

C o n n e c t T e a c h e r s W o r k s h o p



Teacher's Workshop Proceedings

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CONNECT

Teachers' Workshop Proceedings



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CONNECT

Teachers' Workshop Proceedings



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The CONNECT Project

Designing the classroom of Tomorrow by using Advanced Technologies to connect formal and informal learning environments

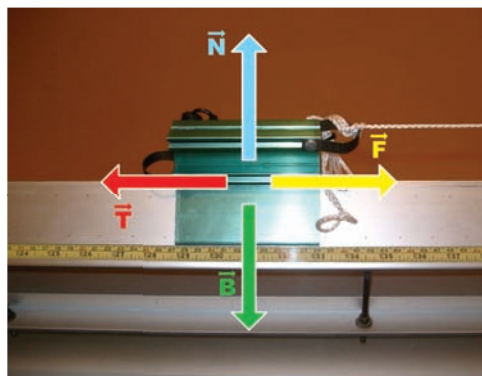


S. Sotiriou
Ellinogermaniki Agogi

In recent years, the need to make a transition to a technology-enhanced classroom has been demonstrated through state-wide and international projects in supplying computerised technologies to schools. While this ongoing effort is already taking place, there is also a need to immerse school students within rich contextualised learning settings. Museums and science centres present great learning opportunities in that direction. However, centre visits by schools remain “special events”, often only narrowly connected to the learning processes in the school. As

day-out experiences, they often have a predetermined value, by making the children curious on the phenomena observed whilst examining exhibits (Salmi, 2003). The impact of such experiences could be improved by embedding these visits, more effectively, into the normal school learning processes (Rosenfeld, 2004).

Current efforts in computer-mediated learning, as employed in many fields of science, such as medicine (Tang et al., 1998), mathematics and geometry (Kaufmann & Schmalstieg, 2003), attempt to enhance reality with synthetic (computer-generated) information, and thus improve the perspective of the learner's complex concepts understanding. The concept of Augmented Reality (AR) incorporates the use of technology applications that allow the use of 2D or 3D scenes of synthetic objects to enhance and augment the visual perception of the real environment (Starner et al., 1997; Feiner et al., 1997; Argotti et al., 2002). The co-existence of the computer generated virtual objects and the real environment constitute a "mixed-reality", where users can interact with the environment, through appropriate input devices, in real-time. Azuma (1997) ascertains three identifiers that delineate the field of AR: a) "Combines real and virtual objects in a real environment; b) runs interactively, and in real time; and c) registers (aligns) real and virtual objects with each other."

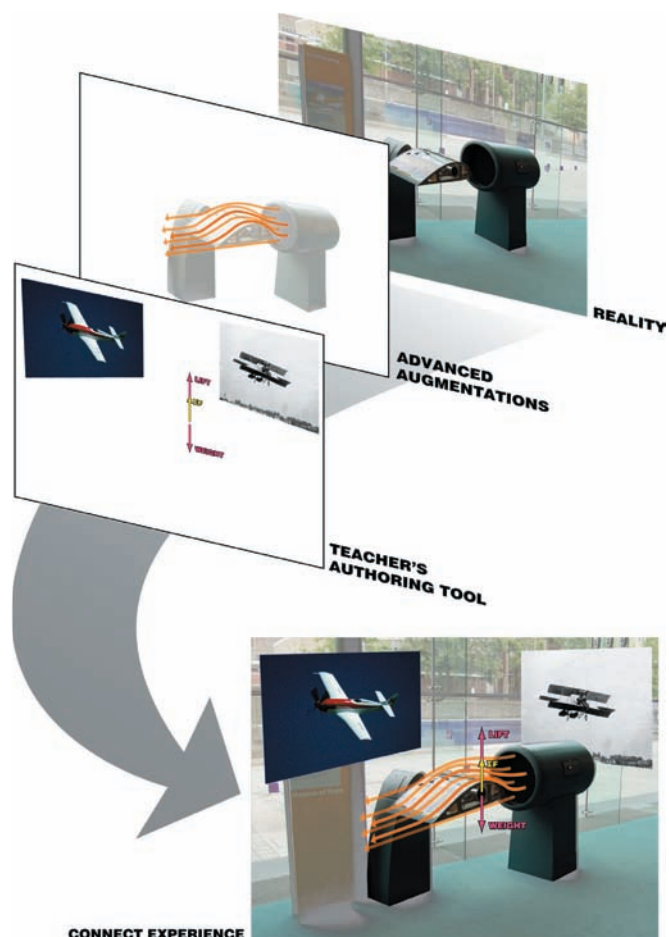


In the context of technology-enhanced learning environments, AR can be used to enrich a student's physical view by virtual extensions. This can help the student to understand non-tangible phenomena (e.g. magnetic fields) that are hard to teach in school and perhaps even open new domains in teaching. In terms of a visit to a museum or science centre, Sparacino (2002) favoured an approach where an AR system adjusts itself according to the behaviour of the visitor. In addition, in a teaching context, broadband technology can be used to stream an AR view into schools, providing students, back in the



classroom, with the ability to interact with exhibits in distant science centres.

The CONNECT project 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 –



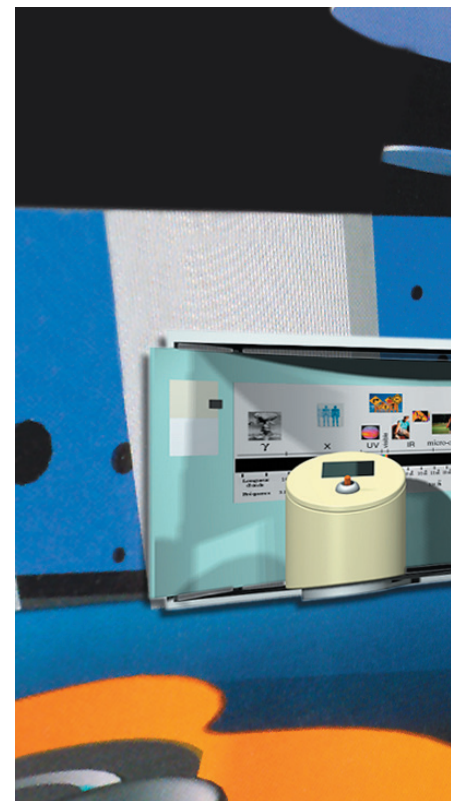
Visualising the invisible

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 flux, 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.



museum collaboration. The aim of the project is to explore, test, refine and demonstrate an innovative approach that crosscuts the boundaries between schools, museums, research centers (e.g. observatories) and science centers 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 impact of information that is provided when the motivation of the student is highest. Specifically and practically the project will map the evolution from the wired virtual learning environment of today, to the wireless learning environment of tomorrow.

In the framework of the proposed project a network of science museums, science centres, research centers and schools will be created to test the proposed approach. An advanced learning environment, the virtual science thematic park, will be developed. This virtual science thematic park will be the main “hub” of resources available in the developed network and will serve as distributor of information and organizer of suitable educational activities. This virtual science thematic park will incorporate all the innovative use of the technology for educational purposes and will also interconnect all the members of the network. It will also organize students’ virtual and conventional visits to the science museums and science centres. These visits will serve (through an informal but yet structured way) main educational aims of the official curriculum.





The CONNECT Virtual Science Thematic Park

C o n n e c t T e a c h e r s W o r k s h o p





Pedagogical Approaches

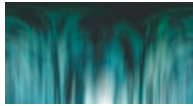


K. Hoeksema
University of Duisburg-Essen

The CONNECT project has brought together pedagogues, technologists and human factors specialists to develop innovative systems that bridge formal and informal learning environments. By using interactive visualisation, embedded systems, AR techniques, and open access web-based applications, the project aims to develop and evaluate personalized learning paradigms, which integrate contextual information between science centres and classroom settings. In the following paragraphs, a brief discussion of the pedagogical context will be presented, in order to understand the context of use for the developed technology.



The CONNECT project follows the contextual model of learning, which emphasises the importance of the learners' contexts (i.e. personal, physical, and socio-cultural) when learning (Falk, 1999) and explicitly points out the role of free choice learning (Falk and Storksdieck, 2002; Dierking, 2003). Within this approach, the design of specific pedagogical scenarios needs to be flexible enough to allow the integration of free choice learning. As such, a certain degree of freedom is required when selecting the pedagogical question to focus on, within a science centre setting.



The potential of informal learning environments

Imagine an educational environment in which youngsters at the age of seven or eight, in addition to -or perhaps instead of-attending a formal school, have the opportunity to enroll in a children's museum, a science museum, or some kind of discovery center or exploratorium. As part of this educational scene, adults are present who actually practice the disciplines or crafts represented by the various exhibits. Computer programmers are working in the technology center, zookeepers and zoologists are tending the animals, workers from a bicycle factory assemble bicycles in front of the children's eyes...During the course of their schooling, youngsters enter into separate apprenticeships with a number of these adults...If we are to configure an education for understanding, suited for the students of today and for the world of tomorrow, we need to take the lessons of the museum and the relationships of the apprenticeship extremely seriously. Not, perhaps, to convert each school into a museum, nor each teacher into a master, but rather to think of the ways in which the strengths of a museum atmosphere, of apprenticeship learning, and of engaging projects can pervade all educational environments from home to school to workplace.

Gardner, 1991





Of particular relevance are the pedagogical approaches employed to project and problem based learning, which focuses on a driving question or problem that the students focus on (Jonassen, 1999). Within this context, students should be able to perform scientific experiments and thus construct their own knowledge. To achieve such learning skills as self-regulation, the system has to be designed in a way that provides the appropriate level of flexibility to the learner. During traditional learning processes this flexibility can be lost due to organisational and logistical problems (such as the educator: student ratio). Conventionally the teacher instructs, asks questions, gives additional information and provides additional learner focussed educational material. Typically employed media include books, chalk boards, overhead projectors, and small experimental physical environments. Computer usage remains limited to conventional tools such as word processing and presentation media. Opportunities of informal learning in science centres often give the students the possibility to explore a variety of interactive exhibits fostering their curiosity. Boards next to the exhibits, sometimes audio systems and computer monitors, show additional information. It is accepted that science centre visits can have a positive impact on students' beliefs towards science, yet there is still a discussion to what extent students acquire skills that are re-usable within a classroom setting (Walton, 2000). Current research on science learning focuses on inquiry-based activities that bring the students closer to science (Chinn and Malhotra, 2002; De Jong and Van Joolingen, 1998). Engaging students in authentic scientific activities such as modelling and hypothesis building attempt to make a shift from learning about science towards actually engaging in science. The underlying idea of this approach is to support students in an active meaning making process (Jonassen, 2002). The employment of interactive visualisations through AR technology introduces this absent flexibility into science education.

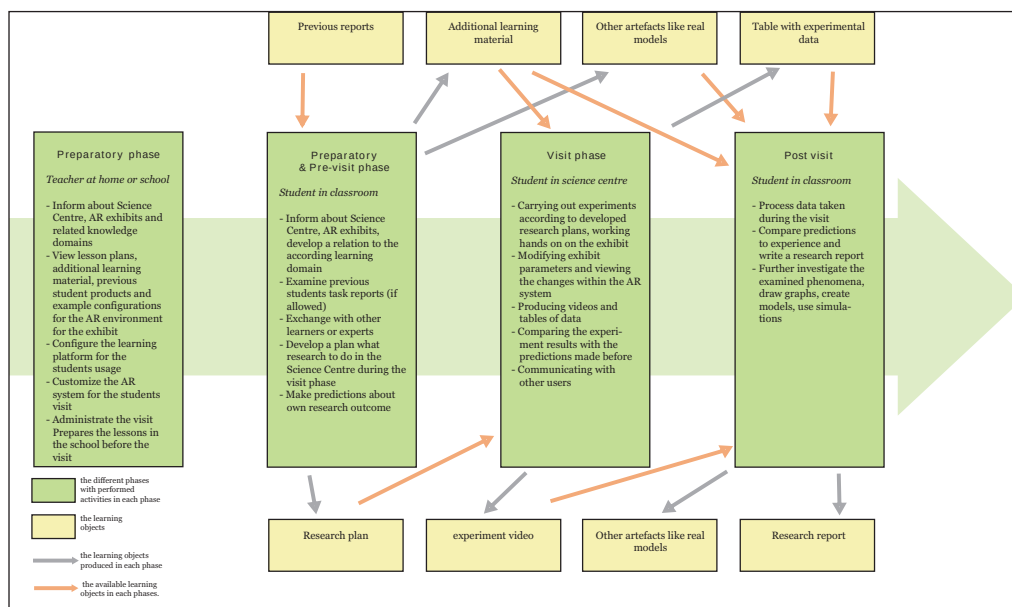




The CONNECT Educational Pathways

The CONNECT Pathways are 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 into everyday coursework heavily involving 'real' experiments in the "student-friendly" and engaging environment of a thematic park. The field trips in the thematic park will enable students to follow their individual pathway of learning. And they will enhance a factor that guarantees success in every educational approach: the fun factor in learning procedure.

Each student-visitor can, through the fusion of "mixed reality" 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.





The CONNECT System

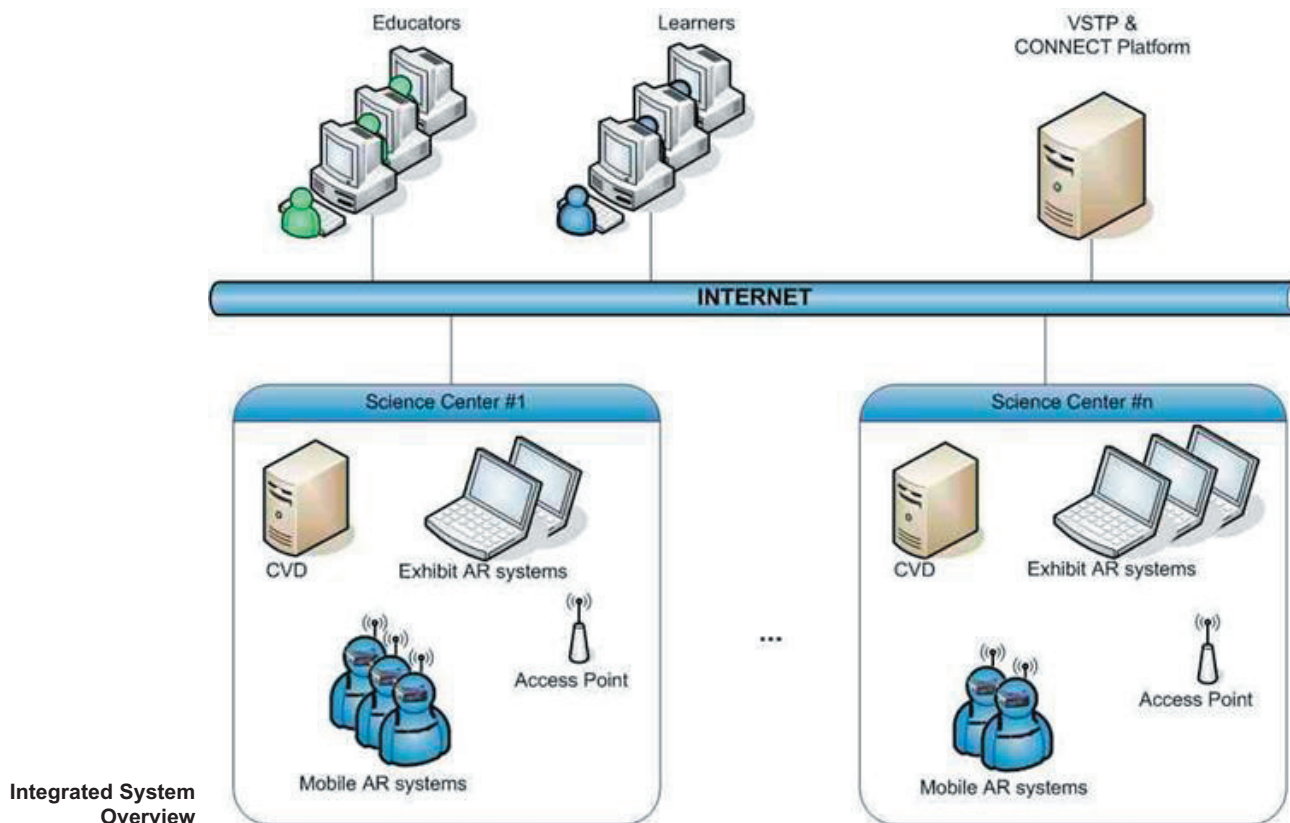


A. Maier, A. Ramfos
Intrasoft International SA

In the framework of the project an advanced learning environment is being developed, the Virtual Science Thematic Park, in order to act as the main “hub” of resources available in the developed network that will serve as distributor of information and organizer of suitable didactical activities. This comprises two principle high level elements:

1. **CONNECT Platform:** For communications between users and institutions, and for the creation of and access to content and information.
2. **The mobile AR system:** For displaying the educational content to the student and allowing him/her to interact with it.

This section will give a conceptual view of this architecture; an introduction in the form of an overview is shown below followed by a brief description of each component, as it is not within the scope of this booklet to detail low level integration and implementation factors.



Integrated System Overview



CONNECT Web Applications

The web applications convene towards an advanced learning environment that consists of the Virtual Science Thematic park (VSTP) and the CONNECT platform (CP).

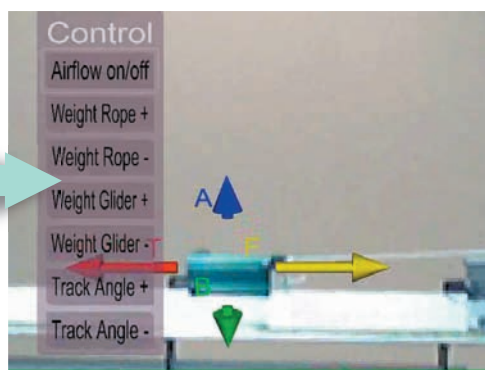
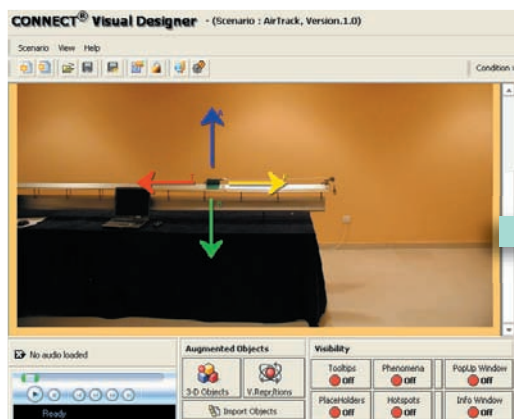
Virtual Science Thematic Park (VSTP)

The VSTP acts a central resource for distributed educational resources. This in effect creates a virtual network of science parks, science museums and research centres across a European wide community. The visitor's first information relating to the entire process resides with the VSTP. This is the publicly available section of the CONNECT integrated system. The user can learn generic details regarding the project, the pedagogical processes, details and links to museums and exhibits resources.

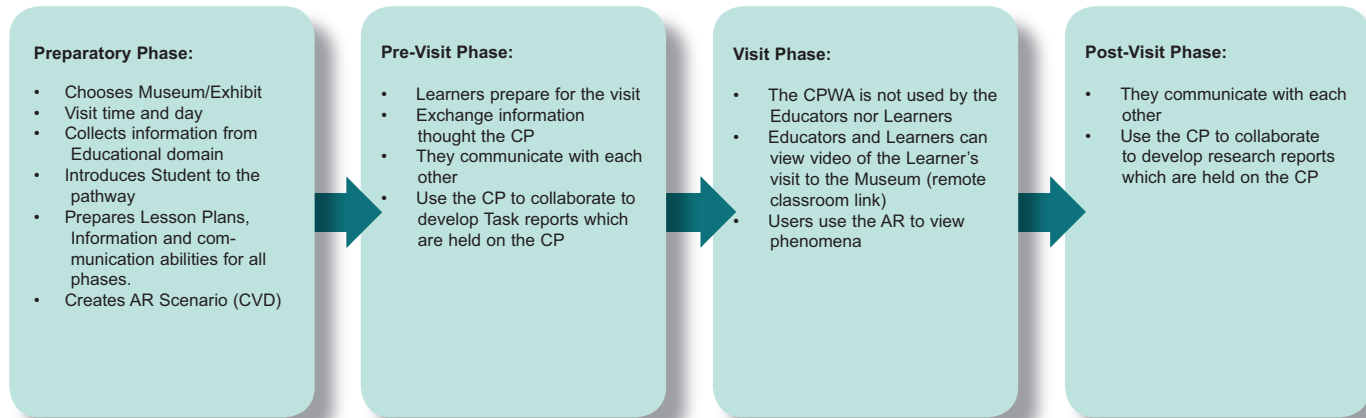


CONNECT Platform (CP)

The CP provides teachers, students and museum staff with a collaborative environment that guides the users through the pedagogical



Creating CONNECT Senarios
Through the CONNECT Platform the teacher will be able to create a series of augmentations (forces, fields, etc.) to be presented to the students during the field trip.



General workflow of a CONNECT visit.

processes whilst managing and maintaining the generated content. The suggested workflow is based on the pedagogical process, whilst the design is based on HF design and evaluation. The diagram above summarises the available activities and general workflow for a CONNECT visit.

CONNECT Visual Designer (CVD)

The CONNECT Visual Designer (CVD) is a CONNECT Platform sub-system which allows educators to specify AR experiences for later use by the student via the mobile AR system. The most important requirement for the CVD is that it is web based and therefore open-access to all intended users with an internet connection.

The CVD allows the educator to personalise the AR experience for the intended student within the context of use by specifying the interactions the learner can have within the AR environment. The educator builds a collection of rules. Each rule specifies conditions, which denote what will happen in the environment when a user performs a specific action. The users' interactions indicate to the system when and how to react. The reactions are presentations of multimedia content such as images, sound, video, text and 3-D objects.



Mobile Augmented Reality System

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

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

To deliver the required AR experience to the user, the following functionalities have to be performed by the mobile AR system, highlighted by the user need analysis:

- Determining the visitor's head position and orientation (head tracking),
- Presenting the real view captured by a camera in a video see-through display (video augmentation),
- Presenting virtual objects in the display that augment visualisation of exhibits,
- Supporting interaction with the scenarios through virtual head-up menu and exhibit parts,
- Recording the learner's view for use in the post-visit phase (image and video capturing),
- Recording the experiment variables for use in the post-visit phase (data capturing),
- Streaming the learner's view to a server that relays the video stream to remote classrooms,
- Operating a bidirectional audio communication line between visitor and remote classrooms,
- Transferring the scenario specified in the CVD into an interactive AR scenario description.





In addition, the augmented exhibits offer specific and unique functionalities:

- Determining the position and/or orientation of exhibit's parts (object tracking), 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 (data acquisition), e.g. temperatures inside and outside of the Hot Air Balloon, CO₂ concentration within BioTube.
- Control specific variables of the environment, e.g. switching on/off neon lights in the BioTube.

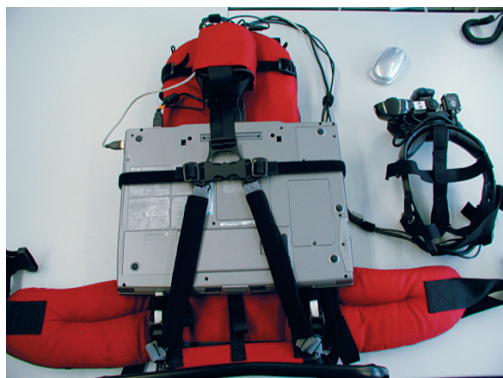


Description of the mobile AR system



M. Wittkaemper
Fraunhofer Institute for Applied Information Technology

This session focuses on the design and implementation of the mobile AR system. A supplementary section regarding the headset, central processing unit, tracking technologies and communications is presented here.



Central Processing Unit (CPU)

The CPU consists of a stripped baby carrier mounted by a high-end laptop with stereo graphics capabilities. All software components are run on this system in addition to other student and exhibit-specific hardware components are connected to it. The most significant aspect of the system is the NVIDIA Quadro FX Go 1000 graphics board with OpenGL quad-buffered stereo support, to ensure that the users' AR experience is immersive and occurs in real-time (i.e. minimal lag). A small bag fixed at the carrier is used to hold all the wires and an additional battery pack to supply the Head Mounted Display (HMD) with power. The backpack can be adjusted according to the specific back dimensions of the learner. By fastening the waist belt a proportion of the weight (approx. 5 kilograms) is supported by the users' hip, reducing the strain placed upon the users' shoulders.

Head Mounted Display (HMD)

The headset comprises a binocular video see-through stereo display (i-glasses SVGA Pro 3D).

The real world view is captured by a webcam attached to the front of the display and displayed within a non see-through display that is also utilised to stream to the remote classroom. It is critical for the translation from a single captured real-world image stream to be transformed to the two eye positions of the student and to the field of view of the display. This is accomplished by projecting the image onto the inner surface of a sphere located in the background of the virtual scene. The position of the sphere differs for the left and right eye and can be adjusted so that a stereoscopic experience is created and so that the video augmentation matches with the peripheral real view outside the display, this in turn aids immersion and user presence within virtual environments. This is important as the Field of View (FOV) of the displays is limited to 20° - 25° horizontally, thus increasing the users' FOV is beneficial for the mobile user walking around the science centre, by



increasing awareness of their immediate environment and to avoid colliding with other visitors or exhibits.

Tracking Technologies

For registration of real and virtual objects, a precise tracking of the student is essential. Science centres tend to be large space in which the student will walk around interacting with a number of exhibits, which presents a highly demanding challenge in terms of accurate user position and orientation tracking. A marker-based optical tracking such as the open source ARToolKit (Kato & Billinghurst, 1999) and ARTag (Fiala, 2004) were considered due to the minimal cost. However these toolkits were not designed to run in an “inside-out” configuration, whereby the markers are fixed at known locations and the camera is mounted directly onto the HMD. Consequentially the precision of the tracked rotation component is not sufficient for the high demands of the CONNECT student.



In addition to the position tracking, the HMD has an inertial tracking sensor for the precise tracking of the users head rotation, and a second webcam for tracking head position. This second webcam is detecting black and white patterns (fiducial markers) printed on paper and positioned around the exhibits. The pattern positions are known to the system which can be translated to determine the accurate head position of the user. Consequentially the user is restricted to an area immediately around or in front of the exhibit. Therefore as long as the user is within a predefined proximity of the markers, the position is tracked by the camera. Conversely, the orientation is always tracked. Thus the user can look in directions with the camera seeing no markers without a problem. However, if the user moves without seeing the marker, she has to bring them into sight of the tracking camera to update the head position.

Dimensions and weight

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



Table I: *Dimensions and weight of the CONNECT mobile AR system*

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



Communication and Collaboration Technologies

Various communication and collaboration technologies have been highlighted and implemented within the CONNECT integrated system. These are addressed in subsequent sections.

Human Computer Interaction

There are two ways to interact with the exhibit. In the first instance, natural gestures, taking advantage of normal-use interaction such as affordances involving real properties of the actual exhibits, are utilised as Tangible Interfaces. Secondly, a virtual menu is used to access a number of higher-level operations specific within the context of the AR environment.

Gesture based interaction

To allow interaction with parts of the exhibit, the same tracking technology is used. In most cases only the position or the orientation is required. In addition to this, physical experiments conducted at the sci-



ence centres often include exhibit-specific data such as temperature, CO₂ density or lighting condition, measured by a variety of sensors.

Interaction Device

A wireless mouse is used to interact with a virtual menu displayed within the FOV of the user. Only the buttons and the mouse wheel are enabled; as a positional cursor is not required. It should be held such that the wheel and buttons can be operated with a single thumb only.



Computer to Computer communication: Mixed Reality Interface Markup Language (MRIML)

To describe the educator's learning scenario, in specifying both the content and the interaction for the learner's museum visit a user interface description language was developed by Fraunhofer FIT. Instead of creating a project specific interface between authoring and AR system, the aim was to specify a general platform independent language for both Augmented/Mixed Reality user interfaces as well as a WIMP based user interface. With the help of Mixed Reality Interface Markup Language (MRIML) the learning scenario can be specified outside the system in which it will be used (rendered) (Broll et al., 2005). Apart from the AR system, this could also be the CVD or a desktop environment allowing the educator to simulate the museum visit. This requirement allows the user to confirm their intentions by "previewing" their objective prior to uploading the generated content to the mobile AR system for use by the student, thus increasing the confidence level of the educator in their intended action.



C o n n e c t T e a c h e r s W o r k s h o p





Evaluation Method and Guidelines for the Tests



F. Bogner
University of Bayreuth

Introduction

The CONNECT project aims to facilitate the connections between science centres visits and classroom activities. Part of this facilitation is to find methods to evaluate the learning outcome of the proposed activi-



ties. Taking into account that there are no evaluation tools and methods that consider both classroom activities and science centre activities, the project evaluation team has to provide an innovative methodology to support such efforts. The CONNECT evaluation approach is to wed classroom evaluation methods and informal evaluation methods in an innovative way.

The CONNECT evaluation team is a blend of researchers with expertise in evaluating innovative applications in school environments and in evaluating informal learning scenarios (e.g. field trips, outdoor programmes and projects). This consortium gives new insight into evaluation methods which evolves through a systematic, multi-step assessment process. A collection of methods will measure the effect of the pedagogical approach, some of which are quantitative and some are qualitative.



The CONNECT approach in designing an advanced learning environment follows the idea that teachers, museum educators and students participate in the design process. This idea is generally known as 'participatory design' process. In this process, the evaluation itself is subject to an intensive participation influenced by designers and the users of the system.

The evaluation in the CONNECT project focuses on answering the main research question of the project which is: Under what conditions can the technologies of Augmented Reality (AR) combined with interactive science exhibits support student learning? The evaluation design concentrates in measuring the "added value" of the CONNECT approach, in terms of the students' increase in scientific understanding as well as their motivation and attitudes.

Pedagogical Evaluation Questions and Methodology

The pedagogical evaluation will include both formative and summative phases. The formative stage occurs during the first two test runs (First



Run and Test Run) and gives feedback to the designers of the pedagogical approach and the technological system. At the end of the Final Run (third test run), the summative phase will take place.

The formative phase has taken into account the following considerations:

1. general usefulness of the pedagogical approach and VSTP as perceived by users,
2. the potential for the system to be integrated into the learning process,
3. suggestions for improvements for an enhanced future system (not the one being tested),
4. suggestions for how to integrate the system into current field trip practice,
5. suggestions on how such a system might change future science museum visit practice.

For the summative phase to take place and considering that the final run will be occurring, we are making the following assumptions:

1. The AR system is fully operational at four sites. Scenarios have undergone further development and refinement. Teachers' workshops have been provided.
2. Local museum staff will assist with data collection.
3. Not all questions need to be answered at all four sites: some qualitative research maybe restricted to two sites or even one site. Some of the strictly quantitative surveys and standardized instruments will be translated into four languages and used at all sites.
4. Scenarios might include multiple exhibits, even though only one will be augmented.

We will attempt to separately assess some of the specific CONNECT factors, e.g., the use of the CONNECT technology, the use of educational pathways, etc. While we want to assess the relative value of these factors, we also want to assess all of these factors together, i.e. the usefulness of the educational pathways and the VSTP in use.





We will assess the system for mainly three target groups: teachers, students, and museum staff.

In the next section, we present the specific evaluation questions and methodology of each of the two phases of the evaluation (formative and summative).

Formative Evaluation

It is important to note that the usability analysis and formative evaluation will be conducted in parallel. They will share instruments and will be conducted in a highly coordinated fashion, though each may pursue different questions. The usability analysis will ask how students respond to the technology. The formative evaluation focuses on the overall potential of the pedagogical approach to affect the students' and teachers' affective, social and cognitive learning. Both usability analysis and formative evaluation will address the novelty effect, though from different angles. The usability analysis will determine to what degree novelty affects students' and teachers' ability to use the CONNECT technology to conduct a science museum visit to a science centre, while formative evaluation is concerned with the degree to which novelty may impede on learning.

During the first prototype testing in situ, the evaluation team sought feedback primarily on future instruments. It also gained insights into the procedure of the science museum visit through focus group and general group discussions. Additionally, through direct observation, the team gained initial insights as to the educational potential of the system.

The Test Run will work with an extended sample and an improved set of augmented exhibits and scenarios. Instruments will be tested again, and initial summative data will be conducted. However, the focus is still on improving the system to make it ready for the final run. Focus groups, structured observations and written questionnaires from students and in-depth interviews with teachers will provide ample feedback on: (a) the appropriateness of the CONNECT technology; (b) further needs for improvement; (c) initial feedback on the system's educational potential; (d) further refinement of summative instruments; (e) feedback on the procedure





It is important to notice the need to embed data collection seamlessly with the science museum visit without undue interruption and disturbance.

Summative Evaluation

The final run phase 2 will form the basis of the summative evaluation. Considerable overlap is expected with validation research which addresses the potential of the system to function outside of the project (scalability and transferability research). It should be noted that the validation research will focus strongly on the context of the system, assess the educational potential of pathways, and the willingness and ability of school systems and science centres in general to adapt such a system more broadly. The summative evaluation is part of the pedagogical evaluation; it will also address these issues but in less detail.

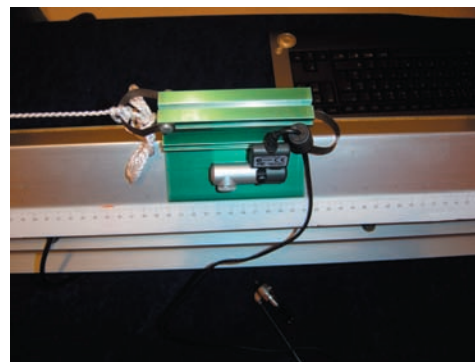
The summative evaluation is designed to address the following two evaluation questions:

1. To what extent does the CONNECT technology add value to the science museum visit experience? In other words, is an augmented science museum visit experience that is supported by the specific CONNECT technology better than a similar science museum visit experience without VSTP linking classrooms and science centres?
2. Do the educational pathways provide added value for teachers and students, and if so, in what ways? In other words, is the CONNECT pedagogical approach superior to traditional classroom teaching and if so, under what circumstances?

Methodology

A quasi-experimental design includes three different treatment groups:

1. A group of classes that study the content material without any science museum visit (control group).
2. A group of classes visiting the science museum and completing





pre- and post-visit activities, but without any CONNECT technology.

3. A group of classes visiting the science museum, completing pre- and post-visit activities and making use of the CONNECT technology.

How do these treatment groups address the two above evaluation questions? The comparison of groups 2 & 3 will test the first evaluation question, regarding the added-value of the CONNECT technology. The comparison of group 1 to group 2 will test the second research question regarding the added value of the CONNECT pedagogical pathways (without the technology).

In each of the four participating countries (Greece, Sweden, UK, Finland) the learning experiences of the students cooperating with the science centres will be surveyed with several standardised instruments in pre-, post-, and delayed post-test schedules. Some of these instruments are translated from English to the other relevant languages following a specific methodology.

The measurement instruments are standardised and proved to be valid and reliable in informal learning settings.

Assessment Tools

The evaluation includes quantitative and qualitative aspects. The quan-

Table II: Overview of the Evaluation Categories and Instruments.

What assessed?	Instruments
Background variables	Raven-test Semantic differential
Cognitive assessment	A knowledge test, specific for each exhibit Questions asked by students
Motivation	Intrinsic Motivation Inventory Semantic Differential
Usability of technology	Heuristic evaluation
Other (unforeseen) factors	Focus groups questionnaire



titative aspects measure the learning effect by comparing Pre-test with Post-test scores for each pupil with regard to background variables, cognitive effects, attitudes and motivation (see Table II).

Background variables

The evaluation team will collect a variety of psychographic and demographic background information. Instead of surveying how the project's approach and technology impacts students, we will use this information to ask how did the project impact what kind of students. Other variables to monitor include age, gender, grade (form), and school type and attitudes about science.

Additionally, the Raven's Progressive Matrices and Scales (Raven's test) will be given to students to measure two major components of general intelligence: a person's intellectual and reasoning ability and the ability to make sense of complex data, to draw meaning out of ambiguity and to perceive and think clearly. The purpose of using the Raven test is to stratify the student population and to investigate the impact of the CONNECT project to students of different abilities.

The Raven test consists of standardised multiple-choice items. Each item has a 3x3 matrix containing a series of figures with the last one missing. The students have to select the missing figure from six given alternatives. There is a time limit of 30 minutes to complete the test.

Furthermore, there is an interest to know about the students' attitudes towards science. The Semantic Differential questionnaire will be used to collect the required information before the students go to the science centre. The Semantic Differential measures people's reactions to statements in terms of ratings on bipolar scales defined with contrasting adjectives at each end. An example of an SD scale is:

Important						Not important
	2	1	0	1	2	



Usually, the position marked 0 is labelled “neutral,” the 1 positions are labelled “slightly,” the 2 positions “very”. With such a scale, one measures directionality of a reaction (e.g. good versus bad) and intensity (e.g. slight vs. extreme). For the CONNECT project, a student will be presented with some concept of interest, e.g. visiting the exhibit was important. S/he will be asked to rate the concept on a number of the above scale.

Cognitive assessment

Cognitive change will be the most important vehicle for addressing our two research questions. Hence, they need to be extremely sensitive towards the students’ experience and thus require new and CONNECT-specific questions. Questions in the questionnaire can be open (e.g. “explain the preconditions for lift”) or multiple choice. The tests will be conducted before and two times after the visit. All three samples will be statistically compared.

Table III: Outline for Developing Cognitive Assessment Tools

Goal of Question	Details	Type
Exhibit specific questions		
Observations checking	Identifying what was the focus of students observations	Open-ended
Meaning of augmented visualizations	Checking whether the students understood the visualisations (e.g. did they understand that the arrows in AirTrack represent forces; or the dots in the balloon represent molecules etc.	Multiple choice
Understanding core concepts	Students will have to explain the phenomena in their own words and answer some questions regarding it	both
Questions for all exhibits		
Application	Using the knowledge acquired in the CONNECT experience in a different context (explaining or relating to different but related phenomena)	both
Specific Items	Raising hypothesis, Planning a simple experiment etc	both



In Table III we present an outline for developing the cognitive change tools across all four exhibitions.

Attitudes

Apart from collecting the general information about students and their knowledge, another assessment tool will look into student's attitudes and motivation. An important outcome variable for the CONNECT project is how does the CONNECT approach change the characteristic of students' attitudes. This information will be gathered from comparing the Semantic Differential test regarding attitudes against science to another Semantic Differential test to assess students' attitudes towards the specific exhibit-related activity.

Additionally, students' motivation will be assessed with a specific questionnaire named 'Intrinsic Motivation Inventory'. This is a collection of 25-items intrinsic/extrinsic motivation scale which has been developed and field tested by Deci & Ryan. In this questionnaire, one item is a statement like: "I enjoyed doing this activity very much". The students will value this statement on a seven-point scale ranging from "strongly disagree" to "strongly agree".



Qualitative Assessment

At some, but not all science museum sites, we will use a few open-ended questions to determine the perceived learning and perceived benefits of students and teachers from the experience. To code and quantify the answers validly, reliably, swiftly, and timely, we will use an iterative coding procedure. We will also use student answers as illustrations.

The qualitative survey is based on interviews, focus groups, and open-ended questions on the written knowledge assessment test.



Time-line for Test Assessment

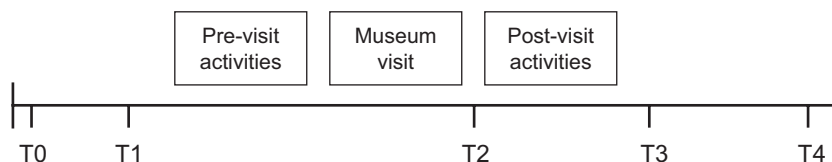
The following graphic will give you an overview of the activities and the evaluation procedure:

T1: We will test the knowledge of the students to see what they know about the certain topic. Also, we want to assess the attitude of the students of studying science in class by using a semantic differential. Both tests should take place around one week before the pre-visit activities. Test-time: 20-25minutes.

T2: Immediately after the museum activity while at the museum site we want to assess first issues concerning the usability and the comfort of the Headset and technical advices. This takes around 8 minutes. Then the students are asked to answer questions about their motivation (IMI) in the activities and they may fill out again a semantic differential (SD) which asks about the attitude experiencing the exhibit. Following the SD, there is one last question where we invite the students to write down any question they have. These tests take no more than 15 minutes.

T3: One week after the post-visit activities we test again the knowledge to see if there is any learning outcome. This test takes only 15 - 20 minutes.

T4: Six weeks after T3 we test again the knowledge to see to what remains in the long term memory.



Phase T0: ~ 6 weeks before Pre-visit activities

Phase T1: ~ 1 week before Pre-visit activities

Phase T2: immediately after the Science museum visit



Phase T3: ~ 1 week after the Post-visit activities

Phase T4: ~ 6 weeks after the Post-visit activities

Phase	Time needed	Questionnaire to be administered
T0	45'	-Raven test -Background variables
T1	25'	-Knowledge test -Semantic differential
T2	25'	-Semantic differential -Intrinsic Motivation Inventory (IMI) -Focus groups Questionnaire -Questions asked by students -Usability evaluation
T3	25'	-Knowledge test
T4	25'	-Knowledge test



C o n n e c t T e a c h e r s W o r k s h o p





Usability Evaluation Issues



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There are many challenges in the process of educational innovation that must be addressed in order to take advantage of these technologies for improving learning. When developing novel technologies, (Stone, 2004) argues that it is imperative to pursue a human-centred approach in order to minimise both risk and cost, which in turn maximises return on investment through the selection and implementation of appropriate technologies and learning content. In addition, Stone (2004) ascertains that ergonomics standards and other sources of human factors data are often either misinterpreted or misused, assuming, indeed, they are even consulted in the first place. Such that, when

they are misapplied, the focus of investigation is prone to suffer from a wide range of problems, particularly with respect to content presentation, usability, lack of target audience focus and relevance, poor refresh schedules and obsolescence.

There are a number of factors that contribute to the failure or misapplication of ergonomics methods, and indeed the application of human factors (HF) processes in general. It is within the scope of this paper to directly address these issues. Maguire (2000) summarises the primary contributing factors as:

- Conservative attitudes to the concept of taking up the ideas of usability and user-centred design beyond a basic level;
- Problems of integrating usability methods and tools within the design lifecycle;
- Usability activities taking place too late in the lifecycle to have any tangible influence;
- Over-formalised procedures that are soundly based, but take too long to apply to be effective.

When developing educational technologies, the design of the device or system is instigated by specific user needs, with respect to a pedagogical framework. With reference to these needs, the design solution is often determined and even constrained by technical issues (such as processing, hardware and software capability, functionality, power consumption and cost). Human factors issues are often an afterthought, with the most common misconception being that usability evaluation depends on the availability of a fully functional system, to be applied (Mill et al., 1986). As such, human factors considerations often appear too late in the development lifecycle to be of any benefit in the design and implementation of technology.

To prevent the employment of human factors considerations as an afterthought when designing educational technologies, a user centred design approach should be adopted. In such an approach, HF specialists interact with pedagogues, technologists and the actual users during the design process, before a prototype solution is developed. Within this design perspective, a pedagogical framework states the context of use. This user-centric contextual knowledge enhances the





technological requirements and identifies the balance between technology constraints and technological innovation. This balance is indeed what is broadly called “usability”.

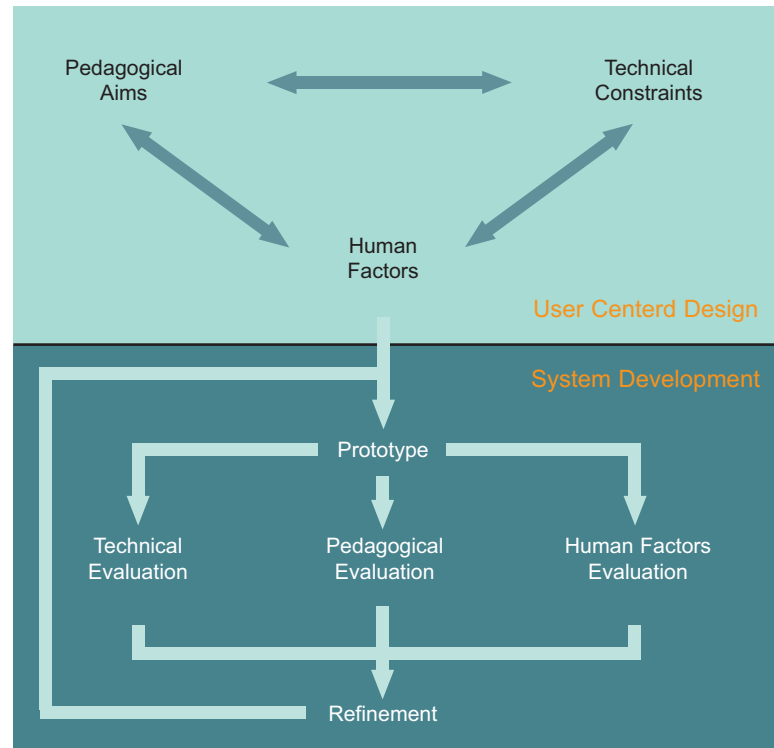
Shackel (1984) has defined usability as “the capability in human functional terms [of a product] to be used easily and effectively by a range of users, given specified training and user support, to fulfil the specified range of tasks, within the specified range of environmental scenarios”. Moreover, ISO9241 defines usability as the effectiveness, efficiency and satisfaction with which specified users can achieve specific goals in a particular environment and context. Here, efficiency is defined as the resources expended in relation to the accuracy and completeness with which users achieve goals and effectiveness is defined as the accuracy and completeness with which users achieve specific goals (ISO9241, 1998). As one of the important goals of educational technologies is to enhance and facilitate learning, an immediate impact of ensuring efficiency and effectiveness would be to increase the opportunity for learning. In addition, ensuring satisfaction, which in terms of usability is composed of comfort and acceptability of use (Bevan, 1995), would ensure the best possible environment for learning. In other words, the technology becomes transparent in that it is not obtrusive to the learners tasks.



A complete evaluation of educational technology should include all technology, pedagogy and human factors considerations. Technical evaluation concentrates on determining that the system functions reliably, is robust and maintainable. Pedagogical evaluation concentrates on determining if the user benefits from the learning experience. HF evaluation ensures that the system is usable, as defined by ISO9241, and may also concentrate on aspects regarding good practice, correct usage, and health and safety issues. Furthermore, HF evaluation may elucidate information for interpretation of the outcomes from the technical and pedagogical evaluations.

The user-centred lifecycle encourages iterative techniques, which are a method of formalising and controlling the evolutionary improvement of a user interaction with technology (Bury, 1984). As such, such iterative techniques provide further recommendations for technology

improvement that can be implemented in subsequent re-designs. This cycle of re-working and re-evaluating is of utmost importance, as it facilitates the evolution of design solutions towards usable technology. The process of setting up a user centred design, prototype development, evaluation and refinement is shown in the graph below.



*User centred design and
system development for edu-
cational technology derived
from ISO 13407*



The science museum settings



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In order to understand the context of science education within the CONNECT project, this section describes the different science museum settings and associated exhibits. In the framework of the test runs of the CONNECT project, four exhibits are augmented.



The Aerofoil exhibit

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

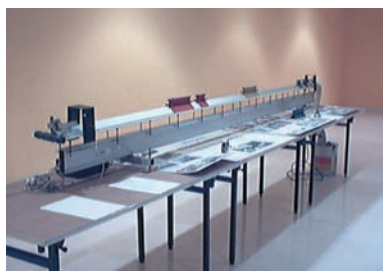
The Aerofoil is an interactive exhibit that aims to demonstrate why planes fly. The exhibit uses a fan that blows air across an aeroplane wing. The wing pivots on a horizontal tube that can be tilted by the operator, adjusting its angle with respect to the airflow being blown across it. Within the wing, ping-pong balls are located, which rise and fall, due to the lift force generated by the airflow across the wing.

The concept of friction: The Airtrack from Eugenides Foundation, Athens, Greece

Using a cart, which slides along a track, the AirTrack is an exhibit that aims to demonstrate the principles of friction. Along the surface of the track tiny holes allow air to be blown, which reduces the friction and facilitates the cart's motion. Within the exhibit, the weight of the cart and the angle of the track can be altered. Through this exhibit, students can experiment with the laws of motion, investigate the nature of frictional forces, and ultimately deduce the law of friction.



The AirTrack exhibit





Concept of Buoyancy and Particle Collision: The Hot Air Balloon from Heureka, Vantaa, Finland

The Hot Air Balloon is a closed system exhibit that presents a balloon rising when air within the balloon is heated, and descends as the air cools. The exhibit requires no manipulation; rather the participant observes the motion of the balloon with respect to the temperature of the air within the balloon. The temperature is displayed on a gauge located on the base of the exhibit.

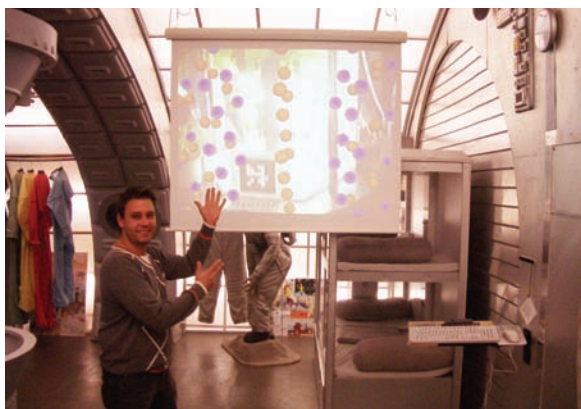


The Hot Air Balloon

Photosynthesis: The Biotube, Xperiment Huset, Växjö, Sweden

The BioTube is an exhibit in which plants are encased in a Perspex tube. Within this controlled environmental, the conditions of light, humidity and temperature can be altered by the participant. The variable can be altered by the user and the concentrations of oxygen and carbon dioxide, displayed on a standalone monitor change in real-time. The aim of the exhibit is to teach aspects of photosynthesis with specific respect to sustaining plant growth in outer space.

The BioTube exhibit.



Moments of the CONNECT Teacher's Workshop





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