefs and explanations about buoyancy and gas laws.

Visit Phase

Carrying out experiments: After the initial student investigations and a classroom discussion about the guiding question, one student from the class travels to Heureka and approaches the "Hot Air Balloon." The student puts on the AR system and interacts with the exhibit, making observations from several distances (1 m to 30 m), doing measurements, reading labels, and testing different hypothesis to discover the real reason(s) for the phenomenon. Also writing the observations as a research notebook to be analysed, fulfilled and reported later.In the AR view, the student can see a visual representation of the Hot Air Balloon and textual placeholders showing information regarding the occurring changes, i.e. temperature, balloon height, balloon state, and experiment time.

After the first AR-trial, when the student is observing the balloon movements (up and down) colourful small circles appear on the student's glasses. The coloured symbols and particles are representing the atoms and molecules, and their movements and changes in the movements while the temperature is varying.

Make sure that the students understood the exhibit and how it works. The visiting students should actually be able to teach others (students in class, friends, and parents).

Suggestion for additional activity: the student at the exhibition can keep the ball down by griping from the lowest part of the balloon and keep it down for example extra 15 sec; 30 sec; 45 sec; 60 sec; the result of the temperature - and the time the ball is keeping in the air close to the roof - is different!

Provided here are three Educational Activity containing AR features, for different age-groups:

1st Educational Activity: Linking air temperature to winds and weather

Objective: Understanding the correlation between the temperature inside and the height of the balloon.

Suggested Grade: 4-6th grade

There is no "scientific explanation" here, just a descriptive level of the phenomenon

- Students can take different temperature measurements and save them in table.
- Students can take height measurements and save them in table.
- They can also see images of air pressure in different altitudes.

- Through the AR system they have access to augmented visualizations of the balloon changing colours from blue to red and vice versa, in different positions (The colour represents the air temperature in the balloon)
- Through the AR system they can also see animation of air movements (arrows representing cold air down, hot air up)

2nd Educational Activity: Linking between thermal energy to the molecular level (speed, collision, density)

Objective: Understanding that there is a correlation between the temperature inside and the height of the balloon.

Suggested Grade: 7-9th grade

- Students can take different temperature measurements and save them in table.
- Students can take height measurements and save them in table.
- They can also see images of air pressure in different altitudes.
- Through the AR system they have access to augmented visualizations of the balloon changing colours from blue to red and vice versa, in different positions (The colour represents the air temperature in the balloon)
- Through the AR system they can also see animation of air movements (arrows representing cold air down, hot air up)
- Students can see graphs of temperature vs. height
- They can also see the molecular view which emphasizes the differences between air density inside and air density outside the balloon. Also important - the fact that the balloon is not a close system: “hot air” can go out, and “cool air” can get in.

3rd Educational Activity: buoyancy and gravity

Objective: In the balloon there is always a balance between two opposite forces: buoyancy and gravity.

Suggested Grade: 10-12th grade

- Students can take different temperature measurements and save them in table.
- Students can take height measurements and save them in table.
- Students can see graphs of temperature vs. height
- They can also see the Molecular view
- They can see visual representation of buoyancy and gravity forces

Evaluation questionnaire: At the end of the trial the student were given a questionnaire regarding their motivation and the usability of the technology.

Post-Visit Phase

Reflecting and processing the visit: The students should reflect and discuss the visit when back in the classroom. They can write a detailed description about the exhibit and how it works. All students should try to answer the questions that the exhibit addresses. They can be engaged in a new scientific inquiry regarding related topics such as weather, hot/cold streams in the ocean etc. They can also discuss the role of observations, data measurements and hypothesis generation. The role and meaning of a model can be discussed too.

Further investigate the examined phenomenon: Students can suggest alternative ways of designing a hot air

balloon. They can discuss several options. For example, the most obvious thing is that "lighter than air" is nothing at all. A vacuum can have volume but does not have mass, and so, it would seem, a balloon with a vacuum inside should be lifted by the buoyancy of the air around it. This doesn't work, however, because of the force of surrounding air pressure. Air pressure doesn't crush an inflated balloon, because the air inside the balloon pushes out with the same force as the outside air pushing in. A vacuum, on the other hand, doesn't have any outward pressure, since it has no particles bouncing against anything. Without equal pressure balancing it out, the outside air pressure will easily crush the balloon. And any container strong enough to hold up to the air pressure at the earth's surface will be much too heavy to be lifted by the buoyant force.

Another option would be to fill the balloon with air that is less dense than the surrounding air (meaning has less particles per volume). Because the air in the balloon has less mass per unit of volume than the air in the atmosphere, it would be lighter than the air it was displacing, so the buoyant force would lift the balloon up. But again, fewer air particles per volume means lower air pressure, so the surrounding air pressure would squeeze the balloon until the air density inside was equal to the air density outside. Another option will be to use a different gas that is less dense than air, e.g. helium. This option is actually working and students can look for some information regarding other gases used for hot air balloon on the web.



Suggestions for hands-on activities: The students can be engage in designing and building their own balloons. There are many links on the web providing instructions. Attached are few of them, but maybe it will be best to look for instructions in Finnish.

http://www.lerc.nasa.gov/WWW/K-12/TRC/Aeronautics/Hot_Air_Balloon.html

http://www.concord.org/~barbara/workbench_web/unit1/AdditionalMaterials/pdf/SmallHotAirBalloon.pdf

http://www.concord.org/~barbara/workbench_web/unit1/AdditionalMaterials/pdf/LargeHotAirBalloon.pdf

A relatively simple and fun experiment in the context of Kinetic theory of gases can be an experiment answering the question: What pushed the boiled egg into the Erlenmeyer? Put an empty Erlenmeyer flask on a hot plate and warm it (the air inside the Erlenmeyer warms up). Place a boiled egg (without the shell) on top of the Erlenmeyer's neck. Let the Erlenmeyer cool down (it can also be cooled by placing the Erlenmeyer in a wider flask containing cold water). As the air inside the Erlenmeyer gets cool, it's pressure decreases and the atmospheric pressure of air outside the Erlenmeyer will push the boiled egg slowly in. The students should propose their own explanations to what they saw and raise suggestions how to get the egg outside the Erlenmeyer.

Working with educational applets: One applet is 'the ideal atmosphere'. Students can interact with it, and then try to explain the impact of each variable on atmosphere composition. In :

http://chem.ps.uci.edu/education/undergrad_pgm/applets/canonical/canonical.htm

Another applet deals with controlling a temperature inside a balloon filled with gas. In:

http://jersey.uoregon.edu/vlab/Balloon/index.html

Filling in Evaluation Questionnaires: The students were given an evaluation exercise to record their learning outcome.

Why do plans grow? The Biotube, Xperiment Huset, Växjö, Sweden

Preparation phase



Figure 54: The BioTube exhibit

Scientific Content: The exhibit aims to teach aspects of photosynthesis – in particular how we can sustain plant growth in space. Photosynthesis is the process in which green plants and some bacteria -- with the help of chlorophyll and light energy -- turn carbon dioxide, and water into sugars and oxygen. This is the process which is responsible for creating nearly all of the food used on Earth by non-plant organisms. While this process is extremely complex, it can be understood on a relatively simple level, in terms of the above relationships.

Relevance to curriculum: Plant biology, Photosynthesis, Carbon Cycling between plants and animals, Plant Anatomy, Engineering of Controlled Environments.

Age level: 13 and up.

Exhibit Description: The BioTube is a show and tell exhibit in which plants are encased in a Perspex tube among controlled environmental conditions of light, humidity and temperature that act as the independent variables for experimentation. A stand alone monitor currently displays these conditions. The dependent variables are CO_2 and O_2.

The BioTube is an exhibit from Xperiment Huset, Växjö, Sweden.

Focal Research Questions: Examples of research questions are: How do different temperatures affect the rate of photosynthesis? How long does it take for the plant's rate of photosynthesis to react to different changes in temperature? How does humidity affect the rate of photosynthesis? How long does it take for the plant's rate of photosynthesis to react to different changes in humidity?

Common Student Misconceptions: Many students believe that plants "get their food" from the ground; these students have not developed a deep understanding that most of the plant's mass comes from atmospheric carbon dioxide. Another common misconception is that respiration (the process in which organisms break down organic compounds to release energy) occurs in plants only during the night, when it's dark.

Possible AR Realizations: The gases of CO_2, O_2 and humidity that are produced in the process of photosynthesis are shown depending on the level of light density, which the student can control. The student could select which of the three molecule augmentations should be visible. The gases are visualised as particles that move away from the plant or not move at all. O_2 and CO_2 arrows could blink and/or point towards specific direction. The amounts of CO_2 and O_2 in the air will be represented as dots within the Tube.

Pre-Visit Phase

Communicating concepts under investigation: Several concepts need to be introduced to grasp meaning of the BioTube exhibit such as advanced life support, photosynthesis, biomass.

Example: Life on Mars: In Tanja's 10th grade science class, she introduces her students to the questions: "How would you survive on Mars? What would you eat? How would you live?" The students start by reading their science text, using the Internet and talking to farmers (and greenhouse growers) about agriculture and gain insight about how our food is grown and how important transport of food is to our survival. Students discover that transport to the moon or Mars

is impractical and come to the conclusion that we need to engineer and build controlled environment habitats. They discover that the space scientists call this an Advanced Life Support System or a Bio Regenerative Life Support System and they find lots of information on the internet.

Formulating Inquiry questions: In the attempt to help them answer the question, the teacher discusses what food seems to be appropriate feeding people on a remote planet. She introduces them to plant life and the process by which they grow. They discuss about the cycle of photosynthesis and the parameters which affect it. For example:

- What are the parameters of plant growth? How do materials and energy flow?
- Where does the Photosynthesis take place?
- What are the effects of different temperatures in plant growing?
- Are the plants with different sunlight different that those with more light? If yes, how?
- How long does it take to see the reaction of the plant to different temperature, humidity, levels of CO_2 ?
- What changes can be observed when increasing light intensity?
- How will changing the humidity of the air affect the CO_2 rate?
- How do the CO_2 gas particles change, when reducing the light intensity?
- How do the CO_2 and O_2 arrows change when light intensity increases?

Additional questions to stimulate inquiry are:

- Which crop gives the most edible biomass in one harvest cycle?
- How do plants respond to changing the harvest length?
- If lettuce is placed under a higher amount of light, is it possible to harvest earlier and then get more biomass than using the standard lettuce harvest condition?

Not all of these questions are testable, but can be investigated using other scientific instruments (bioBLAST, calculations based on standard conditions) .

General functionality of plant grow chambers needs to be discussed (e.g. sensors, hydroponics, ALS). Web-based green houses and also the BioTube itself can be explored on the internet. Sensor effects can be discussed and also explored by using a simulation tool (BioBLAST).

The optimization of parameters is the main task to get healthy and high biomass plants and O_2. This optimization process requires understanding of the PS parameters and their relationships within the dynamic photosynthetic process. Also students should learn a scientific method to optimize conditions systematically. The scientific inquiry process can guide students when making experiments and trying out conditions. These experiments should be based on research questions and resulting hypotheses that should be developed by or with the students.



Suggestion for Hands-on Activity: This activity is best used as segue to a lunch break. Students can prepare their own food while learning about several types of biomass. They can learn to distinguish between edible and inedible biomass, collect data using scales, calculate percentages, analyze data and think critically about data collection methods.

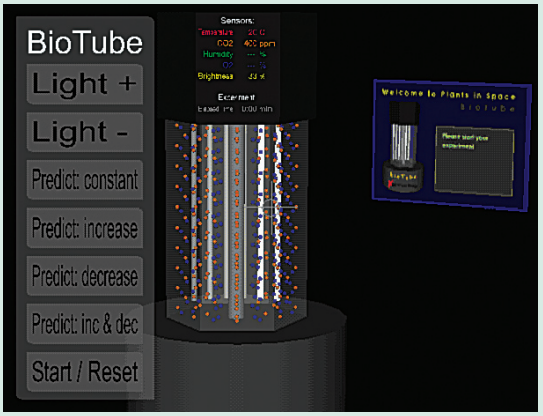


Figure 55: A snapshot of the visual display

Preparing the visit to the science museum:

The teacher in cooperation with the students organizes the visit to Xperiment Huset. The students can view the overall exhibition, a video of the BioTube and other surrounding exhibits, in order to reduce "the novelty effect". If possible, students will be provided with an introduction to the AR headset, in order to allow them to explore its functionality.

The teacher should have communicated with the museum staff to arrange the specific exhibit setups. The conditions of the experimental run should be stored in the system's database.

The visiting students should be informed of time limits, and self-regulate their procedures during the visit.

Evaluation Questionnaires: Identification of previous knowledge and misconceptions were done by administration of a diagnostic assessment tool. Through discussions in the classroom, students can externalize and express their alternative beliefs and explanations about photosynthesis and plant grow.

Visit Phase

Experimental Educational Activity:

Two students from the class, Anna and Simon, travel to the Xperiment Huset (Science Museum) and check out the Space House exhibit hall. When approaching the exhibit, the bright light coming from the BioTube exhibit cathes their eye. Anna puts on the AR system and Simon takes his place at the control panel. Anna's augmented view of the exhibit is streamed back to a group of students in their classroom who are working in pairs at wireless connected laptops. Anna has to choose between a BioTube Sensor Interaction mode (Sensor Interaction) and a Photosynthesis Investigation mode (Micro Investigation).

Anna's view of the BioTube includes several augmented visualisations. On the top of the visual representation of the BioTube, there is the instrument section, where a number of textual variable representations are located (e.g. temperature). Three pairs of neon lights can be switched on or off through the menu. By selecting the menu entry 'Light +' the number of light bulbs is increased by one pair. By selecting the entry 'Light -' the number of light bulbs is reduced by one pair. By selecting the 'Start/Reset'menu entry, the experiment time can be started or reset.

Sensor Interaction:

First, the students from the classroom communicate to Anna via real-time chat that they want to see how the BioTube works and they ask her "what is that thing hanging from the ceiling?" "What happens if you make it really bright in there?" So Simon uses the control panel to raise the light intensity. Anna explains that the hanging thing is a temperature sensor and that it is reacting to Simons control panel settings. She also finds a CO_2 and O_2 sensor and can see that the value is reducing as Simon increases the light intensity. Students can watch the sensor graph change; Anna in the AR view and those back in the classroom via a web interface. The CO_2 is visualized in the chamber as animated particles bouncing around the growth chamber and the humidity is visualized as a fog of various densities. Arrows close to the leaves indicate the CO_2 uptake of the photosynthetic process. As the plants photosynthesize, the students can watch the sensor data and realise that the CO_2 level in the growth chamber decreases.

They can also run an experiment to see the difference in how and if the CO_2 level changes when the lights are at different intensities. Anna picks a graph from the AR menu that represents the shape that is closest to the prediction she has formulated in the pre-visit phase. Anna chooses a linear decreasing trend line to indicate that she predicts a decrease of CO_2 concentration in the Tube. After Anna and her peers took the measurements and put them into a database,

the data is displayed on the Kiosk as a graph and can be compared with the trend line that Anna predicted earlier. The teacher/museum educator asks the group why the gas concentration in the tube decreased.

Suggestion for additional activities: See *http://www.ftexploring.com/photosyn/chloroplast.html* and

http://www.whfreeman.com/LIFE5/CH08/images/photophos_t1.GIF to get an idea about the structures and process that are described in the scenario below.

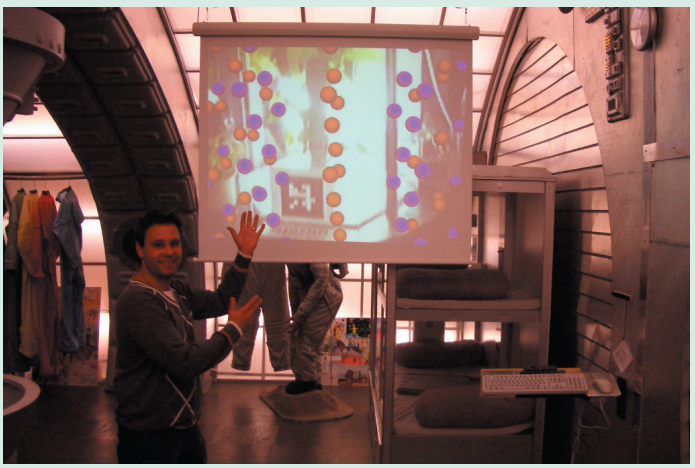


Figure 56: Video projection of the AR view

Micro Investigation: (Not implemented in the first Run). Looking the plant leaf, Anna can zoom in by activating the hotspot. The plant starts to grow around her and envelops her until she has the vantage point of looking at the underside of the leaf in super detail. The stomata of the leaf (the holes where the air exchange takes place) are labelled and she can see CO2 molecules rushing in and O2molecules and water vapour rushing out. Simon controls the level of CO2 in the animation and Anna can see the amount of molecules changing. Then she clicks on the center of the stomata and it grows to surround her and suddenly she is peeking inside the virtual stomata and can see the chloroplasts inside the parenchyma cells. The CO2 molecules are rushing into the airspaces in the spongy parenchyma and across the cellular and chloroplast membranes into the grana where photosynthesis is occurring and the sugar molecules are being produced and stored as starches. Then the classroom students see that Anna can click the grana and it grows to be as big as she is and the light is visible as streaming photons being caught by pigment molecules. Then she goes one level deeper to see the actual photosynthetic membrane where the ATP syntheses protein is pumping H+ ions and attaching high energy phosphates to ATP molecules. She sees the glucose and starch molecules being constructed, one by one, from water and thin air (actually CO2).

Filling in Evaluation Questionnaire: At the end of the trial, the students were given questionnaires for evaluating their motivation and the usability of the technology.

Post visit phase

Reflecting and process the visit. All students discuss the science museum experience with the teacher. The teacher proposes to take a look at the data that was stored during the science museum visit. They discuss Anna's hypotheses and compare them with the ones that students made in the remote classroom. Tanja, the teacher reminds her students about what they learned in the pre-visit about photosynthesis. She asks the students to use their knowledge to explain in biological terms why the CO2was decreasing when the light-intensity level was raised.

Further investigate the phenomenon and apply it to everyday life. The teacher can discuss some broader questions regarding Life in Space. For example: How many square meters do you need, to feed a crew of 10 people? Determine what could be done to make extended Space Station missions possible? What are the disadvantages of food transport?

Suggestions for Hands-on Activities. Later the class agrees to investigate the following research question: How many square meters do you need, to feed a crew of 100 people? The teachers help to divide the tasks between the student groups. Anna's group investigates the internet to find out the nutritional value needed by a human everyday. Simon's group runs simulation experiments to find out which crop is producing the most biomass and the right nutrition value.

Filling in Evaluation Questionnaires: the students will be given an evaluation exercise to record their learning outcome.

Exploiting the CONNECT approach in different subjects and exhibits.

The concept of friction and the "Pathway on wave mechanics", Eugenides Foundation, Athens, Greece

In the framework of the implementation in Greece two major cycles of school-museum collaboration activities were realised. In the first cycle 119 students (15-16 years old) from two conventional schools (Ellinogermaniki Agogi and 2nd Lyceum of Argyroupolis) and 7 students from one special school participated (Special School of Athens). The implementation took place from January to April 2006. The concept of Friction was the main theme of the implementation and an air track exhibit was used. During the second cycle the museum demonstration included an educational pathway between two exhibits (the Electromagnetic Spectrum and the Sound Waves Reflectors) was created to introduce students to the concept of Waves. 71 students (17-18 years old) from the two conventional schools were involved in the study and 7 students from the special school. The second implementation cycle was realized in December 2006 and in January 2007. In every case teachers were familiarized with the CONNECT platform before the museum visit; they were also aware with the idea of developing pathways for their students. The working hypothesis of the CONNECT project is that amending the traditional scientific methodology for experimentation with visualization applications and model building tools will help students and learners in general to articulate their mental models, make better predictions, and reflect more effectively (Mirland, 2003). Additionally, working to reconcile the gaps and inconsistencies within their mental models, system models, predictions and results, will provide the learners with a powerful, explicit representation of their misconceptions and a means to repair them.

In both cases the concepts under study are part of the school curriculum of the participating students. During the first implementation phase an excellent timing was achieved so the introductory lesson in the laws of friction was made just before the planned visit to the museum. Following the curriculum teachers have introduced the concept of friction and the relevant laws during the pre visit activities in the classroom. Usually the class work begun with a question given to the students. They were asked to give an individual answer in their notebook before discussing it with the other members of the group. After the group discussion the students were asked to agree on a group response and prepare a class presentation for general discussion. Class discussions were common and in addition to the group representative all the other children could participate. Students asked questions to the group representative, or made comments in order to clarify or challenge the answer proposed by his/her group. The aim of these discussions was to arrive at an answer to the initial question accepted by all. However, often there were unresolved disagreements amongst the groups and an experiment was proposed that should provide an objective answer to the problem being investigated. Students' prior knowledge and their particular difficulties in understanding the different concepts and explanations of phenomena guided both the selection of the content and of the instructional interventions. We have argued that students operate on the basis of a naïve theory of physics constructed on the basis of their everyday experience and acting as a constrain in the acquisition of scientific knowledge. In the case of phenomena of mechanics such as rest and motion research (Ioannides & Vosniadou Vosniadou, Kayser, et al,) has shown that high school students believe that force is an acquired property of inanimate objects that explain their movement. According to this acquired force model, also known as the impetus misconception in the literature, force is the agent that causes an inanimate object to move. The object stops when this "acquired force" dissipates in the environment. These characteristics of force make very often students to conflate force with energy, and make it difficult for them to understand the scientific explanation of motion.

A model to explain friction

In order to help students construct the scientific representation of the concept of friction force, the "friction model" was introduced in lesson before the visit. This model was introduced after the students had already experienced how the hardness of different surfaces affects the motion of the objects that slide on them. At this point the teacher asked the students to explain the fact that even the polished smooth surface of the top of a table hinders the motion of the objects moving on it. The teacher, then, presented to them slides with photographs of glass surfaces magnified by an electronic microscope as a proof that even the smoothest surface has anomalies that cause the appearance of friction forces. After a short discussion at the class level about how these anomalies of the surfaces can hinder the motion of objects, the teacher presented to the students the 'friction model".

Cognitive conflict was used in certain occasions to make children realise that their explanatory framework could not explain some empirical results. Teacher challenged students' belief that in order to make an object slide on the ground a force must be exerted on the object that is greater than its weight. In this model, weight is considered as a property of the object and not as an interaction between the earth and the object. Children were asked to test their predictions using different objects and dynamometers to compare the weight of the objects and the magnitude of the force that makes the objects slide on different surfaces. Students were surprised to see that the forces exerted were always smaller than the weight of the objects. This created a strong motivation for them to seek the scientific answer. Through carefully selected activities children realised that motion of the object is affected by the hardness of the surface on which the objects slides and thus to approach the concept of friction force.

Electromagnetic vs Sound Waves

The main aim of the didactical approach and the scenario design in the second case was to introduce students in the concept of waves. The concept of waves is fundamental due to its occurrence throughout the natural world (water, sound, and electromagnetic waves). Because the concept occurs in so many places, students come to the classroom with prior knowledge, as well as misconceptions, about waves. Students have misconceptions about what is waving in a wave, what properties of the medium determine wave speed, and how waves interact with each other (Wittmann 1996).

The aim of the CONNECT implementation in this phase was to use the set-up of the museum setting to introduce students in the main ideas of wave physics and mainly to help them to understand the difference between electromagnetic and sound waves. Light (electromagnetic) energy moves by transverse waves. The disturbance is perpendicular to the direction the wave is moving. These waves can move through empty space, they do not need a medium. Sound energy moves by longitudinal waves. Longitudinal waves move parallel to the direction the wave is moving. These waves must have a medium to move through.

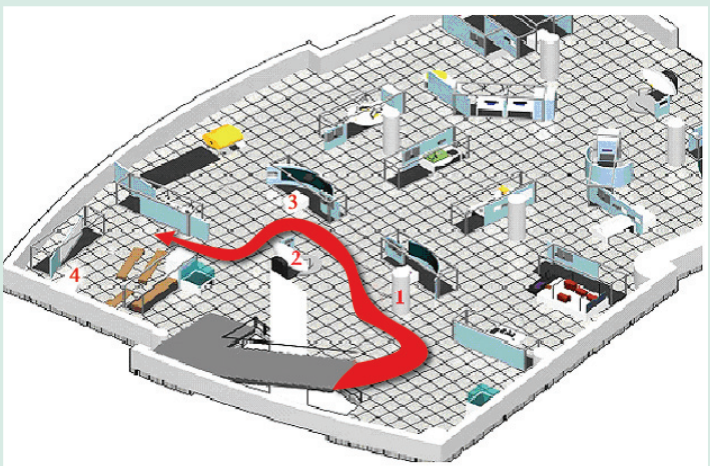


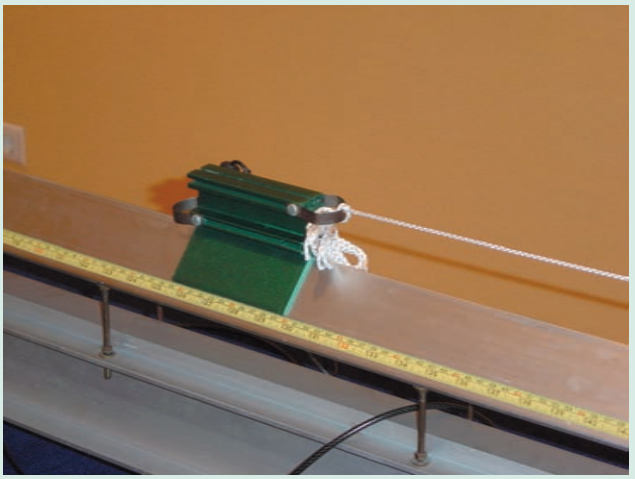
Figure 58. During the CONNECT implementation students had to go through a pathway starting from the Electromagnetic Spectrum Exhibit (1) and then moving to the area between the two Sound Reflectors (2) where the sound waves were simulated as oscillations between the air molecules. In the same are there is an area (3) from where the rest of the class was seeing what the students performing the "pathway" were seeing through the AR system, through a big screen.

What stop things from moving? The Airtrack

Scientific Content: The exhibit demonstates that friction is present when two surfaces are in contact. Friction is very important for our everyday lives. It allows us to walk or run and it is necessary for the motion of wheeled vehicles. Experimentally we can find that friction is proportional to normal force. It takes greater force to start an object moving that it does to keep it going once it has started sliding. Therefore static friction is greater than kinetic friction.

Relevance to Curriculum: The concept of friction is a national curriculum topic for compulsory science in most countries. The exhibit can be further incorporated in a broader thematic area of learning about forces, Newton's laws, elastic/inelastic collisions, mechanical oscillations. Age Level: 15-16

Exhibit Description: The exhibit demonstrates a cart sliding on an air track, under the influence of an external hori-



zontal force. It is possible to blow air through tiny holes on the surface of the AirTrack reducing friction and thus facilitating the cart's motion. Carts of different weight are available. Through this exhibit the students can experiment with the laws of motion, investigate the nature of the frictional forces and can deduce the law of friction. The AirTrack is an exhibit from Museum of Science and Tecnology of the University of Athens which is currently hostedin Eugenides Foundation.

Focal Research Questions: Examples of research questions are: How does free body diagram look like for two masses connected by a cord? How does friction work? How does friction affect movement? What happens when a thin liquid or air surface intervenes? How do we move or stand? How do we hold things? Why don't things slip and slide away? What is the relationship between a moving body's force, mass and acceleration?

Common Student Misconceptions: Some common misconceptions about friction are: Friction cannot act in the direction of motion. Friction always hinders motion, therefore reducing friction is always desired. Friction always converts mechanical energy to thermal. A force applied by say, a hand, acts on an object even after the object leaves the hand. The force of gravity or their weight is what keeps things stationary or is what decelerates moving objects. We can have friction even if objects are not in contact.

Possible AR Realizations: To "make the invisible visible," dynamic representations of the forces acting on the cart on the Airtrack will be created. Additionally, a microscopic representation of the structure of the surfaces (with and without air) can also be created. A representation of airflow could also be created. Using real-time data generated from the exhibit, it will be possible to chart various graphs which represent how friction relates to the pulling force.

Pre-Visit Phase

Communicating concepts under investigation: The teacher can discuss about friction with students and trigger their attention to stress the different forces acting on an object and help them deduce the phenomenon of friction. The role of different surfaces could also be discussed as well as positive aspects of friction.

The teacher can choose to demonstrate friction for different surfaces in class through videos that show: a) vehicles sliding out of control in icy/wet roads, b) machines where lubricants are used to facilitate contact and movement between metallic surfaces, c) intervention of a zone of air for facilitation of movement on earth or sea (e.g. hovercraft), etc.

The example of a man is pulling a dog could also be discussed where students will mention all the existing interactions in that daily situation. They usually mention forces just in one direction; the teacher should make sure that they include the floor and earth as part of the system, etc. More systems, such as ice ski, water ski, can be analyzed in order to ensure understanding.

Formulating inquiry questions: The teacher could encourage the students to raise questions regarding the possible parameters influencing friction and to formulate corresponding hypotheses. For example, does increasing the weight of the object increase friction? What effect will have on an object's motion if we add a cushio or air? Do different angles affect the forces acting on an object?

Motivating questions are very important in terms of meaningful learning and should not be overlooked. These questions can be raised in the pre-visit phase and be discussed and answered during the post-visit phase.

Then, the teacher can focus the class' attention on those hypotheses that will be tested by the air-track exhibit.

We also suggest that teachers may choose one of the following questions to discuss during the pre-visit phase:

- Does changing the area of the surface of the object change the coefficient/force of friction?
- What makes things stand up/stay put and not fall down?
- How don't we fall down every time that we try to walk?
- Why is it more difficult to ski or roller blade than to walk?
- Why wet road or icy road is more slippery than dry road?
- What about the structure of our bodies? How does our body use "lubricants" in order to reduce friction?
- How do hovercrafts work?
- How do Mag-lev trains work?

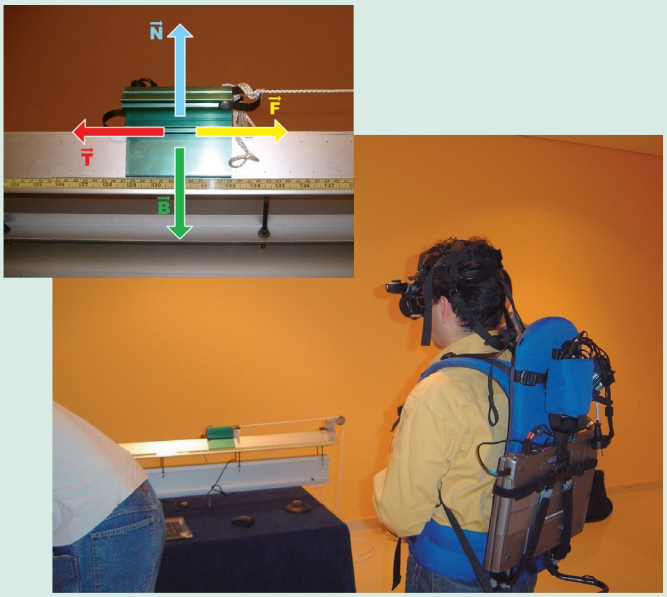


Figure 57: The Airtrack exhibit showing visual augmentations.

Finally, the students design the experiments to be conducted at the science center.

Planning the visit to the science museum: The teacher in cooperation with the science museum staff organizes the visit to the Eugenides Foundation. The teacher will need to set dates and activities for the students to come. The teacher will also upload the material she wants to communicate on the CONNECT platform. She would also need to select the ways different factors will be visualised. Additionally, the teacher needs to arrange the groups of students to visit and those to stay in the remote classroom. The visiting students should be informed of time limits, and self-regulate their procedures during the visit.

The students can view the overall exhibition, a video of the wing and other surrounding exhibits, in order to reduce "the novelty effect". If possible, students will be provided with an introduction to the AR headset, in order to allow them to explore its functionality.

Evaluation Questionnaires: A diagnostic assessment tool was administrated to identify students' previous knowledge and misconceptions as well as a questionnaire regarding their attitude against science.

Visit Phase

During the visit, the visiting student group has a list of setups/experiments in their hands that they perform at the actual exhibit and then checking the list of predictions of their classmates.

The visit phase for this exhibit provides several Educational Activities. Teachers should by no means include all the suggested ones. The teachers/students are to decide which educational activities to use, according to the particular interests and needs of students. A logical sequence of educational activities (3 at most) will be recommended. We believe that the first two activities are most important from the point of view of getting the maximal possible value of the augmented exhibit. Additional help for the planning of the visit will be offered during the teachers' workshop.

Considering the specific Airtrack exhibit, the cart on the airtrack can be moved indirectly by a number of weights pulling on a rope attached to the cart. The number of weights can be changed by the student. When adding a real weight the student has to inform the AR system by adjusting the values through the entries in the 'Control' sub-menu. To add a weight on the rope, for example, the student has select 'Rope weight +' from the Control sub-menu. The virtual representation of the number of weights changes accordingly. Also weights can be added to the glider itself and the air track can be tilted at predefined angles. Eventually the airflow can be switched on or off so that an air stream passes through the track through tiny holes. The 'Control' sub-menu also contains entries to notify the AR system about these changes. As the number of weights changes, a graph (e.g. F vs. T) can be updated to show the relation between the two forces.

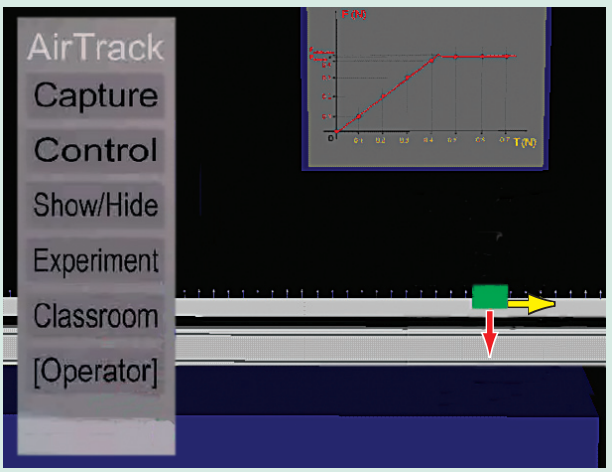


Figure 58: A snapshot of the Airtrack AR view

At the end of the visit, make sure that the students understood all the accessories/parts of the exhibit and how they work. The visiting students should actually be able to teach others (students in class, friends, parents).

Potentially, not all students visiting the museum/science centre need to be involved in the same activity. When one group is busy with the augmented exhibit the rest could be visiting other exhibits. Furthermore, the teacher could suggest a list of potential topics that the students might be interested in following-up. Different groups carry out different activities at the augmented exhibit (air track) and the different results will be presented in class during post-visit activities in a final "Friction session".

Experimental Educational Activities: A class will visit the science centre. Groups of students will take turns in interacting with the exhibit. Each one will try a different educational activity. Each trial will last approximately 45 minutes. After the activity they will answer formal or informal questionnaires regarding technology usability and motivation.

1st Educational Activity: Quantitative Measurement of Friction: Static vs. Kinetic Friction

Objectives: Understanding the forces balance acting on an immobile and mobile mass. Understanding the concepts static friction and kinetic friction.

- A mass is at rest on a surface. The forces exercised on it are vertical on the contact surface: Weight B and Vertical Resistance N. Total Force=0. The student visualizes them through the AR system.
- When acting with a horizontal force F an opposite force T is also acting on the contact surface and opposes the move of the mass towards the direction of F. T is called "static friction". The student visualizes these new forces (through different colour vectors) acting on the mass, while the net result remains the same: the mass remains immobile.
- When F becomes greater than the value that the static friction can take in this particular experiment, then the mass will start moving in the direction of F while the force T that is exercised now is called "kinetic friction" (and in fact is somewhat smaller than the maximum static friction).
- Students should be focused on the moment that the cart starts to move and try to answer the question "what causes the cart to move?" Their answers can be later connected to the perceptions of Aristotle versus those of Newton and Galileo.

Throughout the experiment the data will be stored in tables, for instance F vs. T, etc, in order to create graphs later in the class or to visualize them simultaneously with the experiment, through AR.

2th Educational Activity: Investigate the Effects of the Nature of Surfaces (roughness) on Friction



Objective: Understanding that the microscopic structure of the surface is responsible for its roughness. This roughness affects friction, and is mathematically represented by μ in the law of friction that was previously deduced.

- Make sure the airtrack is in horizontal position.
- Exercise a horizontal force and measure all forces, as the mass starts moving. Save measurements in a table.
- Turn the airflow on and then measure again T. It is zero!

To see the phenomenon of friction in the microscopic level:

- Turn off the airflow and "zoom" in to the contact surfaces to see that they seem smooth but in reality they are not.
- Then "zoom" in again, when the airflow is on and see how the contact surfaces "smoothen" up.

3d Educational Activity: The relations between mass and friction

Objective: Deduce the Law of Friction: The properties of the surfaces in contact μ and the vertical force N pushing the surfaces together determine the generated frictional force T.

- Make sure the airtrack is in horizontal position.
- Exercise a horizontal force F and measure T (and the vertical forces B, N) as the mass starts moving. Save measurements in table.
- When doubling the mass (thus doubling B and N), find out what happens to the forces F and T in order for it to keep moving with constant velocity (they are doubled). In fact, the latter (F, T) are proportional to the former (B, N). Save the measurements in table.
- Try out different mass values and measure the forces applied. Save the measurements, notice the same proportionality.

Thus, the students have in fact deduced the law of friction: $T=\mu N$.

4d Educational Activity: Testing Possible Dependence of Friction on Other Properties

Objective: Deducing that friction does not depend on the moving speed (up to a certain limit) or on the area of the contact surfaces.

- Make sure the airtrack is in horizontal position.
- Exercise a horizontal force and measure T and F, as the mass starts moving (and measuring B and N as well). Save



measurements in a table.

- Make the same mass to move faster but in constant speed with respect to the surface. Notice the same F Save measurements to table.

- The same mass is now positioned on the surface with another side, larger or smaller than the previous one. When moving with constant speed, measure the same F. Save measurements to table.

Thus, the students conclude that the law of friction has the simple proportionality form that they measured earlier, without this depending on the moving speed (up to a certain limit) or on the area of the contact surfaces.

5th Educational Activity: Simulate Cars Breaking/Crashing, with Two Carts on the AirTrack

Objective: Understanding the influence of friction on stopping distance. Understanding real life situations

In this experiment the cart's stopping distances, for the same initial speed and different surfaces, will be compared. Students should deduce that the stopping distance is inversely proportional to the magnitude of friction. For this activity, the students could have a pre-visit activity that predicts how far the mass will travel, in each case. During the visit, students will test these predictions

- Let the students test their predictions for the movement of a cart on the airtrack: when will it stop, or how long will it travel before it stops.
- Turn on the airflow and test the same predictions for different forces/moving speeds.
- Add a second cart and see what force/speed will allow the charts to avoid collision.
- Students will deduce that carts stop sooner without the airflow (on a dry road) than with the airflow (on a wet/icy road).

6th Educational Activity: Investigating Newton's Second Law

Objective: Investigating Newton's second law of motion, which states that acceleration is directly proportional to the force and inversely proportional to the mass.

In this experiment, a cart will be accelerated on the airtrack by applying a force on it.

- The students measure a certain distance on the airtrack (say 40 cm)
- A cart is accelerated by applying a force F=1N.
- The students record the travel time of the cart along the 40cm distance. Save the data (mass of cart m, force F, travel time), in a table.
- The experiment is repeated by applying different forces F (2N, 3N, 4N, etc) while keeping the same mass (cart) m. As above, save the data in a table.
- Then, the experiment is repeated by keeping the same force, but changing the cart's mass (for instance by adding 100 grs each time). Save the data in a table.

Students could realise the proportionalities/inversive proportionalities of the data they recorded by seeing graphs of the measurements they recorded.

7th Educational Activity: Does friction always inhibit motion?

Objective: Stimulating students to use the newly learnt concepts in order to see a positive aspect of friction.

A small fan is connected to the upper side of the cart. The cart and the fan are immobile. Start the air system and see the effects on the cart and the fan (the cart starts to move and the fan starts to rotate).

The students should explain this hypothesis: Friction between the track and cart prevents the cart from moving. However, it is friction between air molecules and the surface of the fan that actually started fan movements. They could also have available a microscopic "zoom" of the different interaction interfaces.



Filling in Evaluation Questionnaire: At the end of the trial, the students will be given questionnaires for evaluating their motivation during the trial and the usability of the technology.

Suggestions for Additional Activities: Find more exhibits in the museum that show objects moving/sliding and/or objects in equilibrium (moving or standing); that demonstrate one or more Newton's laws; that show/involve some kind of forces. Find the connection between these exhibits.

Post-Visit Phase

Reflecting and processing the visit: The teacher could prompt student to answer the questions raised at the previsit activities, giving detailed explanations why predictions were right or wrong. Students could use their measurements during the visit and write a research report or plot graphs that explain their comparisons, e.g. the relation of friction to the pulling force. Students could also find all possible ways that friction applies within the human body (swallowing-saliva, liquid in joints, etc). They could also find out the value of μ for different materials and contact surfaces. They might also write a detailed description about the exhibit in the science museum and what it does.

Students could discuss with the teacher and try to support one or more of the following arguments, with daily life experiences or with data resulting from their experience in the science museum.

- "Friction is an essential force to our daily functioning"
- "Friction is an inhibitory force, it prevents things from moving. It also causes damage to moving things (for example wheels of a car)"
- Galileo's concept of inertia (and Newton's 1st law): "Every object in a state of uniform motion tends to remain in that state of motion unless an external force is applied to it."
- Aristotle's perception: In order to maintain a linear movement in constant velocity, a force should constantly act upon the moving object".

Students together with the teacher could also investigate friction further through the use of lubricants or Teflon. They could combine their knowledge in chemistry to get a deeper understanding of microscopic nature of friction. They can use the AR visualization in order to understand (and explain to others) the use of lubricants as "fillers" and producing a

smooth surface in microscopic terms. They can learn about Teflon as a material with very low coefficient of friction.

Students could also compose a scenario of "One friction-less day". They will have to write a paragraph describing their daily routine in a theoretical friction-less world. This scenario will include biological effects, holding things, walking, driving etc.

They could also visit virtually the exhibit through the CONNECT platform and see research reports from other visitors and compare their results.They could initiate discussions and challenge different beliefs.

Suggestions for Hands-on Activities: Ask students to create a presentation: they should describe the Airtrack exhibir and what they learnt from their interaction with it. What results have mostly surprised them, and why? And which ones happened as they expected them to (and why)? They could connect friction to other physical phenomena and real-life experiences.

Ask students to make a movie: Students could select instances from the video of their visit at the exhibit and in this way they will make a new video that will "walk" their classmates through the exhibit and help them understand the concepts that were tested. In fact, students could write a script along with the video and enrich their presentation with images/material that they found later on the Internet.

An idea would be to also draw the exhibit and the series of experiments they did (for instance use a drawing tool on the school computer if they do not feel like drawing by hand). The students who visited the exhibit could collaborate in preparing this presentation, assigning different roles or/and sharing the effort of presenting. Afterwards, this presentation (together with the classmates' comments/questions/improvements) will be uploaded to the VSTP and/or to the school/science museum sites (if there are many, for instance from classes from different schools or countries, then there could be a selection for the best presentation and a prize, for instance a real visit of the winner class to the science museum).

Filling in Evaluation Questionnaires: The students were given an evaluation exercise to record their learning outcome.

An introduction to Waves, Electromagnetic Spectrum and Sound Mirrors.

Pre Visit Phase

Diagnostic objective: To investigate students' prior knowledge, and identify false beliefs and misconceptions of the students, in order to help them reconstruct their existing conceptions. For example, some common misconceptions regarding the nature of waves, their propagation characteristics and their applications are the following:

- Students believe that all radiation is harmful.
- Students believe that the spectrum of electromagnetic radiation consists of only visible light.
- Students believe that we view all space objects with only an optical telescope.
- Students believe that matter moves along with the waves as the waves move through a medium
- Students imagining sound waves as transverse waves rather than longitudinal pressure waves and cannot distinguish the basic difference between these waves and EM waves
- Students think that sound can travel in space without a medium to travel through
- Students have very little knowledge or confusions regarding the basic real life applications of the radiation coming from the other areas of the electromagnetic spectrum (X-rays, gamma rays, UV, IR, microwaves)

Affective objective: To motivate the students to engage actively, by creating intrinsic motivation and relate the learn-

ing experiences to real life situations. For this reason the new combined wave mechanics Exhibit pathway scenario is ideal because it can provide in simplified manner very useful information regarding the real every day life applications of the electromagnetic spectrum various radiations and information regarding the nature of the acoustic waves.

Cognitive objective: To provide the students with the necessary prior knowledge and to activate this knowledge. In the case of the new wave mechanics educational pathway, part of this knowledge will not be new for the students since it will have already been taught, so the pre-visit activity will act as a refreshment of this knowledge and a summary of its basic concepts.

The classroom activities should directly address the above-mentioned objectives:

Identification of previous knowledge and misconceptions can be done by administration of a diagnostic assessment tool, and through discussions in which the students may externalize and express their alternative beliefs and explanations about propagation of sound, propagation of light and the basic applications of the EM spectrum radiations.

Motivating questions are very important in terms of meaningful learning and should not be overlooked. These questions can be raised in the pre-visit phase and be discussed and answered during the post-visit phase. We also suggest that students (individuals or in small groups) may choose one of the questions and further investigate it during the post-visit phase.

The electromagnetic spectrum, sound waves, the EM wave's propagation theory and the visible light with its basic characteristics are national curriculum topics for primary science in most countries. The existing learning materials can be used for introducing the concept to students. It can be further investigated in post-visit activities, e.g. through simple experiment arrangements in the classroom or at home (in astronomy by observing objects through a simple telescope, using a prism for light diffraction, simple experiments for light reflection or generation of sound waves, etc.)

The Concepts that the Teacher wants to communicate:

- Waves enable us to transmit information (sounds, images) for communication purposes.
- Light is a set of electromagnetic waves produced by the sun? Electromagnetic waves do not need matter to move. To propagate, they rely instead on magnetic and electric fields naturally produced by every object in the universe.
- Visible light is an electromagnetic wave as are radio waves, microwaves, infrared, ultraviolet, X-rays and gamma rays. The human eye can detect only a tiny part of this vast spectrum.
- Sound waves are the result of a mechanical excitation causing pressure variations in the air which has mass and elasticity properties. When air molecules are made to vibrate, they produce a series of compressions and dilations that are propagated until they reach the ear.
- All the radiations of the electromagnetic spectrum have various applications in real life some of which can be of great importance (x-rays in medicine) and others are very frequently met in every day activities (microwaves for heating food, radio waves for cellular phones etc.)

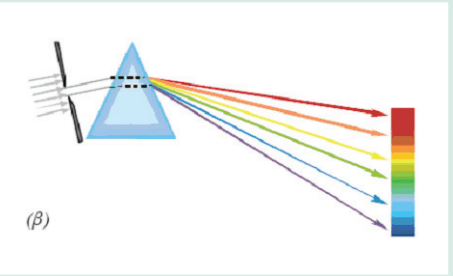
Pre-Visit Activities:

The nature of white light:

The teacher uses a prism and analyses white light in its 7 main monochrome components by setting up a very simple experiment. The teacher will mention the related physical phenomena of the arc of rainbow. The students may refer to their experience from seeing a rainbow and try to explain how this phenomena is taking place (usually although all the students have seen this impressive physical phenomenon they cannot explain it with scientific terms).

Formulating inquiry questions:

The teacher will encourage students to explain the mechanism that generates the 7 monochrome lights when white light passes through a prism. It will also encourage the students to relate this mechanism with the atmosphere mechanism that produces the arc of rainbow.



Question: Why each monochrome light is diffracted with a different angle from the prism?

Students Hypotheses: Each monochrome light ray when propagating through an optical medium is characterized with a wavelength which is unique for this ray. The diffraction angle of each ray is related with its wavelength and the bigger the wavelength of the ray is the smaller the associated diffraction angle.

Possible additional questions:

1. Can the perception of light change when the light passes through a different medium (this question is related with the fact that the frequency which generates the external stimulus for the human eye remains constant for every medium)
2. What is the sequence of the produced seven monochrome lights (red.....violet)? Can this sequence be related with the names of the neighbouring spectral sub-areas UV, IR)?

Then the teacher may focus its analysis to the placement of the white light into the Electromagnetic spectrum and introduce students to the exhibit that will be visited by the classroom. Finally, the students may design the activities to be conducted at Eugenides science centre.

Planning the visit to the museum:

The teacher in cooperation with the students organizes the visit to the Eugenides Foundation where they will experiment with the "Electromagnetic Spectrum" and the parabolic reflectors of the "Communicating at a distance" exhibits.

This activity could include a class visit in the Virtual Science Thematic Park, where the "Electromagnetic Spectrum" and the "Communicating at a distance" exhibits are presented, and information is available about the suggested activities during the visit.

An activity designed to get some familiarity with the AR technology and the relevant AR system to be used during the science centre visit should also be included (even in class).

Visit Phase

a) Description of the 2 exhibits

As mentioned before, the two selected exhibits that were augmented are "Electromagnetic Spectrum" and the "Sound Mirrors" (two parabolic reflectors looking each other at a distance of approximately 20 meters, and used as acoustic devices to present the focusing properties at transmit-receive modes).

The electromagnetic spectrum has the structure shown in Figure 59.

The student uses a joy stick to explore an illustrated representation of the electromagnetic spectrum on a mural. The mural features pictures illustrating the applications of electromagnetic waves – radar, a person talking on a cell phone, someone using an IR remote control, another watching television or listening to the radio, X-rays of the body, etc. – along with related information, such as the frequencies and names of different electromagnetic waves.

The student stands in front of the mural at a control unit equipped with a screen and handle. He uses the handle to point a light beam at the picture of their choice. When the beam lights a picture, the area of the spectrum corresponding to the type of electromagnetic radiation lights up and the radiation's specifications are displayed on the screen. There are 7 independent frequency spectral bands selected by the student. These 7 bands are the following:

a) Radio waves

b) Microwaves

c) Infrared radiation

d) Visible light

e) Ultraviolet radiation

f) X-rays

g) γ-rays



Figure 59: Electromagnetic spectrum exhibit

Nearby the spectrum exhibit there is the exhibit "Sound Mirror"

All hard, smooth surfaces reflect sound waves. A concave surface – a parabola or ellipse – will reflect sound frequencies whose wavelengths are shorter than its dimensions, which is the case for speech, and concentrate them at its focal point. This is the principle that enables two people facing parabolic-shaped disks to hold a conversation at a distance even if they are speaking softly.



Figure 60: One of the two parabolic reflectors of the exhibit "Sound Mirrors"

b) Augmented Reality Features-Visiting pathway

It should be noticed that one of the main innovations of the new introduced scenario was the combination of two museum exhibits and the implementation of a visiting pathway. The idea of the visiting pathway was from the beginning one of the project's main visions and it was made feasible exactly by the end of the project's lifetime with the Greek phase B final run. So during the second run of CONNECT implementations in EF, students had to go through a pathway starting from the Electromagnetic Spectrum Exhibit (1) and then moving to the area between the two Sound Mirrors (2) where the sound waves were simulated as oscillations between the air molecules. In the same place there is an area (3) from where the rest of the class was seeing what the students performing the "pathway" were seeing through the AR system, through a big screen.

In the context of this pathway two independent AR features were envisaged, each one associated with the 2 above mentioned exhibits:

1st feature-EM spectrum

Reference to the above figure the student starts its visit by standing in position 1 of the visiting pathway where with the help of the museums stuff he/she wears the AR unit. The basic functionality of the augmented exhibit is to show the generation of radiation for each spectral region as described below by suing a pre-recorded video, text or image for each independent 7 cases and appearing when the student wearing the AR unit looks to a specific spectral region (grey round images of figure 62) on the surface of the Electromagnetic spectrum (alternatively each spectral region could be selected through the wireless mouse the user has)

So, when the student selects one of the 7 spectral bands with the procedure described above this is sensed by the AR sys-

tem. Then after the system recognizes which band is selected, the pre-selected material that the teacher has uploaded on the VSTP from the previous day (a video, or an image, or a combination of an image and an explanatory text) is projected to the user /observer until he/she selects another area of the exhibit corresponding to a different spectral band. At this point the material projected to the user changes again to a different image, video or text that refers to the new band.

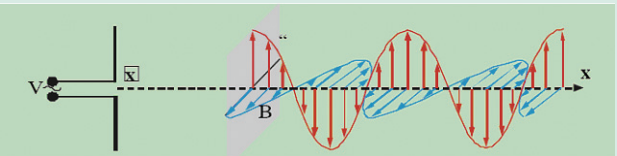


Figure 61: The theoretical representation of a traveling transverse EM wave

When the student visits the exhibit and begins it augmented reality tour thought the visiting pathway, the first thing is to introduce him to the nature of EM waves by playing to him a video of a traveling EM wave. He/she actually seem a moving wave as in the following picture:

This is very important because it directly introduces the visitor to the nature of the electromagnetic waves and gives the opportunity to the teacher to discuss with him/her and the rest of his fellow students observing the experiment the basic parameters of a traveling EM wave and some of the basic misconceptions related with this (e.g. the EM wave is a transverse wave). At the same time the group of students which are also visiting the same exhibit can see what the AR user sees because the video image of the see-through AR glasses is streamed to a nearby video wall and therefore everybody can closely follow the procedure. Then the student may freely explore the other bands of the EM spectrum and focus to the related material (video, images, text), while at the same time he will be discussing with the teacher what he/she is seeing and what the related material refers to.

The reader may observe the EM exhibit and its different spectrum subareas with the additional material. The first introductory wave traveling video appears as the user starts its visit in front of the control panel. Then there are different photographs or videos corresponding to different spectral areas. For example in the radio waves spectrum area (1st area from the right in the above picture) a photo showing radio-telescopes appears in front of the user. Nearby, in the microwaves area there is another photo presenting microwaves antennas used for the mobile telephony. In the X-ray area of the spectrum an X-ray of a hand appears taken for medical reasons, while exactly nearby (in the left side of the picture) in the gamma area of the spectrum a video explaining the phenomenon of the generation of gamma rays is projected to the AR user. Finally in the IR area there are two videos showing the IR image of a woman taking a hot bath and using a hair dryer. Each of the above material (photo or video) is also accompanied with a short explanatory text that each time appears in front of the EM control panel (in the place where the traveling wave introductory video is shown).



Figure 62: Photograph of the EM exhibit enhanced with typical augmented content for each spectral sub area

All the above content displayed to the user, is typical content for the formation of a visiting scenario to the EM exhibit and of course it can change according to the pedagogical needs/goals of the visit. The aim of this content is to stimulate the interest of the student and enhance the relation that is being made between each spectral band with its theoretical back round or its real every day life applications. The teachers can very easily upload new material on the VSTP prior to the new visit and the scenario could be re-structured. This is one of the main advantages of the wave mechanics educational pathway, since it is the best case for exploring the capabilities of connecting a formal learning environment with an informal one and exploiting free choice learning.

2nd feature-Visualization of a parabolic reflector outgoing rays

As already mentioned above, nearby the Electromagnetic spectrum there are two parabolic reflectors. Since the two reflectors are at large distance (25 m) the visualization of only one parabolic reflector is implemented (the one nearby the EM screen).

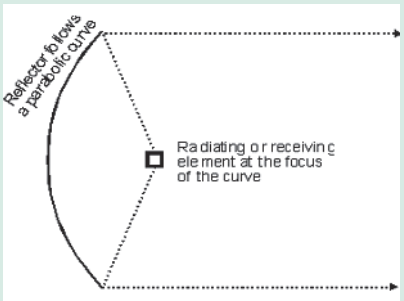


Figure 63: Outgoing Rays of reflector

The user from its current position in front of the EM spectrum and after having finished its exploration of this exhibit, can turn his head and look towards the parabolic reflector or alternatively the user may walk from area 1 and stand between the two reflectors (area 2 of the visiting pathway) facing the one where the augmented material is projected. At this point it can see the animation of the acoustic waves traveling from the one reflector to the other. The visualization of the acoustic waves is done in three separate ways/modes of operation: a) either showing rays starting from focus and after a reflection running parallel to the reflector's axis. b) Alternatively one can see small oscillating spheres shorting out from focus and after a reflection running parallel to reflector axis and c) the user can also see the acoustic waves as plains traveling in space towards the other reflector.

These three separate modes of visualizing the acoustic wave propagating phenomenon are selected in order to enhance the student's understanding of the phenomenon and raise the misconceptions that are strongly related with the nature of propagation. The three different visualization modes can be directly selected from the user with a wireless mouse.

When the student has finished it exploration of the augmented parabolic reflector and the acoustic waves either by doing this from area 1 or by moving into the area between the two reflectors (this is more exciting because the student in reality moves inside the field of the acoustic waves and sees the waves traveling towards him) then its visiting pathway is terminated and the whole procedure is repeated with another student who will perform the same steps. The next student can of course explore with more detail a different sub-area of the EM spectrum and discuss with his/her teacher and fellow students his/her particular interest for this area.

Experimental Set-Ups during Museum Visit

General:

1. The visiting students should be well prepared for the visit. During the pre-visit phase the teacher should have described the exhibit setups and asked the students in the class to make guesses about the experience proposed in the museum. During the visit, the visiting student group has a list of activities in their hands that they could perform at the actual exhibit and then checking the list of predictions of their classmates. The visiting students should be aware of time limits, and self-regulate their proceeding during the visit.

2. The visit-phase should by no mean include all the suggested here set ups. The teachers/students are to decide which set-ups to use and with what sequence, according to the particular interests and needs of students. Consulting with the teacher a logical sequence of set-ups will be recommended. Additional help for the planning of the visit will be offered during the teachers' pre-visit to the exhibit for the definition of the visiting details. The visiting pathway shown in figure 3 is a suggestion and teachers could change this according to their particular planning of the visit.

3. Potentially, not all students visiting the science centre need to be involved in the same activity. When one group is busy with the augmented exhibit the rest could be visiting other related exhibits that could eventually be located in the same area (there are several other exhibits related with light and sound in the same floor with the EM and the parabolic reflector exhibits). Furthermore, the teacher could suggest a list of potential topics that the students might be interested in following-up.

Post-Visit Phase

Some Suggestions for After-Visit Activities:

- Reflecting and processing the visit: Make sure that the students understood all the accessories/parts of the exhibit

and how they work. The visiting students should actually be able to teach others (students in class, friends, and parents). They can write a detailed description about the two connected exhibits and what they do.

- All students should try to answer the questions raised at the pre-visit activities, giving detailed explanations why predictions were right or wrong.
- Visit virtually the exhibits through the VSTP and come up with a different way of exploring (test students' exploration skills). Suggest if more material could be added and which type of material (more photos, more videos and what kind)? Discuss whether the existing material was adequate and gave them the opportunity to explore better the exhibit.
- Find more exhibits in the museum that are related to electromagnetic and sound waves. The teacher during the pre-visit phase will encourage students to visit the following exhibits: Sound waves, Sound spectrum, play with light.
- Find the connection between these exhibits.
- Presentations: Describe, rather than name all the exhibits that the students have visited. What did they learn from their experimentation with each exhibit? What results have mostly surprised them, and why? And which ones happened as they expected them to (and why)? Connect the science principles that these exhibits investigate, to physical phenomena and real-life experiences.
- Make a movie: Students could select instances from the recorder video of their visit at the exhibit and in this way they will make a new video that will "walk" their classmates through the exhibit and help them understand the concepts that were tested. In fact, students could write a script along with the video and enrich their presentation with images/text/videos that they found later on the Internet. The students who visited the exhibit could collaborate in preparing this presentation, assigning different roles or/and sharing the effort of presenting. Afterwards, this presentation (together with the classmates' comments/questions/improvements) will be uploaded to the VSTP and be used as a guide of good practise for future visitors that will visit the specific pathway.
- Finally the students using their visit experience and their evaluation of the scenario they were introduced (quality and clarity of the offered material), could develop there own scenario by using different images videos and text that will be directly uploaded to the VSTP. By this way the next visitors will have a chance to choose from a pool of scenarios developed by other teachers or students from the same or different schools that visited the same exhibits.

Practicing argumentation Skills:

The students discussed and try to support one or more of their activity, with daily life experiences (e.g the use of X-rays in medicine, arc of rainbow)

Learning Environment variables

Learning Objectives

The main learning objective is to improve the students' understanding of the concept of the electromagnetic and sound waves and how they are related to daily phenomena. The students will acquire an understanding of the following concepts:

- Propagation of the sound
- Propagation of electromagnetic waves

- Light is a set of electromagnetic waves
- Light propagates through mediums following specific laws (laws of reflection and diffraction, Snell's law)
- The EM spectrum consists of different types of radiations with different characteristics and different applications
- Sound waves are different from EM waves

The learner

Grade: C' Lyceum, Students' Age: 17-18 years, Course: Physics.

Relation with Local curriculum: According to the National Curriculum, the whole experience will be related to the program of the third grade of lyceum. Whereas the suggested educational scenario has been developed for the third grade of lyceum that will participate in the final run of the project, the concept of electromagnetic and sound waves offer the opportunity for the development of a multi-layered scenario that will be appropriate for different age groups. A perfect example for an alternative scenario is for the lesson of astronomy taught in the same or younger age groups. The teacher may upload to the system different photos of sky objects photographed with telescopes in different spectral area, and the student while visiting the EM exhibit can relate each photograph of the sky object with the specific radiation of the EM spectrum sub-area that was used for its capturing.

Pre requirements:

Content requirements:

The students should understand:

- The difference between acoustic waves and EM waves
- The mechanism through which acoustic waves and EM waves propagate
- The different areas of the EM spectrum and the basic every day applications of each radiation
- The nature of light and the basic laws of light reflection and diffraction

Skills requirements:

- The procedure of selecting a specific area of the Spectrum requires increased concentration of the student during the visiting phase. Therefore the student must be able to comprehend clearly the system's functionalities and the way each different area of the EM spectrum can be selected.
- The student must be aware the fundamental propagating mechanism of the acoustic waves in order to be able to understand the animation that the system is projecting when the parabolic reflector is observed.
- The student must have a good primary knowledge of the EM spectrum and of its consistency of the various sub-areas in order to be able to freely chose the area of its interest and not lose time wandering in various areas trying to understand which area is re-presenting what. This would also help to decrease the visit time/student and give the opportunity to more students to have the AR experience

The use of AR

- Visualization of photos and videos from real life examples related to all different radiations of the electromagnetic spectrum.

- Visualization of photos and videos explaining the theoretical back round for the generation of the different radiations of the electromagnetic spectrum.
- Visualization of the molecules of the air and the way they move between the two parabolic reflectors during the production of an acoustic wave.
- Visualization of the plain waves during the production of an acoustic wave when a student is whispering to the centre of one parabolic reflector.
- Visualization of the acoustic wave rays travelling from the one reflector to the other
- The experiments will be videotaped, as a standard procedure.

Basic Scenario Principles

(a) Personalization:

High level of personalization is foreseen. Provide different opportunities for choice (photos and videos related to Radio waves, Microwaves, Infrared radiation, Visible light, Ultraviolet radiation, X-rays, γ-rays).

Motivating questions relate the various activities to real-life situation, and to various fields of interests. For example the use of cellular phones excite the interest of students of this age who use them in their everyday activities, while images of planets like the moon photographed with different telescopes can also stimulus high interest.

(b) Interactivity:

Medium level of interactivity is foreseen between students and the exhibit + AR system during the visit. The student will interact with the system in order to choose the area of the EM spectrum he/she wants to learn more about and also he /she will interact with the system in order to explore the various ways that the system offers in order to visualize the travelling acoustic waves from the one parabolic reflector to the other.

(c) Collaboration:

Collective work is recommended through all phases of the scenario. As it has already been mentioned the rest of the students will be able to see through a video wall what the AR user sees and discuss at the same time with him/her and their teacher his/her experience.

(d) Perceived choice and control:

The inquiry process provides students with free choice oppurtunities in choosing the inqury question designing and performing the experiment. The scenario is designed in such a way that each student may select and emphasize in a different area of the EM spectrum for which he/she has an increased interest.

(e) Authenticity:

All motivating questions are connected to real life situation (e.g video of someone taking a bath or using a hair dryer or a cellular phone) as much as possible. Many post-visit activities address this goal.

(f) Learning strategies:

Visualization through AR in order to promote profound understanding of difficult/complex concepts

Developing inquiry skills

Developing argumentation skills

Some post-visit activities promote creativity such as making a movie, writing an imaginary scenario etc.

Needed resources and tools

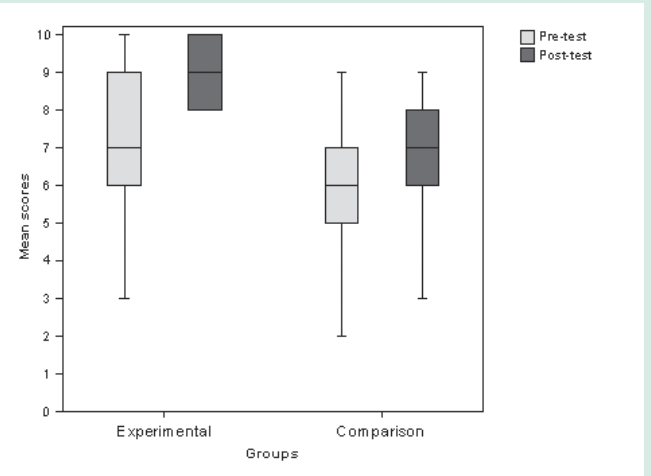
1. Need to develop specific knowledge item in order to evaluate each class performance prior and after the visit to the AR exhibit for both control and experimental groups. This knowledge item must be coherent with the school curricula and cover the theory already taught in the classroom. The knowledge item must also be able to cross examine with specific questions the theory taught in the classroom with the relevant information provided from the actual visit to the science centre and the 2 combined targeted AR exhibits.
2. Prior to the Final Run a mixed team of the teachers and the museum stuff to conduct all the set-ups with the Electromagnetic Spectrum exhibit + AR system+ parabolic reflector and record the time that each set-up will take to execute. Something like 25% should be added to the recorded time to reach a guess about the time that the students will need to do the same. Then, a logical duration for every set-up can be recommended and ask the students to regulate it, so that they can benefit maximally from the visit to the exhibit. Finally based on the above, an estimation of how many students could actually have the AR experience could be made.
3. Defining the content needed for the VSTP (videos, images, explanatory text) that has to be included by the visiting teachers in the context of Electromagnetic Spectrum and the parabolic reflectors exhibits scenarios.
4. The pedagogical team can design a model scenario and store in the VSTP. This scenario can act as the reference scenario for the teachers in order to help them create their own during the pre-visit phase.

Airtrack Results and Discussion

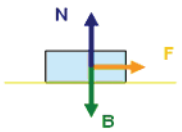
Knowledge Results

A comparison between pre- and post-test in each group revealed that both groups learnt significantly.

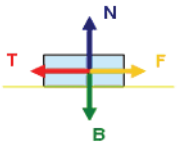
Supporting Conceptual Change in Science Teaching: There are several studies which refer to students' alternative ideas, about the concept of friction (Stead & Osborne, 1980; Osborne, Schollum & Hill, 1981; Stead & Osborne, 1981, Ravanis et al. 2004, Tsagliotis, 2006). The data from all surveys demonstrate that the majority of the students believe that "Friction does not occur if there is no movement between surfaces" and that "Friction is a constant force". The current survey verifies these results. 73% of the students that participated to the CONNECT survey have selected the graph on the left as the correct answer to Question 2 in the pre-test as they believe that there is no friction as there in no motion. Their ideas changed dramatically after the AR demonstration. 91% of the students who participated to the experimental group answered correctly the same question in the post-test.



2. Pull the object horizontally by means of a string. The object remains immobile. Which forces are acting on the object now?

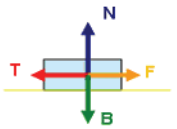


pre-test: 73%

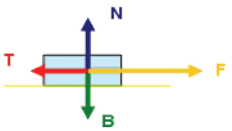


post-test: 91%

4. Which of the following drawings shows the correct forces acting on the object when it is accelerating to the right?



pre-test: 81%



post-test: 92%

5. An object was at rest. We increased the pulling force until the object starts to move. Which of the following diagrams represents the friction against the pulling force?



pre-test: 45%



post-test: 78%

The results from Questions 4 and 5 demonstrate that the initial belief that friction is a constant force changing dramatically after the AR demonstration.

Waves Results and Discussion

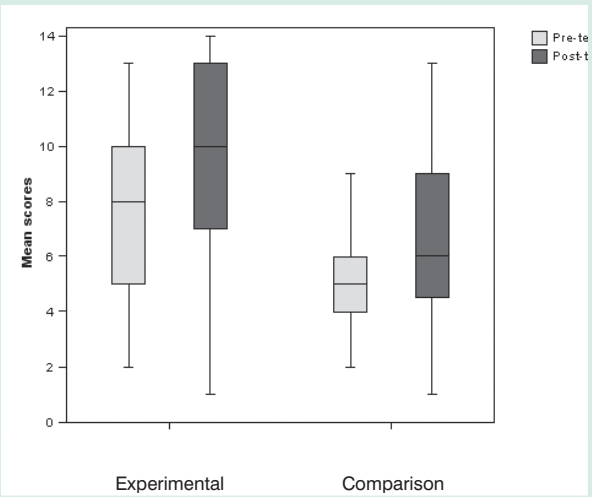
Understanding wave physics is important for making sense of physical optics, quantum mechanics, and electromagnetic radiation. Previous research has shown that students have fundamental difficulties with some of the basic concepts of wave physics (L.C. McDermott and E.F. Redish, 1997).

The basic students' misconceptions about waves are the following:

- Students believe that all radiation is harmful.
- Students believe that the spectrum of electromagnetic radiation consists of only visible light.
- Students believe that we view all space objects with only an optical telescope.
- Students believe that matter moves along with the waves as the waves move through a medium
- Students imagining sound waves as transverse waves rather than longitudinal pressure waves
- Students thinking that sound can travel in space without a medium to travel through.

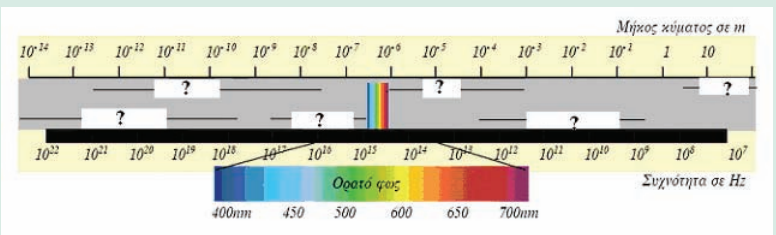
The scenario that was implemented was designed to support the change of these ideas through the visualization of specific parameters and phenomena. The students of the Comparison Group follow the same scenario but they have not used the AR system.

In both groups, the students learnt significantly during the proposed activity. However, the learning effect is higher in the Experimental group. This is probably due to the setting of the museum and the explanations given on the different labels next to the exhibits. Still there are cases which demonstrate the potential of the AR system as an educational tool.

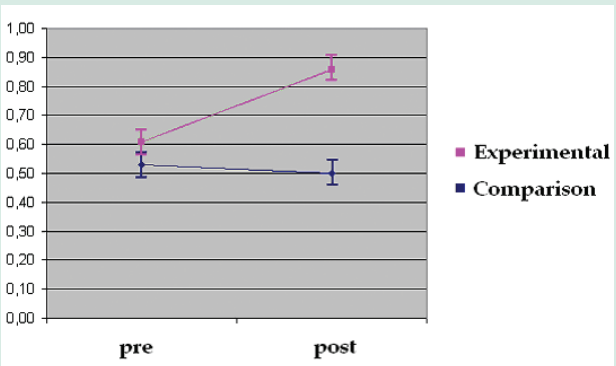


Between group comparison revealed significantly higher achievement scores in the pre-test of the experimental group ($p < 0.005$) and the post-test ($p = 0.001$).

More specifically during the test students had to assign the different kinds of E/M radiation to the specific areas of the E/M spectrum. It has to be noted that the specific graph - although it is taken from the school book – could create further problems to the students as it is mixing logarithmic with normal scale (for the visible area of the spectrum) for the wavelength of the radiation. The students of the comparison group have increased their performance by 10% while the students participating to the experimental group have increased their performance by 21%.



Additionally students that participated to the experimental group are capable to discriminate between the ultraviolet and infrared radiation while students of the comparison group cannot perform this task successfully even after the visit to the museum.



Students were also asked to identify the way the E/M field varies in time in the case that an Electromagnetic wave is emitted from a point source. The results (see figure above) demonstrate that the students that participated to the CONNECT pathway using the AR system are performing significantly better than the students of the comparison group. It has to be notes that the E/M fields variation is presented both in their school book but also on the label next to the exhibit. The AR system though simulates the E/M production and its propagation in space and time through a high quality simulation while at the same time the main parameters of an E/M wave are presented in the students view. This result is considered as of major importance as it demonstrates that the students were capable to understand the difference between transverse and longitudinal waves.



5. Evaluation conclusions and recommentations

5.1 Evaluation Approach and Results

The central question of the CONNECT evaluation was:

> ***Under what conditions, if any, does the advanced technology (AR, CVD, Internet) add value to science learning within the context of a school-museum program? In other words, under what conditions will an augmented field trip experience be better than a similar field trip experience without the advanced technology linking classrooms and science centres?***

To answer this question, we compared students who engaged with the AR versus students who did not, at each interactive exhibit. Experimental and comparison groups of students were studied at each of the 4 museums. Students from both groups were exposed to pre-visit, visit and post-visit activities, focusing on the particular interactive science exhibit. The only difference between these groups was that the experimental group used the Augmented Reality (AR), while the comparison groups did not. A variety of student outcomes were measured for both groups (using relevant quantitative and qualitative measures): student knowledge (specific site-specific knowledge tests), student intrinsic motivation (IMI Inventory), student attitude (semantic differential), student perceptions (interviews), student explanations (analysis of open questions) and student curiosity (student question-asking). Teacher perceptions (using a teacher questionnaire) were also measured for both groups. Below is a summary of the evaluation results:

1. Hot Air Balloon. The students in the experimental group (N=308) performed significantly better on the knowledge test than students in the comparison group (N=97). In particular, the former students were much better able to understand and explain phenomena relating to temperature

(e.g., increased temperature results from the movement of molecules) than the latter students. While no difference between the two groups was found on intrinsic motivation, there was a significant effect of the AR condition on student attitudes relating to the "Interactivity" of the AR experience. The teachers felt that the AR visit achieved their learning objectives, especially those relating to "learning to make observations." Some of the teachers were sceptical at first about the cognitive learning of their students, but they eventually saw the positive results of the knowledge tests. The "hands-on" quality of the visit was important for teachers. All the teachers felt that the new AR-technology provides specific advantages for learning and teaching, especially in the area of "scientific visualization."

2. Air Track. Evaluation efforts in Athens focused on the Air Track(N=119) in the Test Run B. In the former, students in the experimental group significantly outperformed students in the comparison group on the knowledge test. In specific, the AR visualizations were shown to help students in the experimental group to correct the common misconceptions that "Friction does not occur if there is no movement between surfaces" and "Friction is a constant force." Regarding motivation, students in the experimental group showed significantly higher scores for Interest and Enjoyment; they also gave the AR-enhanced exhibit a higher value on "Usefulness" and "Value" than the comparison students. The subscale of "Effort/Importance" did not differ between two groups. Also, students in the experimental had significantly more positive attitudes regarding emotions ("Affective"), compared with the other group, while there were no significant differences in student attitudes regarding "Understanding" and "Interaction." It is also interesting to note that twice as many students in the experimental group asked questions than in the comparison group and over 30% of these students asked advanced questions (e.g., "Would the glider move and stop, if we turn on and off the airflow?" The students were particularly intrigued with the "dynamic visual graphics" of the AR technology The teachers were also very positive about the AR technology. As one teacher said: "It helps in the learning process."

3. "Pathway on wave mechanics." Also in Athens, evaluation involved Wave Mechanics (N=71) in Final Run B. Students in the experimental group performed better than the comparison students on the knowledge test. For example, they showed they better understood the electromagnetic spectrum and were better able to distinguish between transverse and longitudinal waves; also, they were able to discriminate between ultraviolet and infrared radiation while students in the comparison group could not. Regarding motivation, the experimental students had significantly higher scores for "Interest/Enjoyment" and "Value/Usefulness" than did the comparison group. Regarding student attitudes, only the factor "Interaction" differed, to the advantage of the experimental group.

4. Aerofoil. In Bristol, there was no difference between the experimental group (N=38) and the comparison group (N=31) on the knowledge test. We believe this result is at least partly the result of the fact that the comparison group also engaged in experimental measurements. We also have evidence of a "novelty effect," in which the experimental students were more interested in the AR technology than in the phenomenon demonstrated. We found significant differences in student motivation, in favour of the experimental group; these students enjoyed the Aerofoil activity more, had a higher interest in the activity and put more effort into it than students in the comparison group; also the perceived importance of the activity was scored higher in the experimental group. Students in the experimental group showed a significantly higher value for attitudes relating to positive emotions ("Affect"); there were no differences regarding "Understanding" and "Interaction" attitudes. Student interviews revealed important insights; for example, students claimed that the AR helped them take an interest in and focus on the relevant phenomenon that they had ignored in classroom lessons. An in-depth analysis of the teacher questionnaires shows that their instructional goals combine cognitive and affective objectives, i.e., student knowledge, student investigation skills, and student attitudes/interest. According to the teachers, the AR effectively develops all of them. They also mentioned the "costs" of this technology, particularly the teacher time needed to learn how to use the system and in adjusting the scenarios. As a result, several teachers suggested more "teacher-friendly" and "student-friendly" materials (e.g., good, pre-designed scenarios).

5. Biotube. Students in the experimental group (N=43) significantly outperformed students in the comparison group (N=38) the knowledge test, in terms of subject matter, factual inquiry and inquiry skills (e.g., interpreting graphs and reasoning skills). Experimental group students also gave significantly higher scores to "Interest/Enjoyment" and "Competence" than the comparison group; this demonstrates that the students who interacted with the AR had higher interest, enjoyment and perceived competency while doing the activity than students who interacted with the same exhibit but without the AR. In terms of attitudes, students who used the AR-technology showed a higher score on the "Affect" and "Understanding" items, i.e., they exhibited more positive emotions and felt they learned more during by the activity than did the comparison group.

There seems to have been a gender effect regarding "Understanding" in favour of the girls, i.e., they appeared to have more positive "learning-oriented" attitudes than the boys. Surprisingly, there was a drop on the "Interaction" attitudes from pre-test to post-test in both groups; perhaps this result is due to the abstract nature of the interaction in the

Biotube exhibit and the accompanying AR (i.e., focusing on molecules of oxygen and carbon dioxide). A striking result in favour of the experimental group was that they wrote much better explanations on the open-ended test items. Specifically, they wrote more correct and more complex explanations (more phenomenological and less descriptive/ physical) than students in the control group.

The above findings can be summarized in the following table:

EXHIBIT/ SITE	KNOWLEDGE TEST	MOTIVATION (IMI)	ATTITUDES (SD)	Qualitative Measures
Hot Air Balloon (FI)	↑	–	↑	Teacher questionnaires
Airtrack (GR)	↑	↑	↑	Student Question-Asking; Teacher Questionnaires
Electromagnetic Waves (GR)	↑	↑	↑	Student Question-Asking; Teacher Questionnaires
Aerofoil (UK)	–	↑	↑	Student Interviews, - Question-Asking
Biotube (SE)	↑	↑	↑	Student Explanations

Table 2. Summary of Report Results from the Science Centre Sites. The arrows represent statistically significant differences between experimental and comparison groups, for the various outcomes, in the respective reports.

Based on the above summary from the 4 sites, the evidence is strong that the AR intervention, used within the context of the CONNECT project, produced significant effects on student outcomes, as well as teacher satisfaction. The fundamental question which arises from these results is: "Under what conditions did this technology make a difference?"

In discussing this question, based on the evaluation findings reported above, we can conclude that these conditions are connected to four related domains: (1) the AR technology, graphics and scenarios, (2) curriculum integration, (3) the teacher's role and perspective and (3) the student experience of the AR. These conditions are discussed below and they are summarized in Table 3.

The following conditions were identified as enhancing or retarding effective use of AR, during the CONNECT Project and it evaluation in the four sites. Each binary pair of conditions can be seen as a continuum between two polar points.

There are several conclusions of the evaluation:

Domain	Conditions which enhance effective use	Conditions which retard effective use
1. AR Technology	1.1 User friendly	Not user friendly
CVD	1.2 User friendly	Not user friendly
AR graphics	1.3 Scientifically valid	Not scientifically valid
	1.4 "Makes the invisible visible" in a clear way	Does not "make the invisible visible" in a clear way
	1.5 Connected to exhibit sensors	Not connected to exhibit sensors
Scenarios	1.6 Follow scenario principles	Do not follow scenario principles
	1.7 Easy to use	Not easy to use
2. Curriculum Integration	2.1 Topic of AR and exhibit fits well into the science curriculum	Topic of AR and exhibit does not fit well into the science curriculum
	2.2 The scenario and activities are well-positioned within the curriculum	The scenario and activities are well-positioned within the curriculum
3. Teacher's Role	3.1 Teachers given sufficient time and support to learn about the system	2.1 Teachers not given sufficient time and support to learn about the system
	3.2 Teacher ownership present	2.2 No teacher ownership present
	3.3 Teacher provides students with appropriate pre-visit and post-visit activities	2.3 Teacher does not provides students with appropriate pre-visit and post-visit activities
4. Student Experience	4.1 Students given sufficient overview of AR and topic in pre-visit activities	Students given insufficient overview of AR and topic in pre-visit activities
	4.2 Students make measurements and conduct experiments during their visit	Students do not make measurements and conduct experiments during their visit
	4.3 Students sufficiently analyze data during post-visit activities	Students do not sufficiently analyze data during post-visit activities
	4.4 Students given free-choice	Students not given free-choice

Table 3. Conditions which Enhance or Retard Effective Use of AugmentedReality (AR).

1. **Effect of the CONNECT Approach.** Our data suggests that under certain conditions, identified and described above, the CONNECT approach, which focuses on the use of AR technology during a museum-school program, provides added value to science learning. We believe that our data suggests that this value-added contribution of the CONNECT approach derives from two central factors: (a) **increased student experimentation** and (b) **increased student interest**. In other words, we argue that, 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. We suggest that the AR-related features that are responsible for these differences include 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.

2. **Connecting Formal and Informal Science Learning**. Many educators today, both in schools and science museums, are searching for ways to "bridge the gap" between formal and informal science learning contexts (e.g., Hofstein and Rosenfeld, 1996). Our studies from the 4 museums suggest that the CONNECT approach, combining pre- and post-visit activities with AR technology, can provide a greater focus on student investigation at the science exhibits, than a similar combination of activities without AR technology. Through the active collection of quantitative data, coupled with the visualization of the unseen phenomenon which helps students understand the observed phenomenon, students are more directly engaged in investigating the phenomena. This emphasis on student inquiry helps the teacher to focus his or her students' work during the pre-visit stage, visit and post-visit stages. Thus, although the actual AR experience during the museum visit may be brief (10-15 minutes), its effects can radiate outward in both directions to the school-based activities, i.e., to the planning/orienting pre-visit activities as well as to the data analysis and summary post-visit activities. As such, the AR experience can act as a catalyst to bridge formal and informal science learning contexts.

3. **Understanding Learning**. Our data supports the argument that learning involves (a) student knowledge gain, (b) increased student motivation and attitudes, as well as (c) improved student investigation skills. These three aspects were mentioned as the three basic "goals of learning" by the participating science teachers at Bristol and they also represent the "criteria of success" for successful school-museum partnerships. In such partnerships, the schools were able to devote more time to the first goal (knowledge gain). During the school visits, the science museums could devote much less student time, but due to the authentic context of the exhibits and AR technology, the museums were able to contribute a great deal to the achievement of the third goal (increased motivation and positive attitudes). In addition, by focusing on the achievement of the second goal (student investigation skills), via the AR-mediated visualizations and measurements, the science museums were able to help provide a "common agenda" for the student work in the two contexts. Each of the four science museum was able to demonstrate significant gains in at least one or more of these areas, as a result of its use of the AR technology.

5.2 Recommendations

Based on our evaluation data, we can make specific evidence-based recommendations, designed to help design AR technology and AR-based activities which will provide more value to interactive science exhibits. These recommendations follow:

Instructional technology

Future efforts should be focused on making the AR technology, now in a prototype stage, more user-friendly. While the teachers should be encouraged to create their own scenarios, using the CVD, "teacher-friendly, pre-designed scenarios" should also be available for the teachers, at least as a first step, in order to allow them to spend more time focusing on the pedagogical and content issues.

The importance of the AR graphics cannot be overestimated. This is the crux of the AR intervention. Efforts should be made to guarantee that the AR graphics are scientifically valid, that they "make the invisible visible" in a clear way and are connected to exhibit sensors, which the students can use for measurements during their investigations.

The quality of the AR scenarios can be insured by following these principles: personalisation, perceived choice and control, interactivity, authenticity and collaboration.

Curriculum Integration and Teachers' Role

The topics of the AR and the interactive exhibit must fit well into the science curriculum. Teachers need to be involved in "making the connection" between the museum visit, the AR and their school curricula. As described above, students need to (a) receive a sufficient overview of the AR and the central topic, in the pre-visit activities, (b) be able to use the AR to make measurements and conduct experiments during their visit (c) be able to sufficiently analyze the data resulting from the visit, in their post-visit activities and (d) be given some degree of free choice, during their pre-visit, visit and/or post-visit activities.

It is crucial that the teachers be needed the necessary time and support to learn about the AR system. The teachers also need time and support to provide their students with appropriate pre-visit and post-visit activities. Perhaps each museum should set up a "Teacher Advisory Council," in which leading teachers could give teachers a voice in making important decisions regarding the choice of AR exhibits, the design of scenarios, curriculum issues and the like. In this way, hopefully teachers will develop a "sense of ownership" with the AR technology, which is a critical component of success for any lasting educational innovation.

School - Science Center collaboration

The augmenting technology introduces specific new learning opportunities, but also some constraints concerning the necessity to be "connected" and to use specific interaction devices. However, there is flexibility on the part of teachers and students in both planning the visit and the experiments as well as in concretely using the exhibits.

During the visit and at each exhibit, different roles will have to be taken over by students. One student may act as the operator, one or more notes may be observers or note-takers. Each role comes with specific responsibilities. The precision of the experiment relies on the quality of operation, observers will have a responsibility for the outcomes which may extend to the post-visit phase. Decisions about role assignments can be negotiated by and between the students.

Whereas basic role assignments related to a specific experiment and student group can be taken in place during the visit, other aspects of planning and design should be handled on beforehand during the pre-visit phase. These are typical planning choices:

- In case several exhibits are offered, but it is not possible for single student to experience all, specify groups and specific selection of experiments.
- If the same exhibit is visited by different groups, discuss and specify different perspectives or foci of attention for the different groups.
- Discuss requirements and rules for different roles of operators, observers, note-takers, pre-specify role assignments. Consider personal profiles and differences in motivation in the formation of groups.

There are also contextual conditions, which are given, but can still be reflected in an explicit way: In one extreme, an experiment supported by an exhibit may be an unknown phenomenon for all the students. Then the experiment will initiate a discovery or inquiry process. Here it is important to stimulate curiosity and self-confidence to explain the experiment. On the other hand, an experiment can already be known in terms of theoretical background and explanatory principles. In this case, a thorough discussion of which perspective should be taken (possibly by whom) and which second order factors (e.g., deviations from the ideal behaviour caused by friction) should be particularly observed.

Planning should also anticipate the post-visit phase in terms of what results (reports, data collections), who would be responsible for what and how different results would be aggregated, compared and discussed (e.g. in a school exchange scenario).

These aspects are described analyticaly in the next session.

5.3 Current School-Science Center collaboration

In order to provide a glance at how the CONNECT pedagogy might influence the future of learning in science centers, we first discuss the principles of free-choice learning and how they relate to the aims of the CONNECT project. We then discuss the future of free-choice learning in science centers, new models for museum-school collaborations, how CONNECT provides new choices for free-choice learning and how CONNECT might affect the future of free-choice lifelong learning of everyday science centre visitors (See Section 5.4).

Formal and Informal (Free-Choice) Learning in the CONNECT Project

The pedagogical approach of the CONNECT project is based upon the principles of free-choice learning (Falk and Dierking, 2000; 2002). These principles suggest that learners construct meaning based on a variety of factors including the content matter presented, as well as their own prior knowledge and experience, the physical and social-cultural environments in which they interact, the nature of the social interaction occurring and the subsequent reinforcing experiences they may encounter. Sometimes referred to as informal learning, Falk and Dierking advocate the use of the term free-choice, which focuses on the nature of the learning rather than upon where it is occurring. This is a critical point to the CONNECT project's design. By grounding it fully in a constructivist paradigm, all CONNECT experiences, be they those designed for the classroom, the museum/science center or home, reflect an openness, flexibility, and 'student centeredness.'

It is important to clarify informal learning and free-choice learning definitions since they can be conflicting within the literature. For example, when referring to informal learning within the CONNECT project, we do not mean discovery-based or unstructured, spontaneous learning, but rather highly structured learning that involves hypothesis testing and the examination of data. However, given the free-choice learning principles underlying these experiences, CONNECT experiences still can be non-sequential and exploratory. As stated by Crane, Nicholson and Chen (1994):

> *"Informal learning activities also may serve as a supplement to formal learning or even be used in schools or by teachers, but their distinguishing characteristic is that they were developed for out-of-school learning in competition with other less challenging uses of time...there are many informal*

> *learning media including exhibits and demonstrations in museums, aquariums, and zoos, television, radio, and community-based programs, books, magazines, hobbies, and newspapers."*

The CONNECT project embraces the idea of moving beyond the term of "informal learning" as it is primarily defined in its opposition to "formal learning" (i.e. schools) and instead to use the term "free-choice learning". Our study of free-choice learning takes place primarily within the construct of the school field trip, with the understanding that as suggested earlier there is an attempt to integrate these principles throughout project activities. Hofstein and Rosenfeld (1996) have this to say regarding the school field trip:

> *"In contrast to the conventional environment of the classroom, field trips take place in a more open, flexible and democratic environment. The field trip (e.g. museum, zoo, science centre and geological field trip) has a potential for providing instructional techniques that are more 'student centered', in which participants usually are able to move around at their own pace and to explore and experiment on their own (Feher, 1990). Furthermore, the field trip can provide students with concrete experiences, allowing them to interact physically and to manipulate objects (e.g. biological specimens and physical phenomena) which are usually unavailable in the formal science classroom."*

The key to a student's personal growth lies in the ability to make the best use of informal (yet well structured) educational opportunities as an indispensable component of school activities. The project views informal education as an opportunity to transcend the traditional classroom-based teaching, to a "feel and interact" student experience, allowing for learning "anytime, anywhere. These pedagogical concepts and learning practices are implemented through a set of demonstrators (guided and open educational pathways), employing advanced and highly interactive visualization technologies, embedded systems, wearable computing and also personalised ubiquitous learning paradigms in order to enhance the effectiveness and quality of the teaching and learning process.

The working hypothesis of the CONNECT project is that by enhancing traditional scientific experimentation and learning activities with visualisation applications and model building tools, students and learners in general will be better able to articulate their mental models, make better predictions, and reflect more effectively (Mirland, 2003). Additionally, providing opportunities for learners to reconcile the gaps and inconsistencies within their mental models, system models, predictions and results, will provide them with a powerful, explicit representation of their misconceptions and a means to repair them.

The overall aim of the CONNECT project is to demonstrate an innovative approach that crosscuts the boundaries between schools, museums, research centres and science thematic parks and involves students and teachers in extended episodes of purposeful, yet creative and inventive learning. In most science-education settings, there is a sharp division between the physical and the virtual. The partnership is developing, testing and evaluating learning schemes that will be implemented on ambient, always available educational environments. They are being developed using emerging technology in order to facilitate in-situ learning, by maximizing the impact of information that is provided when the motivation of the student is highest.

Since each student has different ways of learning and understanding, science teaching should provide a wide variety of learning and teaching approaches. Our aim is to move from a point where the teacher is the focal point in traditional course design, to where he/she now can help his/her students to work independently, co-operatively and in an increasingly self-organizing way. In the same way as we engage the learner in this "sense-making" process by giving control to the learner, we aim to encourage the teachers being involved in creating AR scenarios as they create instructional material, serving in a guiding role to the students. This can be achieved by including different educational scenarios (educational pathways) e.g. field trips that are tangential to the curriculum, pre- and post-visit curricular activities, problem-solving approaches, 'minds-on' experiments and models of different kinds in the everyday coursework heavily involving 'real' experiments in the "student-friendly" and engaging environment of a thematic park. The field trips in the thematic park enable students to pursue their own individual pathway of learning while staying focused on the main topic of study. These field trips also enhance and embrace student motivation as a critical success factor in any educational approach.

5.4 Future School-Science Center collaboration

The benefits of field trips

School field trips have long been hailed as excellent learning opportunities, but they have also been attacked as ineffective, wasteful and mostly entertaining excursions that serve social, rather than educational functions. Integrating out-of-school learning environments like natural history museums or science centers, traveling science exhibitions, planetaria, or Imax-theaters and Omnitheaters into the formal learning experience clearly can provide students and teachers valuable opportunities for critical science learning (Hofstein & Rosenfeld 1996). Recent studies document the range of learning that museums and museum-like settings afford their visitors (cf., Falk, 1999; Falk & Storksdieck, 2002; Hofstein, Bybee and Legro 1997, Rennie, 1999). A range of studies also show clear cognitive gain of students on field trips compared with those students who did not attend (Folkomer, 1981; Stronck, 1983; Wiley & Humphreys, 1985; Wright, 1980), although field trips might reinforce knowledge rather than form new knowledge (Schibeci, 1992). A field trips can also be an effective teaching tool for emotional or affective learning, since students who visited museums expressed more positive attitudes and motivation toward learning about the topic of study specifically, or science in general (Finson & Enochs, 1987; Flexer & Borun, 1984; Orion & Hofstein, 1991; Stronck, 1983).

Some researchers did not find clear improvement in cognitive or affective learning for students on field trips (Borun, Flexer, Casey, & Baum, 1983; Koran & Baker, 1978; Symington, Boundy, Radford, & Taylor, 1986). The relevant question may not be whether students gain from field trip experiences, but under what circumstances they gain, short-term, long-term, cognitively, or affectively, or simply by providing positive experiences which might lead to opening the students' horizons to include museums and museum-like institutions as places for enjoyment and learning later in life (Storksdieck, 2006). Falk and Dierking (1997), for instance, investigated the long-term effect of field trip experiences on elementary school students and found strong memories even after many years had passed; many of the positive memories might entice these former elementary students to return to the field trip setting, if only as parents who accompany their own children.

Field trip challenges

Under- and overutilization. Field trips can go wrong in two major ways: they can be underutilized (i.e. educational opportunities abound but are wasted), or overutilized (the field trip is turned into a tour de force for students and teachers and misses the idiosyncratic teaching and learning opportunity of the setting).

A range of studies shows that integrating out-of-school learning experiences into the school curriculum greatly enhances the overall educational impact of such visits (Bogner, 1998; Buchanan, 1992; Dettmann-Easler & Pease, 1999; Disinger, 1987; Disinger, 1988; Farmer & Wott, 1995; Gutierrez de White & Jacobson, 1994; Hunt, 1993; Stoneberg, 1981; Vars & Vars, 1990; Wolins, Jensen, & Ulzheimer, 1992).

An important element in the semester structure should be the pre-visit preparation in class, the actual visit itself, and a post-visit summary and ideally a second trip to complete the cycle of exposure and repetition. This seems particularly necessary for visiting media-based informal learning environments, in part because active learning is restricted due to the receptive nature in which the subject may be presented and the brief exposure to the learning experience. School children gain most cognitively and emotionally from a field trip when they are well prepared, when they participate actively during the trip, and when the information received during the trip is reinforced, i.e. when follow-up occurs (Bitgood, 1989; Bitgood, 1993; Gennaro, 1981; Koran & Baker, 1978; Koran, Lehman, Shafer, & Koran, 1983; Koran, Morrison, Lehman, Koran, & Gandara, 1984; Marshdoyle, Bowman, & Mullins, 1982; Reese & Moore, 1962; Reynolds, 1984). Conversely, if the topic of a field trip is linked to the current classroom unit, then preparation, follow-up, and a learning-oriented field trip are more likely to occur, i.e. the visit is more useful, at least in cognitive terms (Griffin, 1998; Griffin & Symington, 1997).

Another pitfall in field trips is overutilization: in an effort to ensure the educational effectiveness of a field trip, the visit to an out-of-school learning environment is conducted as an extension of the classroom learning, with task rather then learning-oriented style, rigid time-tables, worksheets, grading, and strict rules. Griffin and Symington (1997), reported in their study of museum field trips by teacher-led classes that many teachers herded their students through a museum, that they simply transferred classroom style instruction to a informal setting (mainly task-oriented teaching practices), and yet made little effort to link topics being studied in the classroom with the informal learning environment. These kinds of visits might not appreciate the specific learning opportunities that informal settings afford students and teachers alike (Falk, 1999; Falk & Dierking, 1992; Falk & Dierking, 2000; Price & Hein, 1991). These kinds of overly structured field trips force classroom practice onto students in the informal arena and as a consequence, students might develop a negative attitude toward the out-of-school learning environment; one that may prevent the learner to utilize

them later on in life for further learning. However, the above discussion is not meant to imply that every level of structure is harmful or undesirable. Research suggests a quasi-structured approach for a visit can be beneficial. (CanizalesDeAndrare, 1990; Finson and Enochs, 1987; Stronck, 1983).

Teachers face a formidable task

In recent years special attention has been given to the preparation and involvement of teachers in the process of reform. The need to support teachers during change processes, and enhance their professional development became one of the main concerns of policy makers and the educational community (Tobin, Tippin, and Gallard, 1994; Loucks-Horsely, Bybee, and Wild, 1996; AAAS, 2003; Davis, 2003; Hofstein, Carmi, and Ben-Zvi, 2003; NSTA, 2003). The literature clearly shows a shift in the role of teachers from the transmission paradigm: the teacher as an agent of implementation (the 'top-down' approach), to the collaboration paradigm (the 'bottom-up' approach) (Elbaz, 1991; Ben-Peretz, 1994; Rosenfeld, Scherz, Orion, and Eylon, 2002). The reason for the change in teachers' involvement in the curricular process was the general lack of sufficient achievements with the transmission paradigm. Teachers' existing perceptions and beliefs, as well as practical difficulties acted as barriers for implementation. It was found that implementation-directed programs had limited success in fostering a change in teachers' practice (Yager, 1992; Loucks-Horsely and Matsumoto, 1999). Parke and Coble (1997) suggested to: "change reform perspective from something that is done to teachers to something that is done with teachers".

Teachers need distinct skills and knowledge to be able to take their students to out-of-school settings: not only do they need to find the right balance between under- and overutilization, they also need a range of managerial skills in order to schedule the trip, arrange for transportation and additional supervision, get permission from parents and the school administration, think about the educational aspect of the trip and how it may fit into their classroom unit; they need to worry about behavior and safety, find the time for the trip and coordinate with other teachers, receive permission from parents and the school administration, research the appropriate setting, etc. If all or any of this is bothersome or otherwise problematic, this might act as a barrier and disincline teachers to use out-of-school settings in the first place (Anderson & Zhang, 2003; Anderson, Kisiel & Storksdieck, 2006; Jamison, 1998; Kisiel, 2003; Lanning & Elton, 2001; Simmons, 1998).

Teachers need to focus on field trip management and safety might deflects their attention from pedagogical aspects of a visit; a tendency reinforced by museum field trip recommendations that focus on field trip management at the expense of field trip pedagogy. Teachers can easily be overwhelmed by the multitude of aspects they have to consider in their field-trip planning. This may lower their pedagogical expectations for the field trip itself: rather than focus on what students might learn (affectively or cognitively), they may be pleased with getting everybody home safe and unharmed.

Whether a teacher uses an out-of-school setting also in part depends on the teacher's level of confidence and sense of being well-prepared to teach the topic presented at the setting and to teach at the setting themselves (Gutierrez de White & Jacobson, 1994; Simmons, 1994). Informal settings provide students with a plethora of observations and questions, and some teachers may feel uneasy with the prospect of not being able to answer all of them. Given the lack of a comprehensive framework and seemingly conflicting research findings on using informal learning environments for science teaching, it may well be that many teachers enter the profession unprepared in terms of educational field trip management.

New Models: Possibilities of Science Center - School Collaborations

In conclusion, school-museum collaborations have the potential to provide a broad range of benefits to learners, many of them encompassed within the principles guiding the development of CONNECT learning scenarios: Personalization, Collaboration, Authenticity, Interactivity. However, one important benefit is often overlooked: learners (i.e., students) are introduced to a more fluid relationship between learning resources. Rather than dividing learning environments sharply into formal and free-choice, school-museum partnerships can provide learners opportunities to integrate the learning experiences they have at school, home and in the community, for example at a science centre. Museum-school collaborations provide a model that enables students to acquire a much broader perspective on what, how, where, and with whom one can learn. These collaborations are models for a new learning society, where learning is life-long, venue-independent, and to a large degree under the control of the learner.

Such museum-school collaborations when designed well, provide a new model for "field trips beyond field trips." As increasing numbers of museums embrace new media to update their offerings and create new bridges to free-choice learners, as well as formal learners in schools, technology offers a means to overcome some of the organizational and pedagogical barriers that currently plague school-museum collaborations and partnerships.

Virtual and augmented reality, real-time data streaming

from museum to the classroom and vice versa, data recording, individually programmed learning pathways, and other types of technology-based enhancements of the traditional school field trip have the potential to build a field trip model that blends the strength of classroom instruction (curriculum-based, building logically and successively on prior experiences previously taught and hopefully learned), content selected based on societal consensus) with the benefits of free-choice learning (opportunities to explore topics of personal interest and relevance in ways that make sense to the learner either alone or with people they choose to visit with, high levels of motivation, strong connection to the learner's prior experiences and knowledge). In addition, these technologies do not limit the learning of that material to the classroom alone. The learner can continue to interact, engage and experiment while at home, alone or with friends and family. The learning experience, and learning that results, truly become the possession of the learner, where, when and with whom he/she chooses to learn.

New choices, potentially afforded by CONNECT:

CONNECT offers technical solutions that extend the potential for choice for the teachers and students. Again, these are summarized below and should be seen as additions to the choices and the possibilities for control that already existed in the field trip system.

Choices due to Augmented Reality System and its potentially flexible menu system:

- Depth of engagement with exhibit
- Use of additional information not provided by exhibit
- Whether to use exhibit to collect data
- Whether and what data to collect
- Deciding on a testable hypothesis
- Using inquiry method to guide discovery
- Choosing the extent of visualization types to avoid extraneous load

Choices due to authoring possibilities:

- Predefine choices for the augmentation menu for each exhibit
- If multiple exhibits are augmented: choice of exhibit to use and sequence of use

These additional choices can dramatically increase the learning process during the visit to the science center. However, for reasons described above, the team had to limit the choices to educational pathways designed by the teacher, and thus afforded teachers the choice to determine learning pathways for the students for a specific exhibit in ways that are normally not possible. Future versions of the system can easily be expanded to include a full set of choices for the learner (i.e., the students) themselves. But as the previous discussion highlights, whether these choices are available or utilized depends less on the system, but on the educational and pedagogical perspective of the teacher and the science center staff and the learners choice.

The test runs represent one possibility of how to utilize the pathway patters (pre-visit, museum visit, post-visit). Besides technological constraints during the museum visit, we also have to limit the pre- and post-visit experience to the knowledge needed to successfully engage in the AR scenario. The evaluation approach taken in CONNECT requires for controlled conditions especially during the pre-visit phase in order to isolate the effect of the CONNECT technology. To assure similar conditions for all classes participating, the pre-visit phase must be based on objectives, which define the content to be taught. Therefore the degree of freedom during the CONNECT Final test runs A and B was limited.

Augmented reality, choice, motivation, and everyday visitors to science centres in the future

While acknowledging the limited number of choices the currently operational CONNECT systems allows, we know that this demonstration of augmented reality in science centres is not the final product, but instead, a major push forward in the evolution of advanced technology systems in classrooms and informal science learning institutions. As we overcome the technology and cost issues inherent in attempting a project of this scale, augmented reality will not only become more of a seamless experience for the user, but will afford significantly more choices and more freedom than it does at the moment. Envision, as the CONNECT designers have, a science centre where multiple interrelated exhibition components within a particular area are augmented. This might be an exhibition devote to physics- including the various component concepts and the overall themes. Many more degrees of freedom are thereby introduced including which interactive is more interesting or appealing, which ones to visit in which order, the overlapping concepts and possibly even hypotheses and data between interactives. These additional choices reinforce the sense of exploration and discovery, the visitors' sense of self-directed learning and ultimately leads to both more playful learning and deeper exploration of concepts. The technology will become more transparent, especially as it more closely mimics the tech-

nology-imbued life of the average student, and allow what computer technology at its best should allow—more choices, more ability to capitalize on the visitors' interests, and increase capabilities for making connections.

CONNECT as a project has been focused on developing a technology-based, pedagogy-supported system that allows for better integration of science centers and schools. The CONNECT vision has been for a hybrid classroom; one that harnesses the excitement and joy of exploration and learning in the real-world situations prevalent in science centers, while extending the fleeting museum experience into a substantive engagement with scientific habits of mind. But the gains from CONNECT project extend beyond tomorrow's classroom-- the vision of CONNECT can easily been transferred to the sixty to seventy percent of science center visitors who are not classroom pupils. Recent research documents both the gap in and the critical need for the general public's science literacy. Most fundamentally is the gap in the understanding of scientific processes and metacognitive skills such as the creation of mental models, the ability to create hypotheses, gather and interpret data, and synthesize and apply the gain information.

Science centers tend to create exhibits that convey one overarching idea or group of ideas, mostly accompanied by labels or touchscreen information that is layered for varying interest and prior knowledge of visitors. As DVD tour guides, podcasts, or other innovative forms of programming illustrate, museums and science centers strive for providing increasingly more idiosyncratic and personalized experiences for a broad spectrum of visitors. The CONNECT system, if developed into a stable and affordable mass product, would allow any visitor to a science center an opportunity to tailor the visit to one's interests, prior knowledge and needs. A visitor could create AR scenarios through a website or on site at computer kiosks, and then rent a pre-loaded AR system for the visit. Alternatively (and more likely in the short run), an AR system, provided through an exhibit card and accompanied by staff, might be made available during announced hours of the day to any visitor, much like demo cards are now being used on exhibition floors. Visitors could opt to use the AR system on one or a set of exhibits in one room, and exercise free choice by selecting from a wide range of menu items. Either way, a stable AR system provides an opportunity to create individualized experiences for any visitors. In a world increasingly demanding personalization, augmented reality would allow all visitors to make a deeper connection to science.



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