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Implementation Guide





connect

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CONNECT

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

Implementation Guide







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For the Science Teacher and the Museum Educator

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

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.

In the framework of the project an advanced learning environment will be 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 will be practically achieved by the use of **augmented reality (AR) system** which will visually explain with the help of virtual objects projected onto the real setting the physical phenomenon manifested by an experiment inside the museum and also connect it to the formal school curriculum. The Virtual Science Thematic Park will include two major components:

- the CONNECT platform which will facilitate the virtual visits to the museums and science parks.
- the mobile AR system (mobile unit) which the student will wear during his/her visit and

The museum visit of a student will also involve an element of excitement and interactivity by setting a communication channel between the visitor, the school and the museum during the visit. This will enable the student who is physically having a tour in a science museum to communicate his/her experiences to his/her virtual classmates through a personalised communication unit. He/she will be able to comprehend the experiment under study and the underlying physical phenomena and connect it to the theory taught inside the classroom; he/she will then be in a position to explain it and become a personal remote guide to his/her virtual classmates or be guided by them through the museum. In this procedure emphasis will be placed on certain innovative pedagogical principles such as the curiosity of young people about the real world, their willing to communicate and share their enlightening experiences with other youngsters, their eagerness on the use of new technologies, their endowment with acquiring knowledge through having fun and experiencing.

The key to a significant contribution to the student's personal growth lies in the ability to make the best use of informal (but yet well structured) education as an indispensable section of school activities. The project looks upon informal education as an opportunity to transcend from traditional classroom based teaching, to a "feel and interact" student experience, allowing for learning "anytime, anywhere", open to societal changes and at the same time feeling culturally conscious. These pedagogical concepts and learning practices would address implementing a set of demonstra-



tors (**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 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 playful learning. To assure maximal usability of the new tools, optimal adaptation to the local environments and realistic evaluation of the pedagogical effects, the CONNECT project uses a heavily student-centred approach. This will be achieved by involving in a series of field trials many students in Finland, Greece, Sweden, and the United Kingdom. Moreover, the trials are used to strengthen the connections between schools and informal learning of all students, i.e. visits in museums and in science parks.

The project includes 3 extended phases of work: (a) the Test Runs, (b) the Final Run (Phase A), and (c) the Final Run (Phase B). During the Test Run, the technological tools will be initiated to different educational environments. During the Final Run (Phase A), the actors involved will be using the technology and learning content in science centres and museums in a second five-month cycle. These two first phases will be performed with scenarios developed by the project's pedagogical team and presented analytically in this guide. With the experience gained from the two first pilots and after the appropriate modifications on both the educational tools and on the educational approach, the final and most important cycle of the user-centred work, will be implemented. The Final Run (Phase B), a five-month phase, is where the implementation of the open educational pathways. In this phase teachers and museum staff will collaborate in order to create their own pathways and motivate

their students. These phases are not only meant for evaluation purposes (technological and pedagogical) but involve teachers, students and museum educators to give direction to the project and its technological and pedagogical results.

The aim of this implementation guide is to support the teachers and the museums educators involved in the project to implement the proposed activities in the school and in the science parks and museums. It consists of four main chapters which include all the necessary information for the CONNECT project's implementation. The **first** chapter describes the philosophy of designing a learning scenario with the educational activities around it. It fully describes the four exhibit related educational scenarios that are available during the Test Run along with several educational activities. It proposes three educational pathways for the realization of the proposed scenarios, to facilitate the linking between the school and science centre activities. The **second** chapter describes the functionalities of the CONNECT platform in the framework of the preparation of the proposed educational pathways for the Test Runs. Initial ideas about the development of the Virtual Science Thematic Park are also presented. The **third** chapter describes the AR system that has been developed in the framework of the CONNECT project. It includes useful information for the user and it describes the main functionalities of the AR system prototype to be used in the initial trials in the participating science centers and museums. The **fourth** chapter describes the evaluation approach of the CONNECT project. It includes the evaluation goals, the design of the project's two-phase study and the rationale for using specific assessment tools. It also provides specific guidelines for the teacher of the time and place to administer questionnaires to the students. As appendices the AR system starting procedure and the evaluation instruments to be used for the Test Runs are presented at the end of this guide.

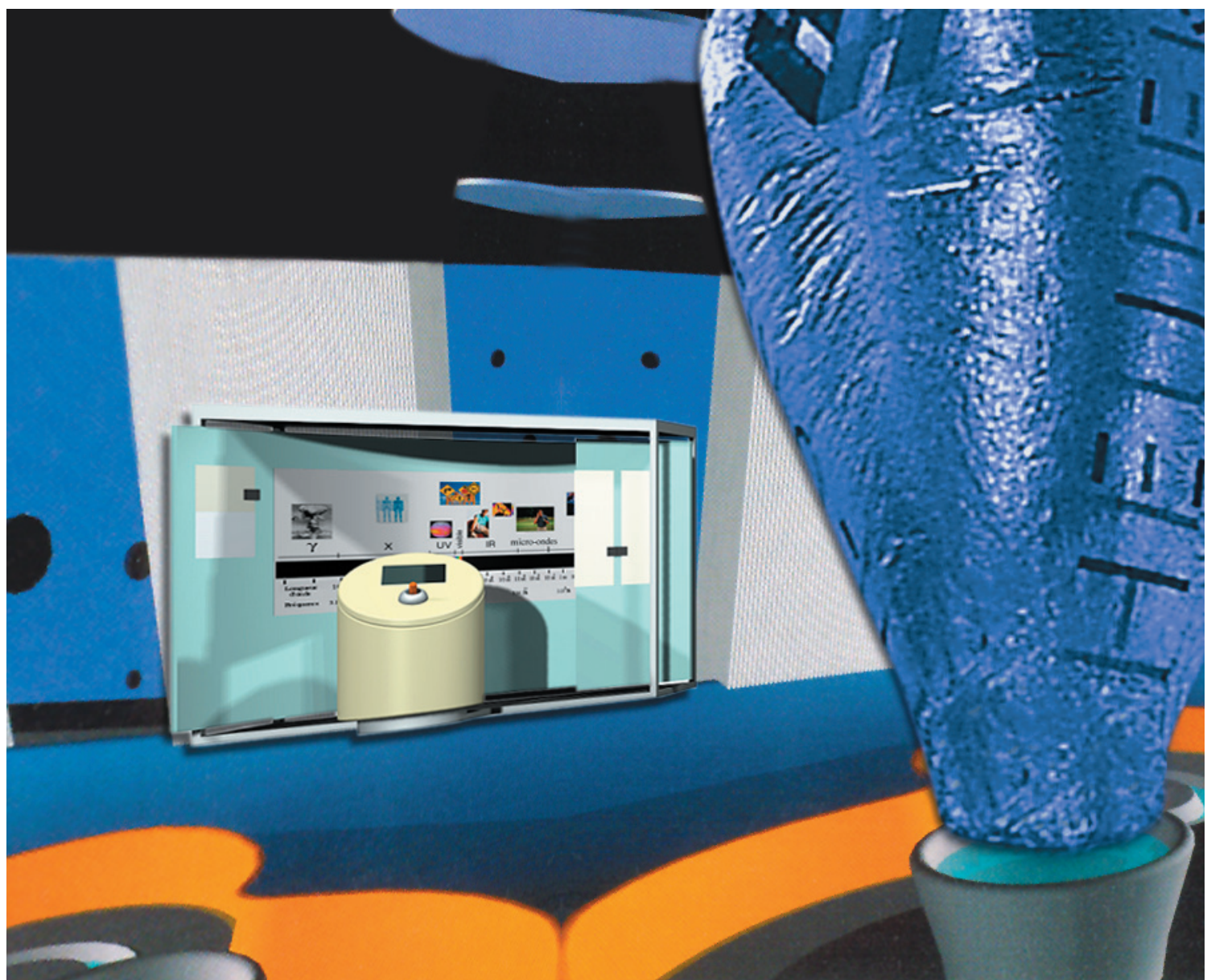




[...As a society we need to recognise and support the vast, important and successful learning enterprise that takes place outside of schools and the work-place –learning from museums, libraries, the Internet, TV, films, books, newspapers and magazines. Collectively these experiences encompass what is 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



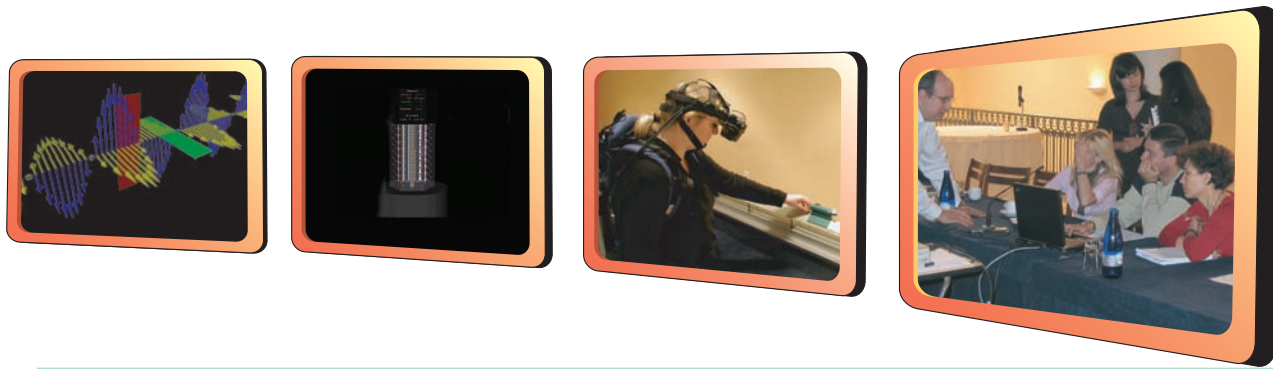




Visualising the invisible: The CONNECT Virtual Science Thematic Park

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.





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 instructional 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?

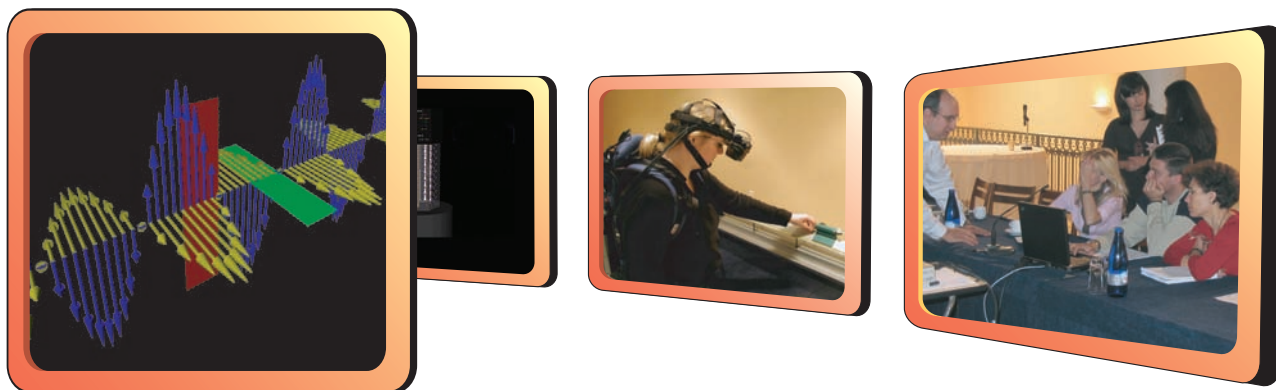
Tackling the research questions of the project demands the coordinated efforts of an interdisciplinary team of workers with theoretical and practical expertise in diverse disciplines. This project brings together schools and science centres, and produces novel computer-based technologies such as augmented 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.







Learning Scenarios

This chapter describes the philosophy of designing a learning scenario with the educational activities around it. It fully describes the four educational scenarios that are available during the Test Run along with several educational activities. It proposes three educational pathways for the realization of the proposed scenarios, to facilitate the linking between the school and science centre activities.

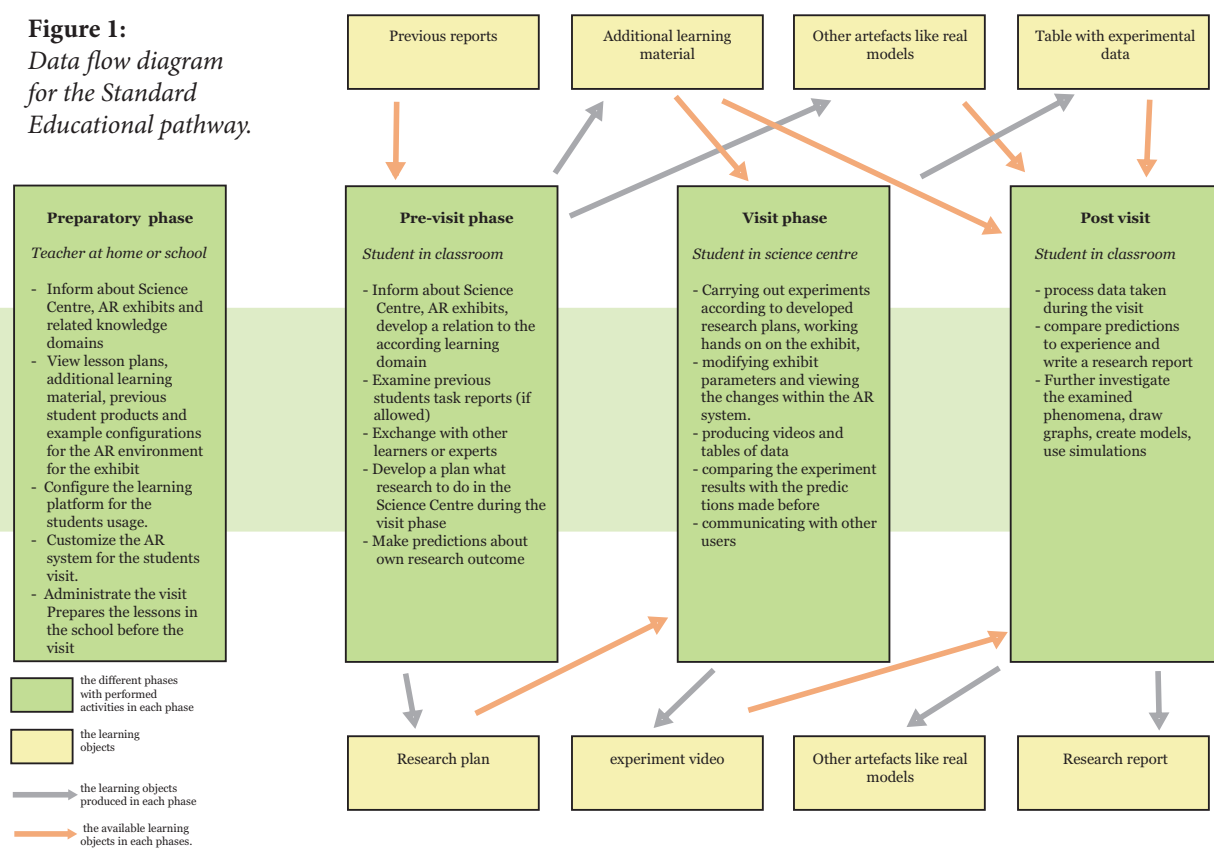
1.1 Educational Pathways for CONNECT

The CONNECT project follows the contextual model of learning, which emphasises the importance of the learners' contexts (i.e. personal, physical, and socio-cultural) when learning (Falk, 1999) and explicitly points out the role of free choice learning (Falk and Storksdieck, 2001; Dierking, 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.

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 to 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, 2001; 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

Figure 1:
Data flow diagram
for the Standard
Educational pathway.





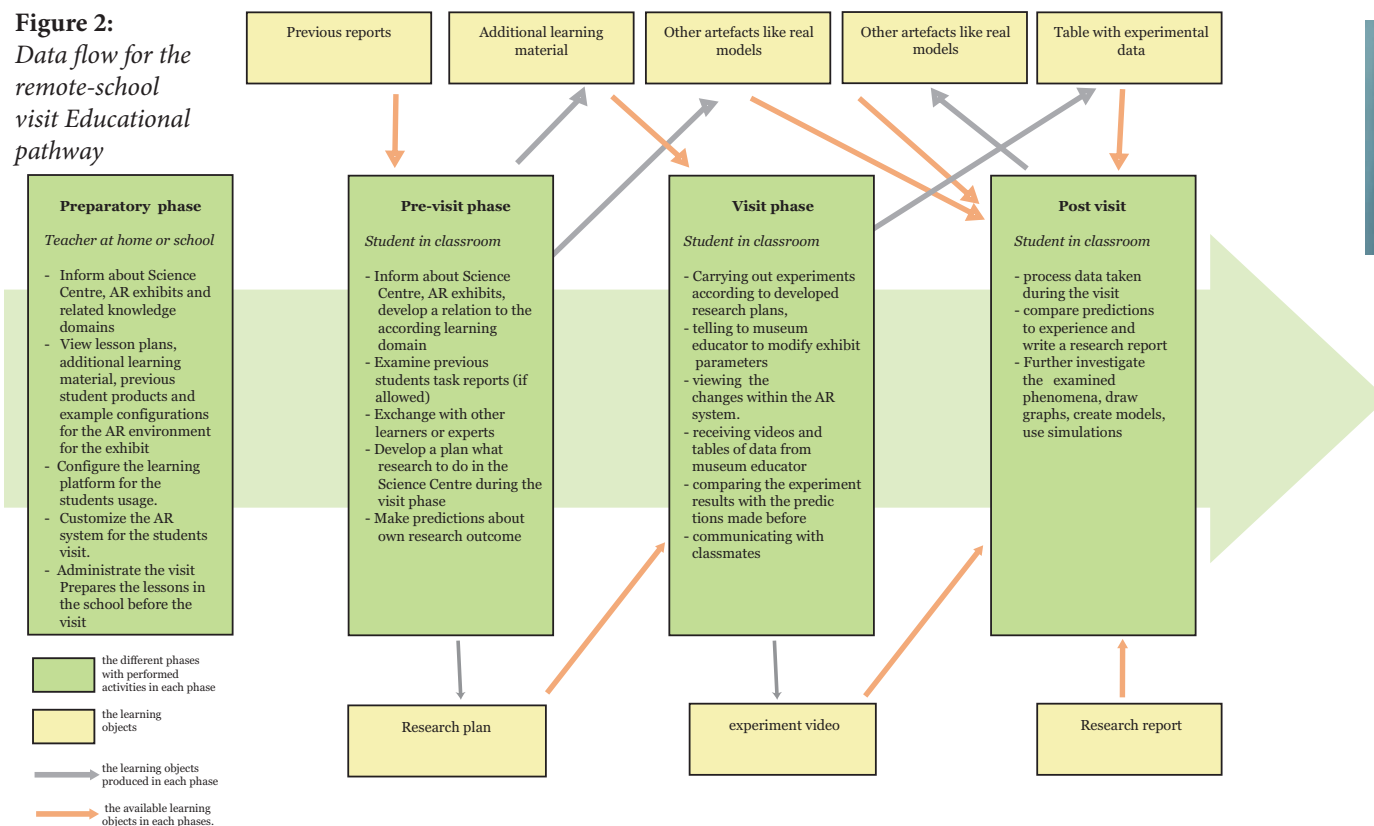
making process (Jonassen, 2002).

To achieve such goals, the CONNECT consortium has created three different educational pathways, the standard educational pathway (Figure 1), the remote school visit educational pathway (Figure 2) and the school exchange educational pathway (Figure 3). The educational pathway refer to a specific series of activities, undertaken by teachers and students, which illustrates what they could do to teach/learn a specific science topic in the CONNECT project. Educational pathways connect schools and science centres to promote quality learning for all students. In addition, they are valuable tools for lesson planning. Creating pathways to connect schools and science centres means identifying methods by which to embed a visit of a school class to a science centre. The aim is the students to learn optimally and the visit to 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. Data produced during the visit while examining the exhibit should be easily accessible when being back in the classroom.

Next to the standard visit pathway, 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 pathway could apply. Pre-visit 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 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 2 shows typically performed activities and data flow according to this remote school visit pathway. It can be observed that the Visit phase is split into synchronized activities performed at the same time in a school and a science centre.

A third, more sophisticated possible pathway pattern might be the school-exchange-educational pathway (figure 3). Two schools collaborate and share knowledge in the pre-

Figure 2:
Data flow for the remote-school visit Educational pathway



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. In this way, more sophisticated research could be done, which cannot happen by visiting just one museum. More complicated pathways or combinations of the proposed ones are possible.

Each educational pathway uses different technology, e.g. the standard educational pathway uses the mobile AR system, the remote-visit pathway uses the mobile AR system and broadband technology. The teacher needs to decide which pathway to use and then choose the educational activities (lesson plan) to carry out. The educational activities can be

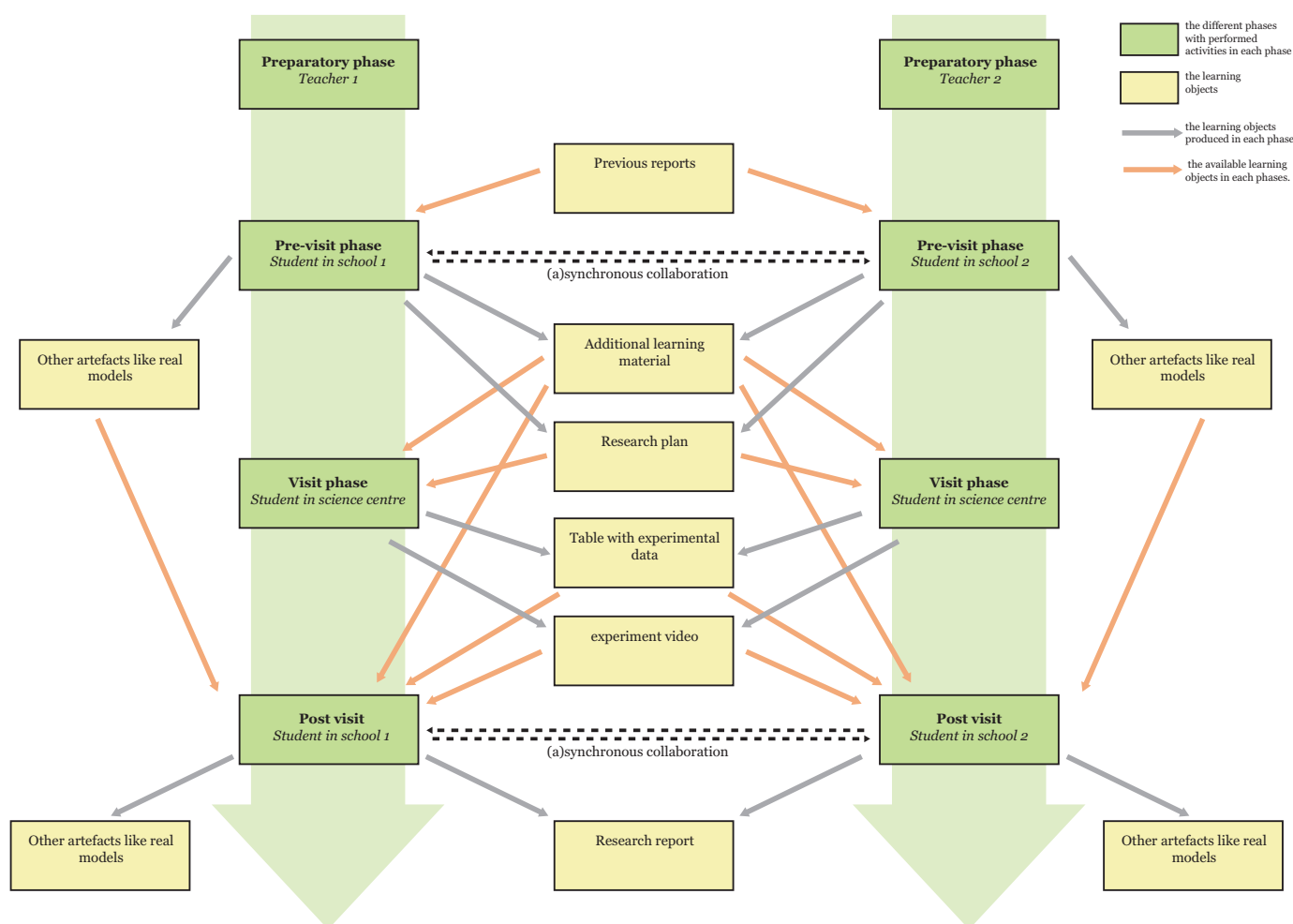
the proposed ones or others chosen by the teacher. Following a user-centred approach for the CONNECT project, you, the teacher, are part of the user’s group and co-designers of the students experience through learning scenarios.

1.2 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 sci-

Figure 3: Data flow for the school-exchange Educational Pathway





ence 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 stu dents?)
- 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 re search 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 1:

1.3 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 facil-

itate 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 1: The General Structure of Educational Pathways.



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?

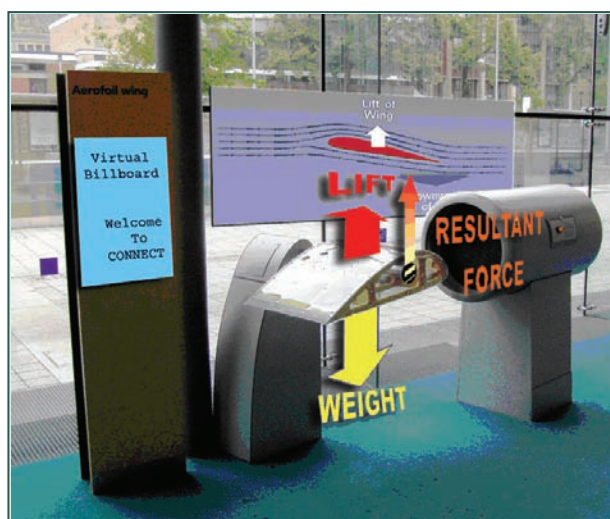
Common Student Misconceptions: A common misconception is that lift is created due to Bernoulli's effect. There is nothing wrong with Bernoulli effect, but it is not complete. There are also problems regarding the invisible nature of the phenomenon. In particular, students often:

- 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.



Figure 4:
the Aero-
foil exhibit
showing
visual aug-
mentations.



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 will be done by administration of a diagnostic assessment tool, and through discussions in which the students can externalize and express their alternative beliefs and explanations about forces and flight.



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.

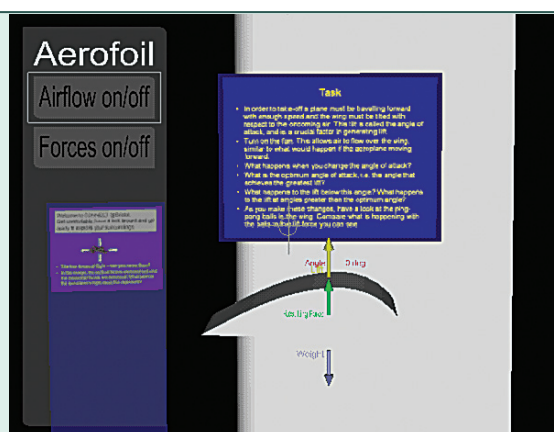


Figure 5:
a snapshot
of the
Aerofoil
AR view

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 will be 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.

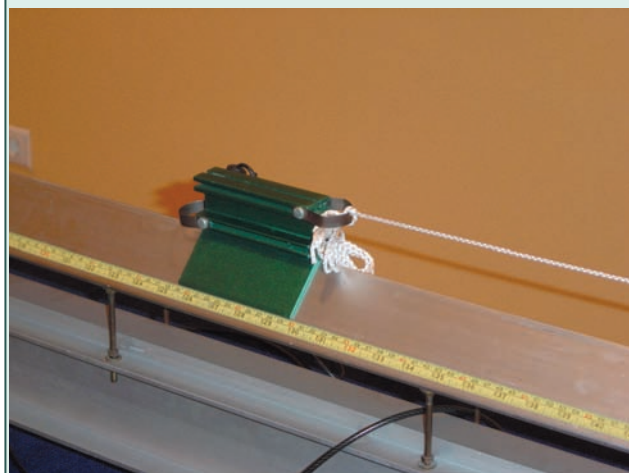
They could watch and analyse the video of their experience and analyse data records that are preset and others that were recorded in real time. They could explore remaining predictions e.g. about forces and air flow.

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 will be given an evaluation exercise to record their learning outcome.



What stop things from moving? The Airtrack, Eugenides Foundation, Athens, Greece



Scientific Content: The exhibit demonstrates 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 than 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 horizontal 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 Technology of the University of Athens which is currently hosted in 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 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 cushion 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?

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

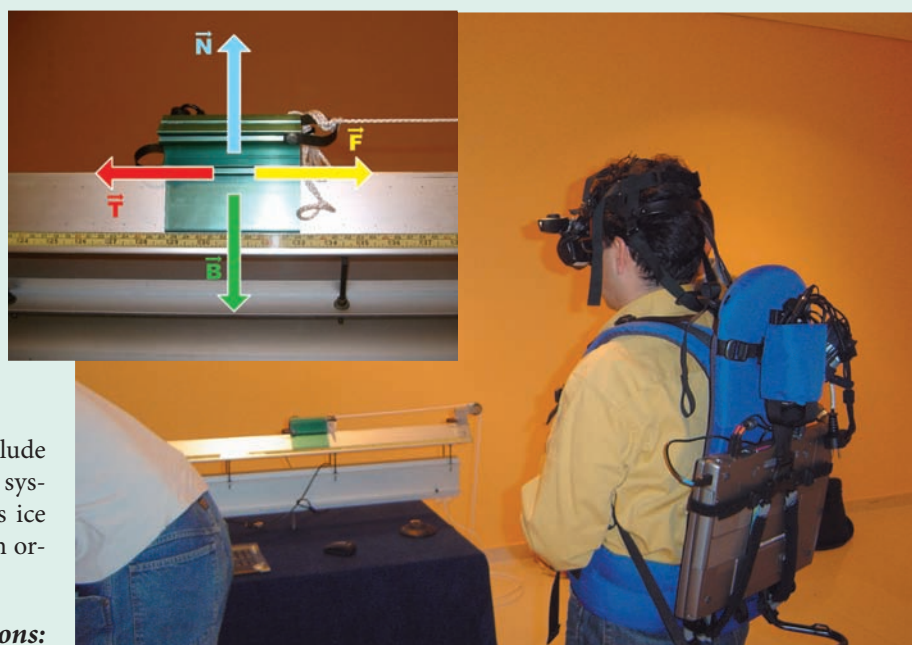
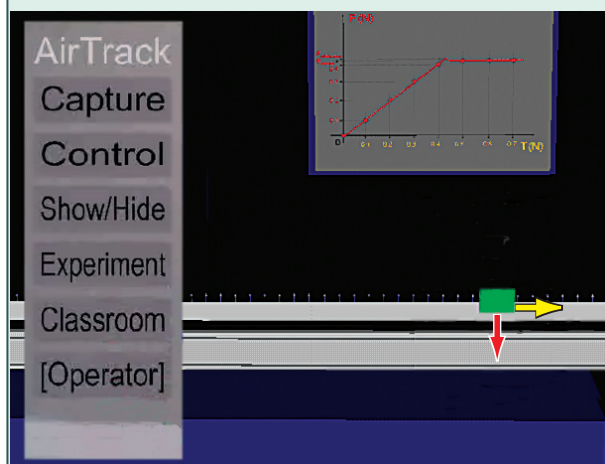


Figure 6: The Airtrack exhibit showing visual augmentations.



Figure 7:
A snapshot of the
Airtrack
AR view



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 will be 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 set-ups/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.

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 $F=1\text{N}$.
- 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 pre-visit 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 exhibit 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 will be 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.

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

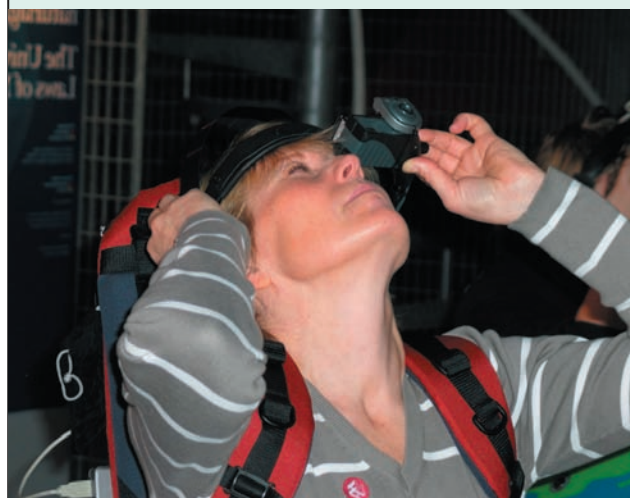


Figure 8:
The Hot
Air Balloon



Exhibit Description: The Hot Air Balloon exhibit shows a balloon 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 °C). 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.

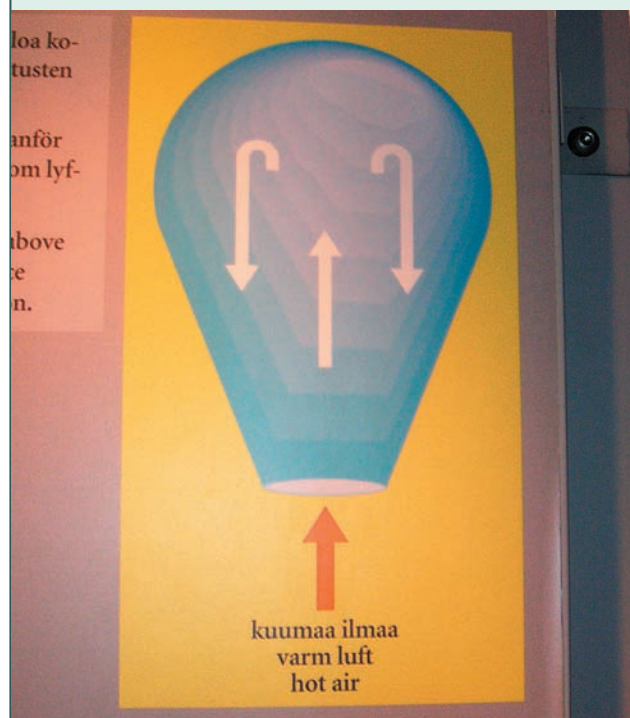
Focal Research Questions: Why does the Hot Air Balloon rise? Why does it stay up in the air? Why does it come down again? What is the relationship between the temperature inside the balloon and these movements?

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 AirBalloon-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 particles (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 teacher in cooperation with the students organizes the visit to Heureka. The students can view the overall exhibition, a video of the HotAirBalloon 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 will be 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 gripping 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 will be 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, its 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 will be given an evaluation exercise to record their learning outcome.



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

Preparation phase

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



Figure 9:
The BioTube
exhibit



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 Bio-Tube 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.

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 will be 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.

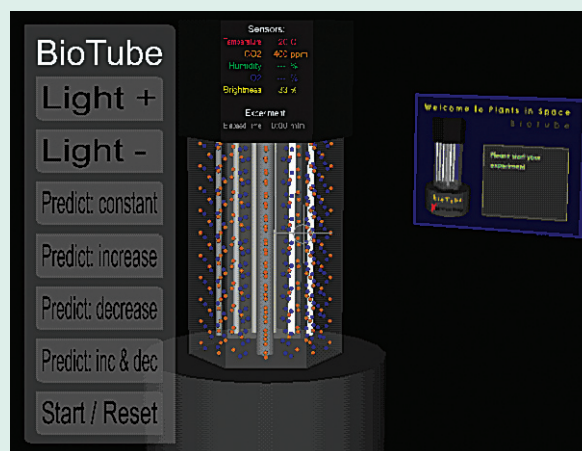


Figure 10:
A snapshot of the visual display

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 catches 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 CO₂ and O₂ 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 CO₂ 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.

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 CO_2 molecules rushing in and O_2 molecules and water vapour rushing out. Simon controls the level of CO_2 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 CO_2 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 synthases 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 CO_2).

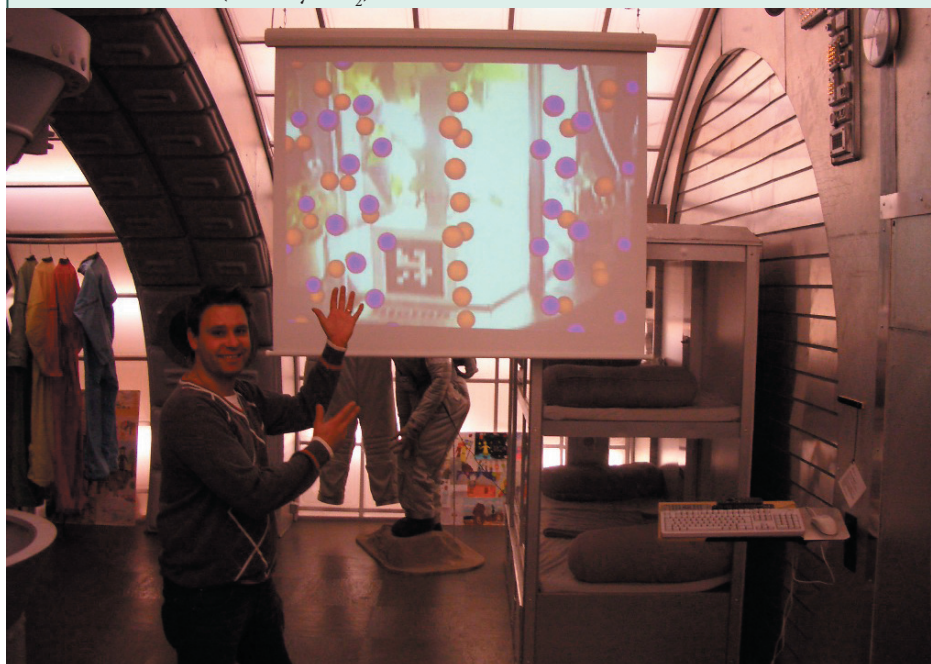


Figure 11:
Video projection
of the AR view



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

Post visit phase

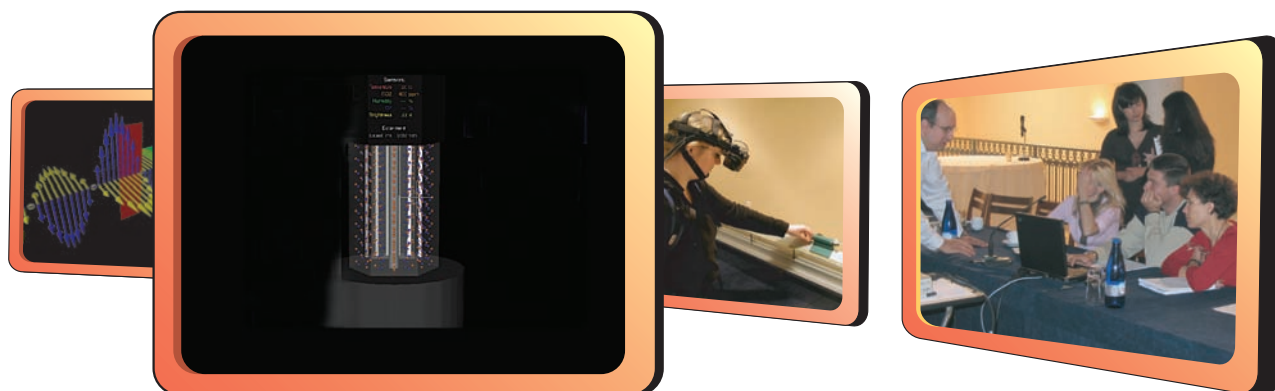
Reflecting and process the visit. All students discuss the science museum experience with the teacher. The teacher proposes to take a look at the data that was stored during the science museum visit. They discuss Anna's hypotheses and compare them with the ones that students made in the remote classroom. 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 CO_2 was 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.





Preparing the Educational Pathways

This chapter describes the functionalities of the CONNECT platform in the framework of the preparation of the proposed educational pathways for the Connect Runs.

2.1 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 also intercon-

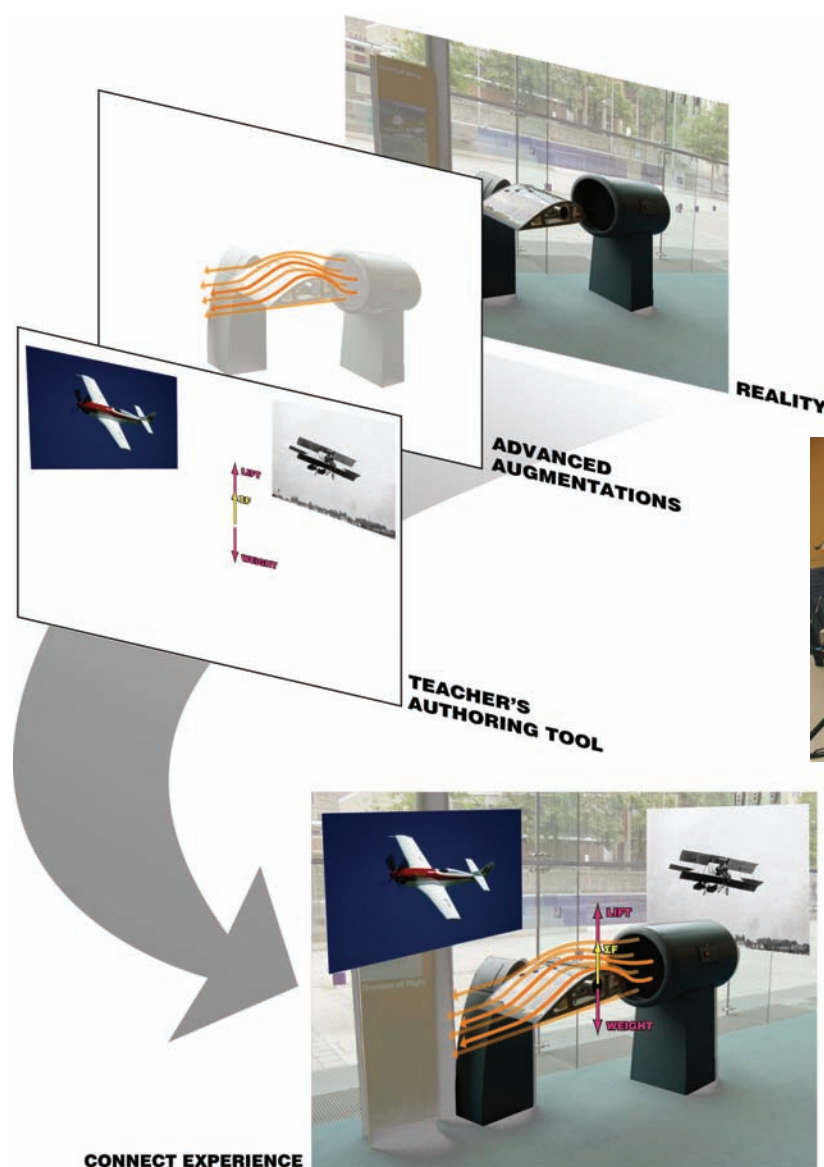


Figure 12: Visualising the invisible
The CONNECT experience could be realized by adding to the student's view a series of augmentations, advanced or simple. The advanced augmentations (E/M fields, molecular motions, air flow, microscopic view of the matter) are created by the CONNECT team. Through an 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.



nects 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 require-

ments 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.

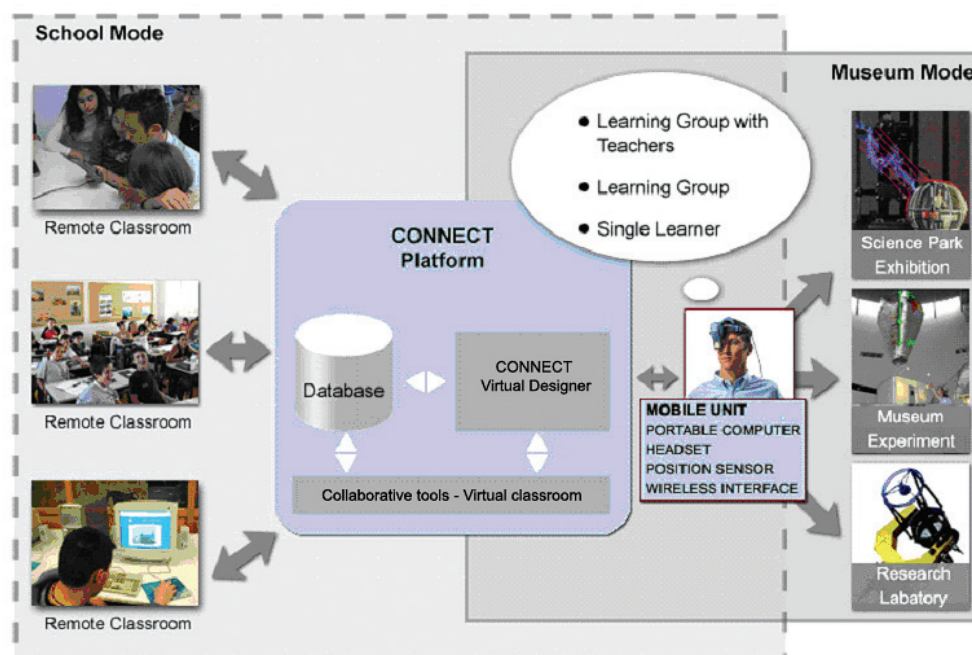
The integrated CONNECT system provides an ambient learning environment which functions in two distinct and equally important educational modes: the museum and the school mode (see Figure 13).

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 audio-visual communication channel. The two groups of students can interact with each other via an audio connection.

2.2 Description of the CONNECT Platform

The CONNECT Platform assumes that someone aims to teach science the "CONNECT way". This person is referred to as the **Educator**. The Educator can be any person. The project focuses on connecting formal curricula and informal learning, which places special attention on the K-12 teacher; hence in many cases Educator and Teacher be-

Figure 13: The system's architecture.



come equivalent. Similarly, **Student** is the person receiving the benefits of the education but for our purposes they are equivalent to K-12 students.

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



Figure 14: 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.

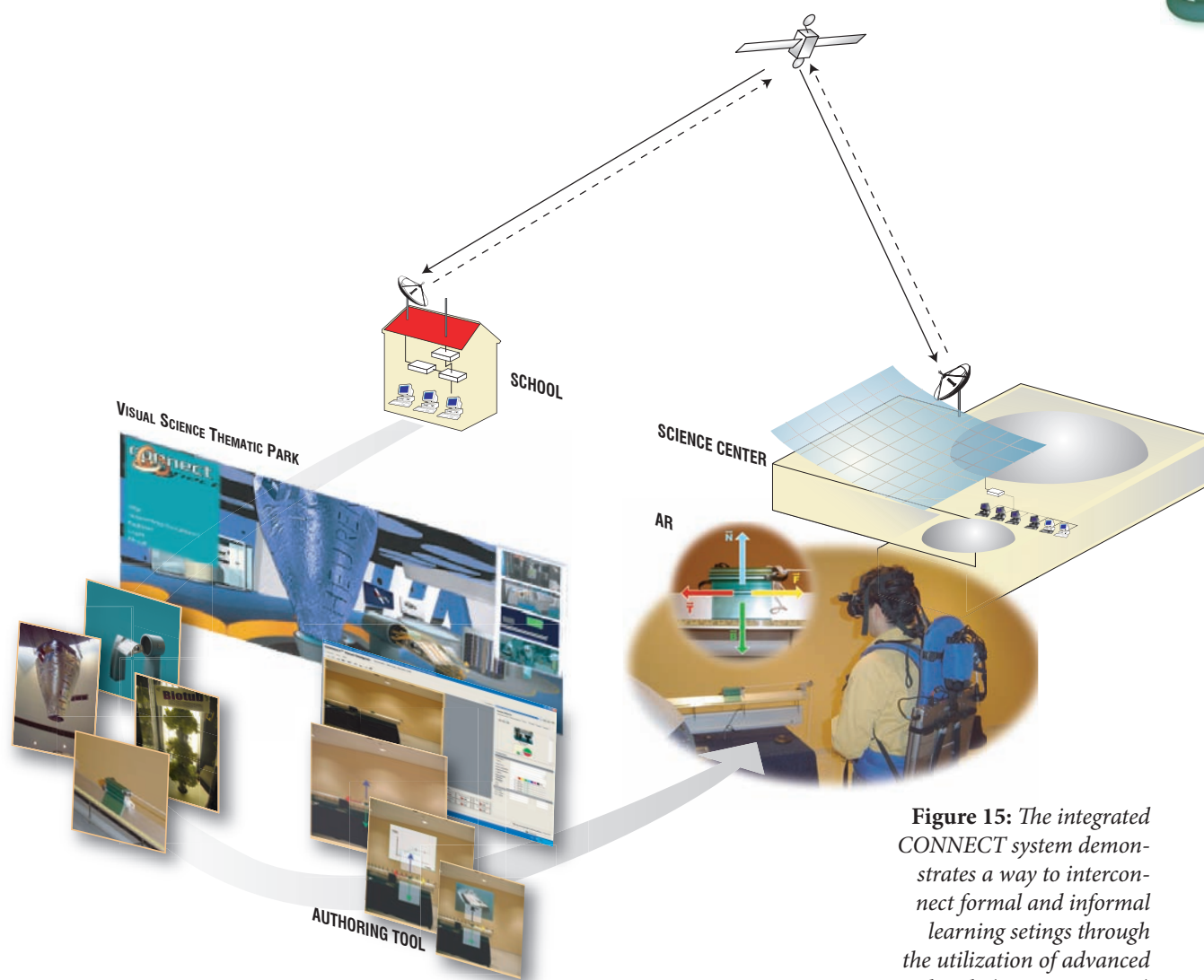


Figure 15: The integrated CONNECT system demonstrates a way to interconnect formal and informal learning settings through the utilization of advanced webtools (VSTP, CP, CVD) and AR applications.

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.

2.3 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 is currently under development and it will not be implemented for the Test Run. An indicative interface is presented in Figure 14. A series of functionalities have been proposed and discussed between the



The VSTP is under construction.

technological and pedagogical team.

The interface will depict 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.

2.4 The CONNECT Platform Tutorial

The CP has been implemented to support the educator in setting up educational pathways. In particular, 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://195.251.41.37/connect/>

The browser should load the initial screen (Figure 16). A

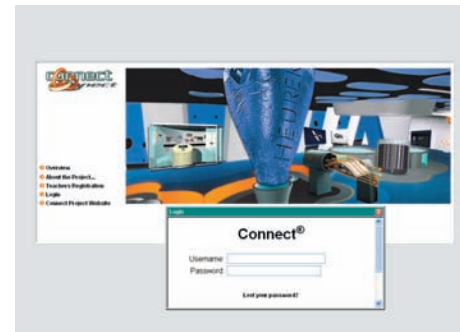


Figure 16

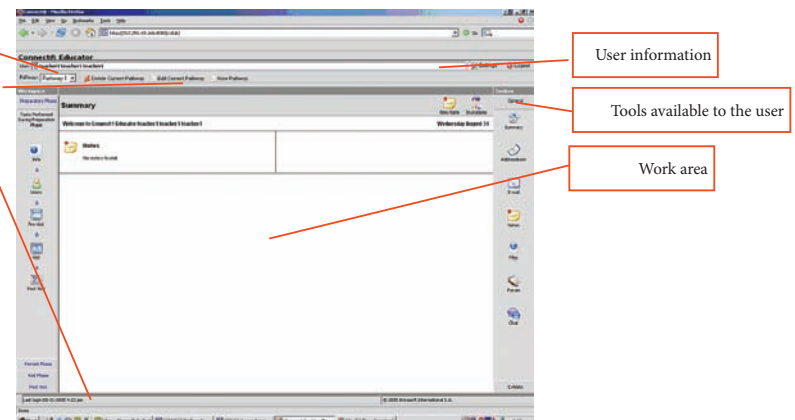
username and password will be provided to you upon request but for the purposes of this training exercise we will use a default account “teacher” with password “123” (remove the quotations when typing in the username and password).

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

Remember to
access the tool
with IE 6.0 +,
enable pop-ups
and have Java
installed.



- 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 chapter 1). 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. You will be asked to enter the following information:

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 discard them.

Preparatory Phase

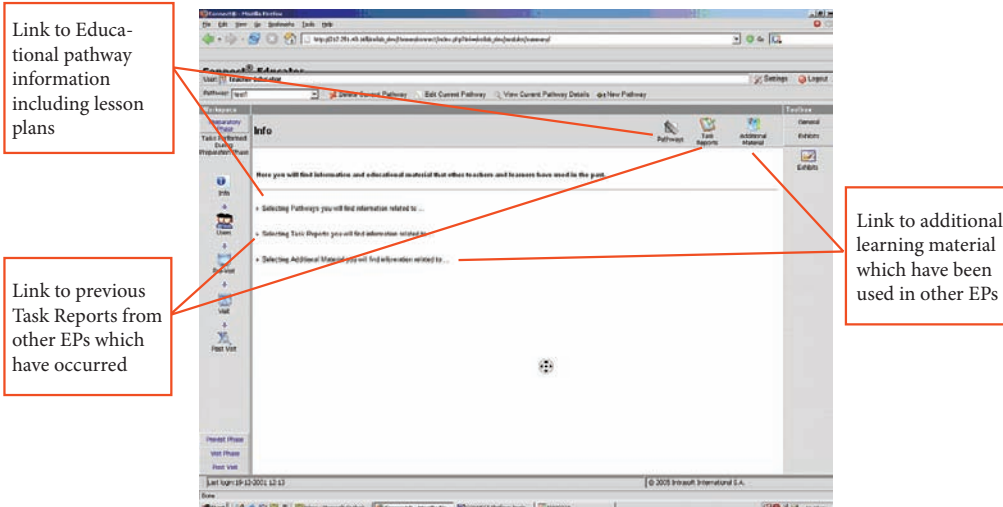
Having created an Educational Pathway, you have taken the first step in establishing an educational pathway. Currently, you are at the preparatory phase of the Educational Pathway. In this phase, as the educator you will need to:

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



“Info”, 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.



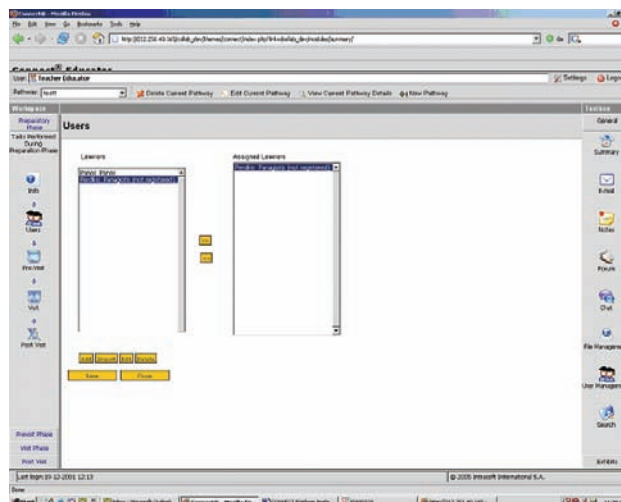
and “<<” buttons you can assign them to the current Educational Pathway. To add a new student simply press the Add button. A dialogue will appear asking for the new students first and last name (Figure 18).



Figure 18:
Preparatory Phase-
Users->
Add User

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 “>>”

Figure 17:
Screen for
Preparatory Phase
-> Users



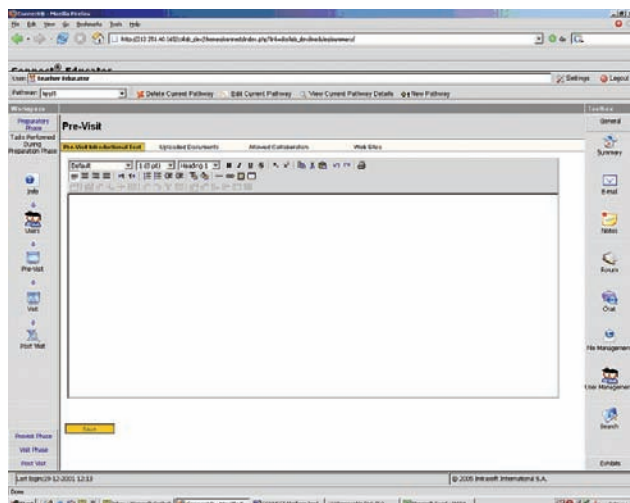
When you type in their names press Add to add the user or Close to cancel the process. In case you have a number of students that you need to enter the system allows you to create them all at once by inputting in a text box with separated pairs of last and first names. You probably have noticed that 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 from the “Learners” list and press the Edit button. An interface similar to the one in figure 18 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 19 shows your current work area.

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

Figure 19:
Screen for
Prepara-
tory Phase
->Pre-Visit

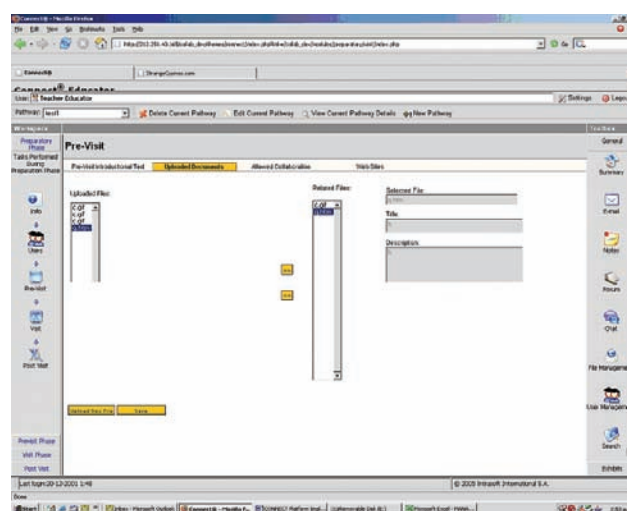


1. **Pre-Visit Introductory Text:** Here, the platform makes available to you an editor where you enter and format text. This text will be presented to the students when entering the CP in the Pre-Visit Phase. You type in the message, you want them to see and save it pressing the Save button.
2. **Uploaded Documents:** The educator can add documents or files they want their students to see during 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 (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 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

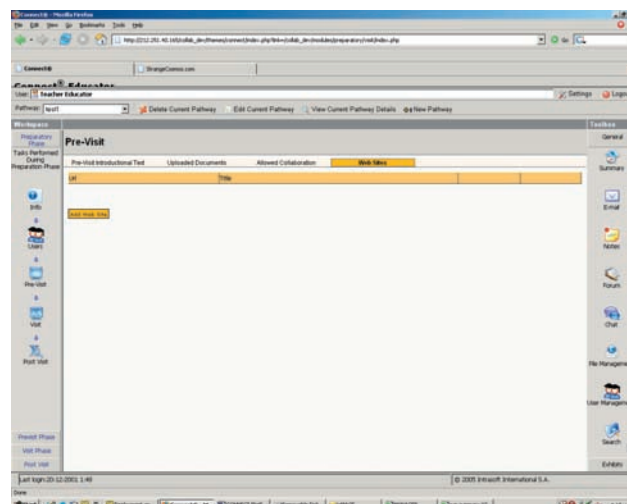


Figure 20:
Preparatory
->Pre-Visit->
Uploaded Docu-
ments

This part of
the CP is under
construction.

Figure 21:
Preparatory ->
Pre-Visit->
Web Sites

this phase. In Figure 21 you can see the interface. 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

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.

 The audio-visual communication between the classroom and the mobile AR unit user is currently under construction.

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.

 The experimental data collected by the mobile AR unit user currently is not transferred to the CONNECT platform. This communication system is under construction.

1. **Set Global Access:** For each piece of content you

Figure 22:
Pre-Visit Phase->
Research Plans

Phase->Research Plans. Figure 22 shows the interface.

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



all the files students uploaded in this phase for the current Educational Pathways. 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 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 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 23. 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.

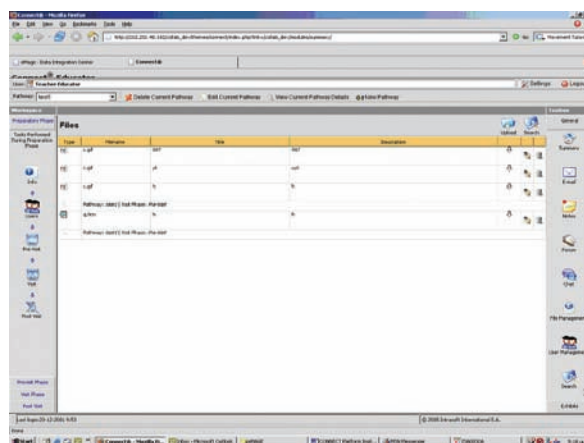


Figure 23:
General->
File Man-
agement

- 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 24.

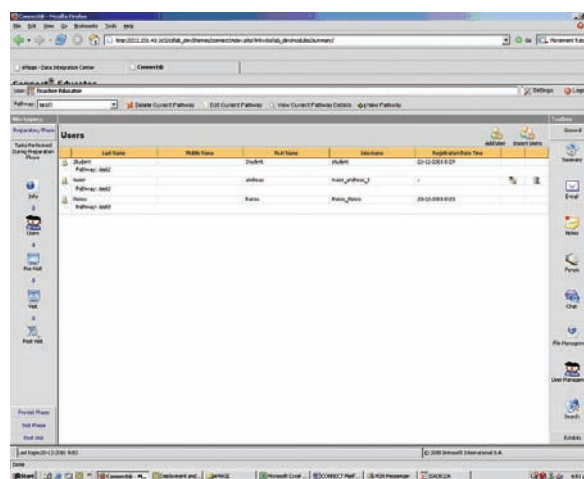


Figure 24:
General->
User Man-
agement



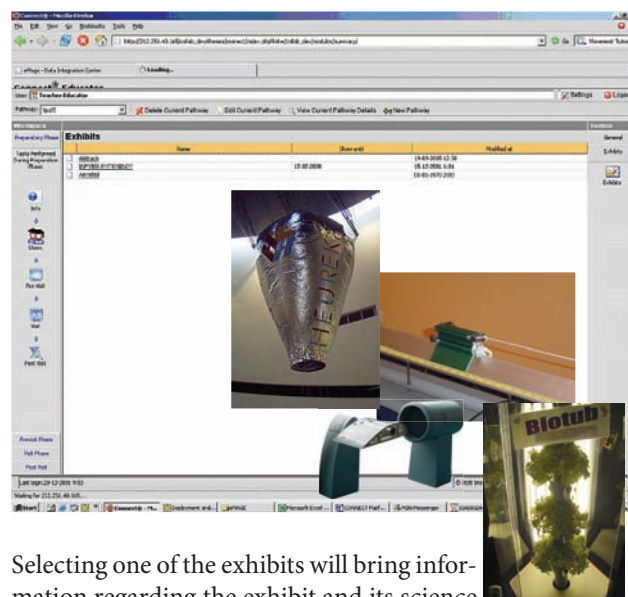
The Search Functionality is under construction.

It 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 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 25.

Figure 25:
Toolbox
Exhibits->
Exhibits



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 clicking on it, you enter the CONNECT Visual Designer.

2.5 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.



At later versions, Teachers will have more control over these objects.

- b. Phenomena Representation: Dynamic 3D objects show what is happening while a specific phenomenon 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:

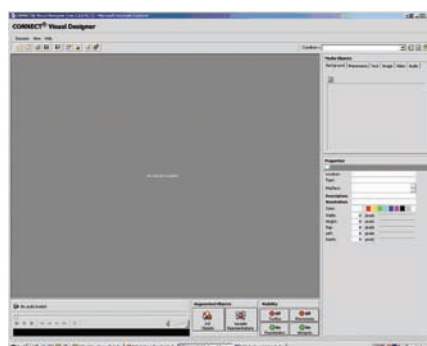


Figure 27:
Entry page to the CVD

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.

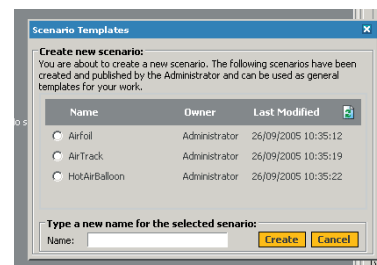


Figure 28:
Create new scenario

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.

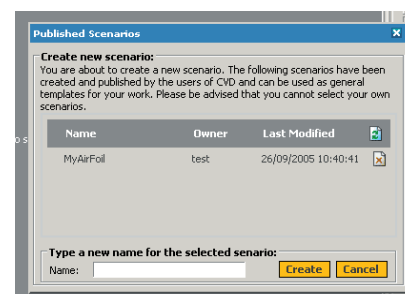


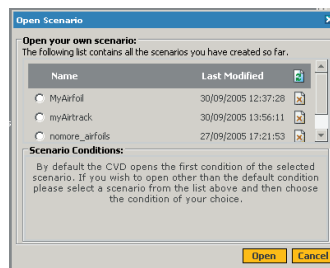
Figure 29:
Open a Published scenario

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 30:
*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 from the first cell in Figure 31. 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

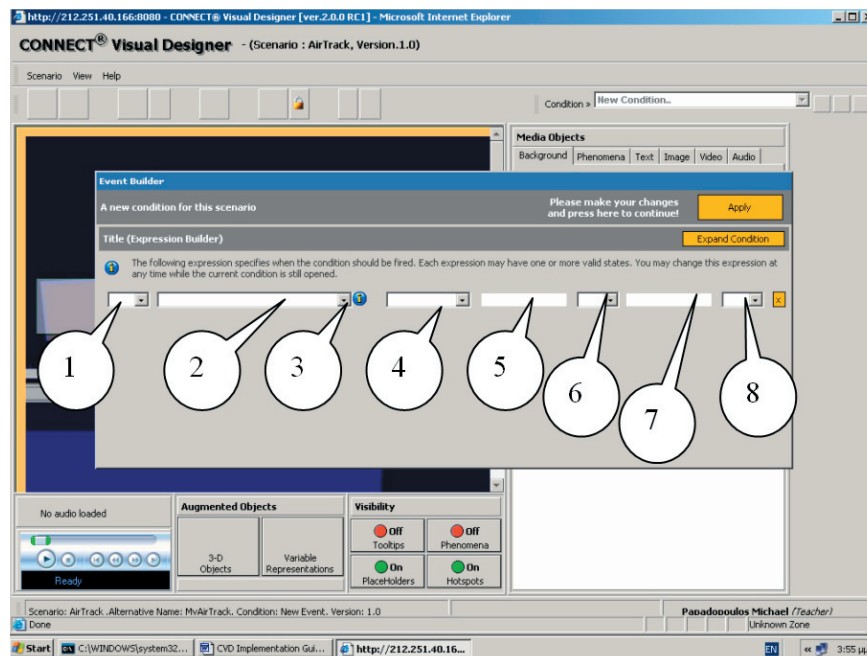


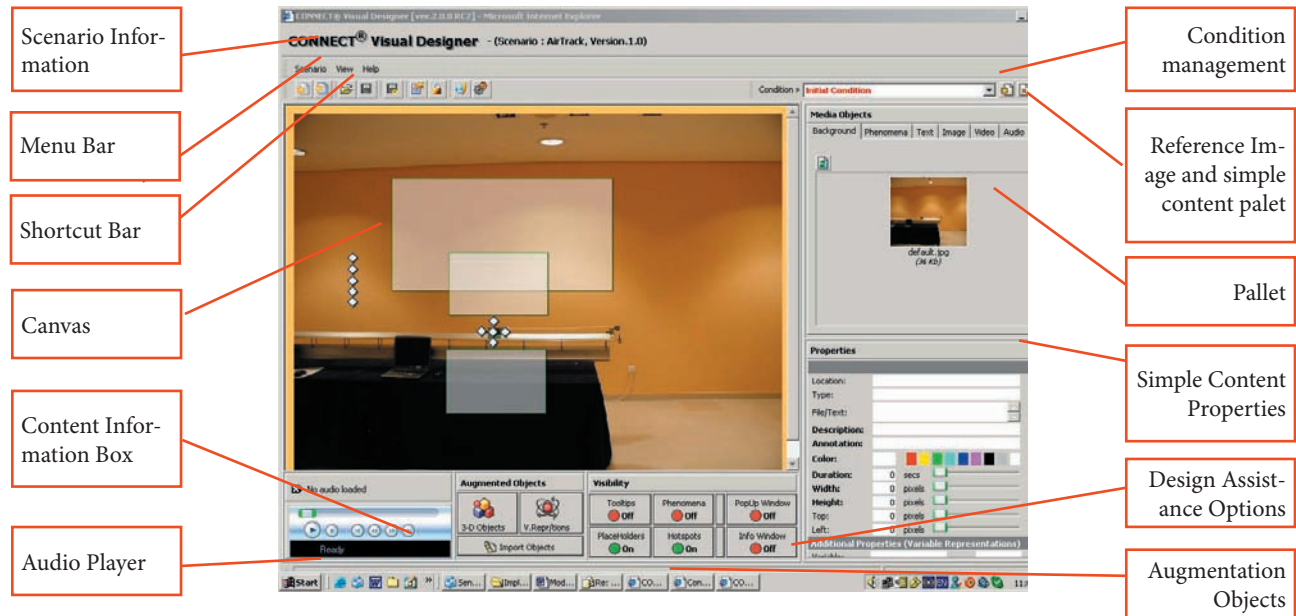
Figure 31:
Condition Builder. Elements are referenced by their position from left to right.

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 be 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 32:
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 32, 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”.

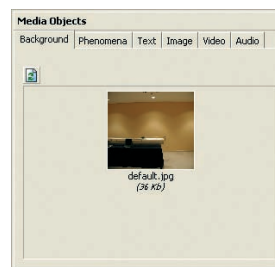
Simple Content is standard multimedia content. With the exception of 3D Static objects, the educator uploads them into the tool. They create 3D Static objects via the CVD interface. The process is very similar to the one described for Variable Representations. All Simple content objects have properties, 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 one. 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 refresh 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.



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 34.

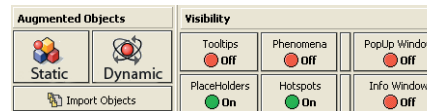


Figure 34:
*Augmented
Objects and
Visibility group*

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 appearance 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 related” 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 related”.

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

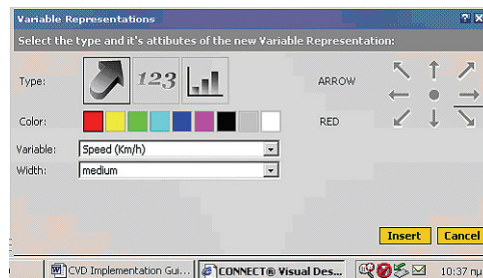


Selection and Placement of Variable Representations

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 34). The two (2) buttons allow access to 3D static objects and Variable Representations. Clicking on the Variable Representations button.

Figure 35:
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 orienta-

tion 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 which follow 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 Representations 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 36.

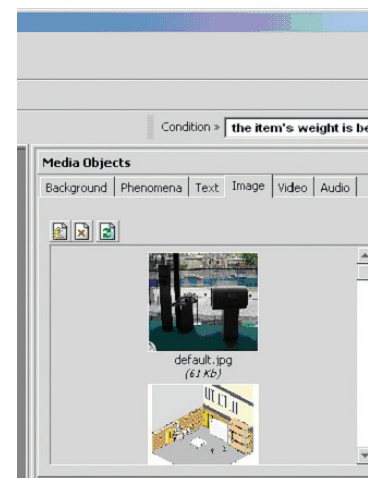


Figure 36:
Media
Objects group,
Images Tab,
available im-
ages pallet.

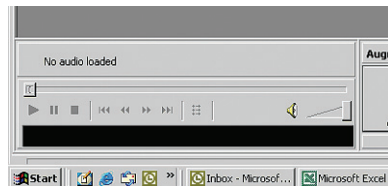


4. If the existing images are insufficient for your design goals, you can add an image by clicking on the first button from the left. In the dialog, which will follow, use the browse button to find the image and press the Upload button to make the image available.
5. A message will inform you that the 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 37.

Figure 37:
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 38, 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.

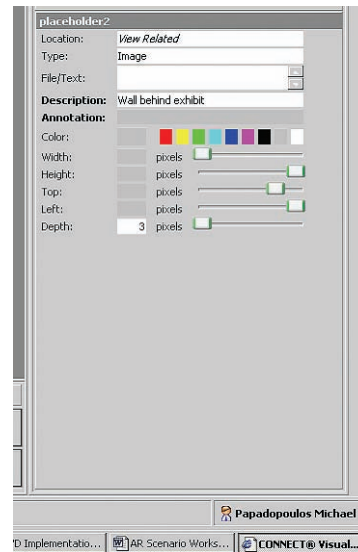


Figure 38:
Properties dialogue

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.





Presenting educational content in-site

This chapter describes the AR system that has been developed in the framework of the CONNECT project. It includes useful information for the user and it describes the main functionalities of the AR prototype to be used in the initial trials in the participating science centers and museums.

3.1 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,
- 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, CO₂ 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 40):

- 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 at the backpack, used at three sites, a wear-



Figure 39:
Learner
wearing the
mobile AR
system.



Figure 40:
The full AR system :backpack with laptop, Headset with video see-through display and tracking hardware, and wireless mouse



Figure 41: *The monocular optical see-through display of the Mobile AR system*

able 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 41). In the first case the real world is captured by a webcam attached to the front of the display (see Figure 41, right) and displayed within a non see-through display. In the latter case the real world is perceived directly (see Figure 41). 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 42). 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.

3.2 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.

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

Figure 42:
Patterns on the Hot Air Balloon for head position tracking in HEUREKA science centre in Finland.

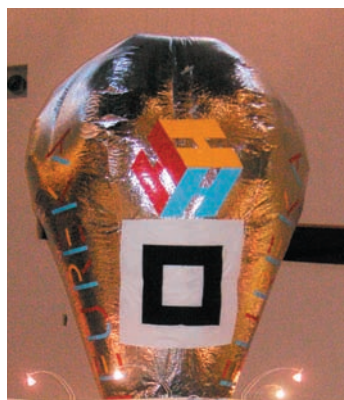


Figure 43:
Fixing the horizontal strap of the binocular headset.

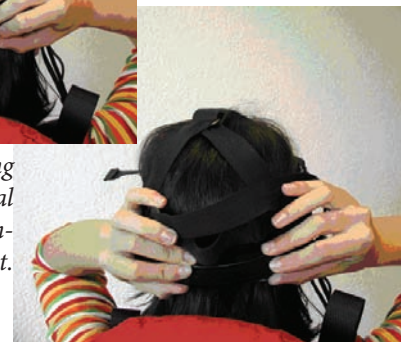


Figure 44:
Using the wireless mouse with the thumb.

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 44).

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.

3.3 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.

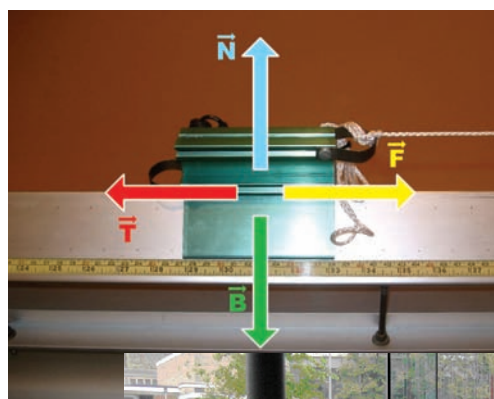
Possible actions besides the visual representation of these variables could be to show images or diagrams related to these values.

Distance to exhibit parts

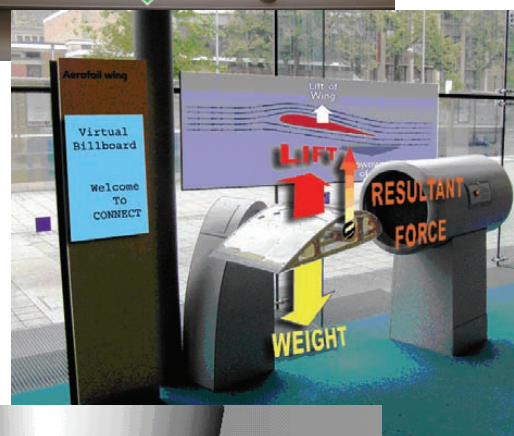
When the student is moving around the exhibit and/or approaching different real or virtual parts, different content can be made visible. Also different levels of detail could be presented depending on the distance.

Objects in focus of view

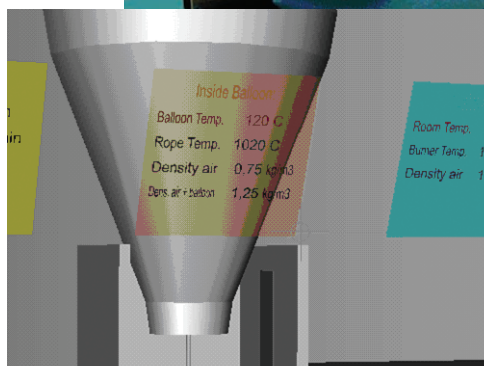
By looking at real or virtual parts of the exhibit, special content could be shown that is related to the specific part. A crosshair in the middle of the display could then be used



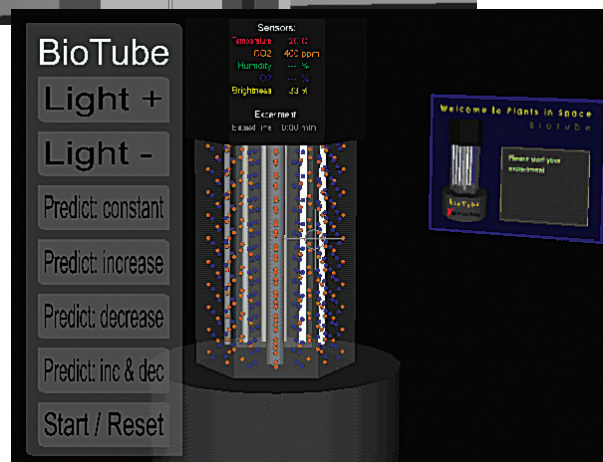
The concept of friction



Why do planes fly?

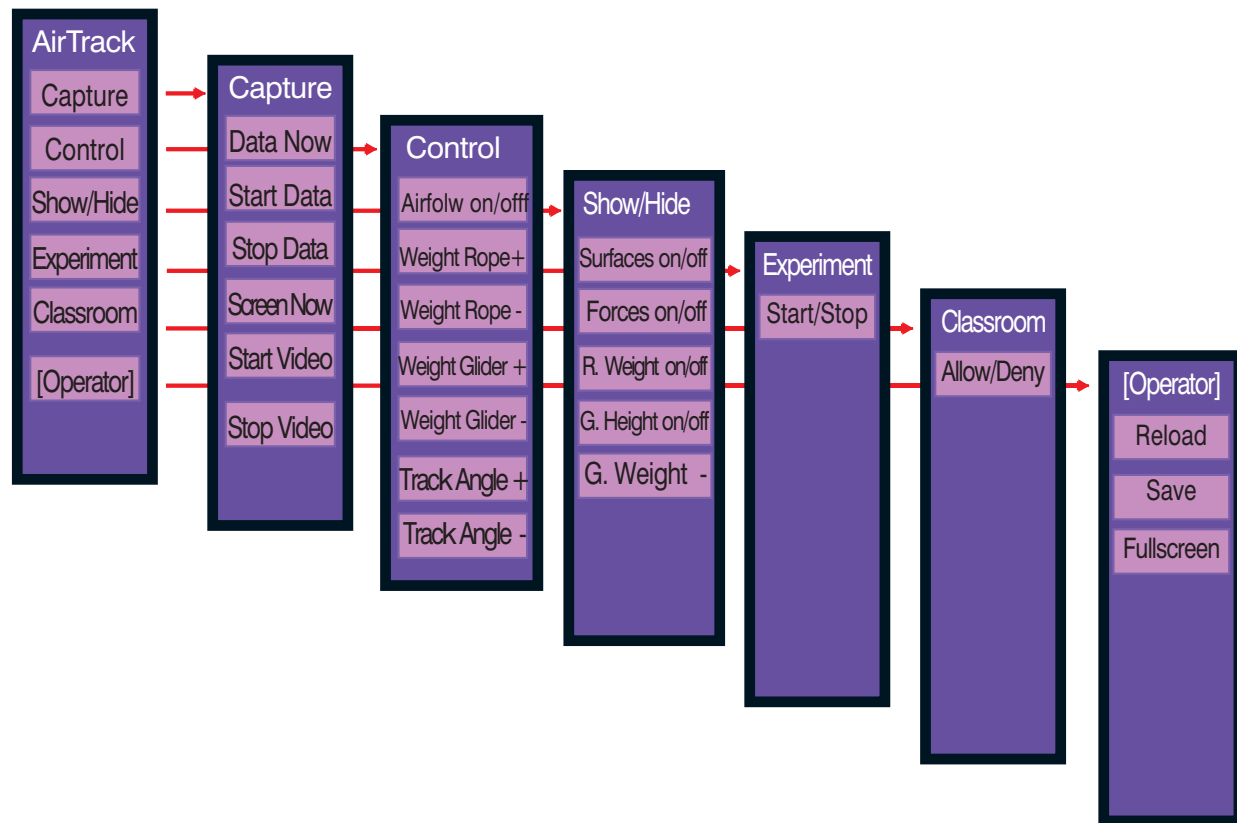


The hot air balloon



Photosynthesis

Figure 45:
Menu Hierarchy of AirTrack Scenario



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.



- 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 46). 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.

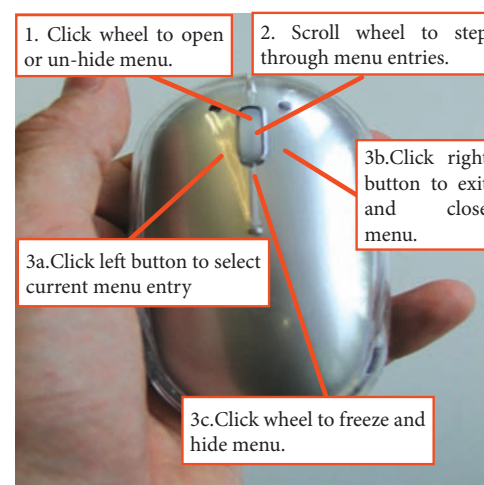


Figure 46:
Operating the head-up menu with the wireless mouse

3.4 Dimensions and Weight

The dimensions and the weight of the CONNECT mobile AR system is shown in Table 2

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 2:
Dimensions and the weight of the CONNECT mobile AR system

3.5 Iterative Developments

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

Wearable computer: x4

Figure 47:
University of
Birmingham's
fourth
generation
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 within 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.

Optical HMD

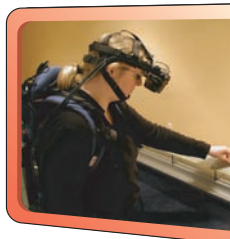
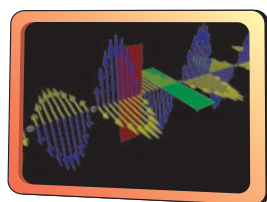
Following symptoms of visual discomfort experienced using the i-glasses SVGA Pro 3D, highlighted during the human factors evaluation, the next design will investigate using a monocular optical see-through display solutions using the Shimadzu Data Glass 2/A and Liteye LE 500. In this instance the real world is perceived directly within the users natural FOV, and not via a mediation webcam stream (see Figure 48).

Figure 48:
(Left)
Shimadzu
optical display
(right) Liteye
optical viewer
(image from
Liteye website)









Evaluating educational pathways

4.1. Introduction

Main CONNECT research question :

Under what conditions can the technology of Augmented Reality (AR) combined with interactive science exhibits support student learning?

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 activities. 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 consortium 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 technology 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.

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

The formative phase has taken into account the following considerations:

- general usefulness of the pedagogical approach and VSTP as perceived by users,
- the potential for the system to be integrated into the learning process,
- suggestions for improvements for an enhanced future system (not the one being tested),
- suggestions for how to integrate the system into current field trip practice,
- 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:

- The AR system is fully operational at four sites. Scenarios have undergone further development and refinement. Teachers’ workshops have been provided.
- Local museum staff will assist with data collection.
- 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.

Moments from the teachers’ workshop





- 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 and other 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 users 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 interviews 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 third run 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 (comparison group).
3. A group of classes visiting the science museum, completing pre- and post-visit activities and making use of the CONNECT technology (experimental group).

Table 3:
Overview
of the
Evaluation
Categories
and Instru-
ments.

What assessed?	Instruments
Background variables	Raven-test, age, gender, grade
Understanding	Knowledge test
Motivation	Semantic Differential Intrinsic Motivation Inventory
Usability of technology	Heuristic evaluation
Other (unforeseen) factors	Focus group interviews

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.

4.3 Assessment Tools

The evaluation includes quantitative and qualitative aspects. The quantitative 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 Table3).

Background variables (Ravens' test)

The purpose of using the Raven test is to stratify the student population and to investigate the impact of the CONNECT project in relation to initial psychographic student characteristics.

The cognitive 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. The so-called Raven's Progressive Matrices and Scales measure two major (and complementary) 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.

*Moments
from the
teachers'
workshop*





Aside from the Raven test, the research 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.

Semantic Differential

The Semantic Differential (SD) measures people’s reactions to stimulus words and concepts in terms of ratings on bipolar scales defined with contrasting adjectives at each end. With such a scale, one measures directionality of a reaction (e.g. good versus bad) and intensity (e.g. slight through extreme). Typically, a person is presented with some concept of interest, e.g., interacting with an exhibit, and asked to rate it on a number of such scales. Ratings are combined in various ways to describe and analyze the person’s feelings and attitudes (see Appendix I).

Knowledge Assessment

Knowledge assessment 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 different questionnaires can be open (e.g. “explain the preconditions for lift”) or multiple choice. The knowledge tests will be conducted before and two times after all activities. All three samples will be statistically compared.

In Table 4 we present an outline for developing the knowledge assessment tools across all four exhibitions.

Motivation

Apart from collecting the general information about students and their knowledge, another assessment tool will look into student’s motivation. Motivation is measured here as background information to stratify the student sample. An important outcome variable for the CONNECT project is how does the CONNECT approach change the characteristic of students’ motivation. This will be tested with a 25-items intrinsic/extrinsic motivation scale, which has been developed and field tested by Deci & Ryan. In this case, one item is a prediction like: “I enjoyed doing this activity very much”. The students may then value this prediction

Goal of Question	Details	Type
Exhibit specific Items		
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 (both: AR and non-AR)	Students will have to explain the phenomena in their own words and answer some questions regarding it	both
Additional Cognitive contribution		
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

Table 4:
Outline for developing the knowledge test

on a seven-point scale ranging from “strongly disagree” to “strongly agree”.

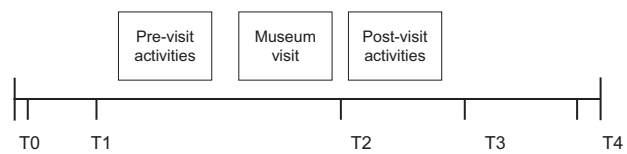
Qualitative Assessment

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 observations, interviews, focus groups, open-ended questions on the written feedback forms.

4.4 Time-line for Test Assessment

The whole process will be tested according to the following time-line:



- 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
T1	25'	-Knowledge test -Semantic differential
T2	20'	-Semantic differential -Intrinsic Motivation Inventory -focus groups, interviews -questions asked by students -Usability evaluation
T3	25'	-Knowledge test
T4	25'	-Knowledge test

Demonstrating the use of the AR system



4.5 Usability and Wearability Evaluation

Aims

The usability and wearability evaluation is designed to be as non-intrusive as possible to the student during use of the CONNECT system. This will include a questionnaire and observation/video/software logging during the science museum visit activity. The wearability studies ideally will not be an add-on during test runs but will be separate session specifically to assess wearability. This will mean that we can focus solely on assessing the wearability without worry of interfering in someone else’s work. More particular, the evaluation will

- Assess the wearability of the CONNECT system.
- Measure and assess perception of physiological exertion, musculoskeletal loading and comfort.
- Determine if a comparative wearable system results in a significantly different effect on wearability.
- Assess the usability (measure of effectiveness, efficiency and satisfaction) of the CONNECT system.
- Assess the communicability between the student and CONNECT system.
- Propose design modifications to improve wearability, usability and communicability.

Requirements: To participate in the evaluation procedures, the student should have access to CONNECT mobile AR system and access to an exhibit, which uses the wearable CONNECT mobile AR system.

Participants: Ideally we would prefer students to be an equal mix of male and female school children of the proposed age of users of the CONNECT system to collect appropriate data. The number of participants will probably be highly dependant on availability and time. Ideally we would require a minimum of 20 participants.

Time: The visit session for each participant will take approximately 15-20 minutes. For the CONNECT system to be assessed, the completion of usability questionnaires will take approximately 10-15 minutes.

Usability Evaluation Procedure

During the assessment session each participant will follow this procedure:



Informed consent. The evaluator will explain briefly the aims and protocol of the assessment session to the student and an informed consent will be requested. Information regarding Age, Height and Weight will be collected. In addition, a short interview with the evaluator will ensure that the participant is fit enough to perform the test, i.e. no history or complaints of back, shoulder or neck pain or health problems that may place the participant at risk.
Time needed for these activities: 2 mins

Put on kit. While the student puts on the system, observations will be made as to ease and feel of the wearable. Any problems encountered when putting on the kit will be recorded.
Time needed: as long as the student puts on the system

Initial wearability assessment. Measurements of relative perceived exertion, pain and discomfort, general comfort and vision effects will be measured as soon as the kit is mounted on the body and initiated to begin interacting with the exhibit.
Time needed for these activities: 2 mins

Perform activity with one of the exhibits. Although the student will be asked to interact with the exhibit as normal, there will be an interest for wearability and usability issues. Therefore, the student will be encouraged to highlight any problems they have, while they are interacting with the exhibit. The evaluator may also ask questions enquiring about

wearability issues. This may not follow a formalised structure but may be off the cuff enquiries to observations made while the student interacts with the exhibit and the wearable.
Time needed for these activities: as long as the trials

Record each session with conventional camcorder. This will support the observations and ongoing dialogue between students and evaluators to act as a record for future reference and post analysis activity.
Time needed for these activities: as long as the trials

Log the session using a software log/recorder. This will enable the evaluation team to observe the session through the eyes of the student, and provide a powerful form of evaluation, especially if this is combined with the camcorder footage (time stamped) – and will provide the basis for the communicability evaluation – where issues of usability are objectively identified and recorded.
Time needed for these activities: as long as the trials

Follow up wearability assessment. Measurements of relative perceived exertion, pain and discomfort, general comfort and vision effects will be measured when the task is completed, along with a follow-up wearability questionnaire.
Time needed for these activities: 3 mins

Follow up usability questionnaires. This will involve the application of a usability questionnaire.
Time needed for these activities: 5 mins

Guidelines for Teachers to Follow

The following list is proposed to help you in the implementation of the project runs:

Timeframe: First of all you should outline a possible timeframe for the whole intervention by considering holidays, important examines which might intervene with the test battery, school or- ganisationally things, etc.

Fixing the date of the science museum visit: All the activi- ties and tests are dependant on the date of the science museum visit. The day of the visit should be discussed with your contact person at an early stage, so that the science museum will be able to prepare and organise everything. Please discuss the fixed date with your school (required permissions, other teacher’s tests, etc.) and take into account possible irregularities in the public transportation system.

Tests: As indicated above, there will be five test sessions. All tests will take place in school, except T2 which is held immedi- ately after the science museum activity. Please plan possible dates for T0, T1, T3 and T4 by considering the time schedule above. You may vary single days for the test, but the time frame should be maintained to be able to compare the outcome of the tests across all participating schools.

Please inform your contact person about the test dates, so that we will be able to send/give you the appropriate tests in time. Af- ter finishing each test session, the questionnaires should be sent back within 24 hours (postage and packing will be paid).

Please note that

- The tests are name-independent. We only want to follow the outcome of each student throughout the different questionnaires.
- This evaluation is NOT about your competency as a teacher! We are only interested in the value of the AR system.

Please stay in contact with your contact person!

Any questions and difficulties can be addressed to your contact person!

The following checklist may help you in organising the activi- ties:

Checklist

		Ques- tion- naires avail- able in school	Dis- cussed / done	Ques- tion- naires have been sent back
Preparing the visit: - School permission - Arranging date for the visit - Arranging transporta- tion - Uploading Material on CVD & CP			☐ ☐ ☐ ☐	
Date of the science museum visit				
Phase T0 (pre-visit)	Raven test Background variables	☐ ☐	☐ ☐	☐ ☐
Phase T1 (pre-visit)	knowledge test SD	☐ ☐	☐ ☐	☐ ☐
Phase T2 (visit)	SD IMI focus groups Usability evaluation		☐ ☐ ☐ ☐	
Phase T3 (post-visit)	knowledge test	☐	☐	☐
Phase T4 (post-visit)	knowledge test	☐	☐	☐

Notes:



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Abbreviations

Acronyms	Explanation
CVD	CONNECT Visual Designer
VTSP	Virtual Thematic Science Park
AR	Augmented Reality
CP	CONNECT Platform

Glossary

Terms	Explanation
Rules	A complete set of properties describing interactivity. It is composed of: placeholder, object, actions and duration.
Actions	Actions refer to the actions of a mobile AR unit user which activate the display of an object in the mobile AR unit view
Conditions	Conditions are the situation which when true will cause the appearance of an Object to appear.
Durations	Duration is the part of a rule which specifies the time period (in seconds) an object will remain in the view of the mobile AR unit from the moment it appears regardless of whether the action which was triggered is true or not.
Placeholder	Placeholders are called the boxes on the picture of the exhibit held in the Canvas window, which indicate the approximate position of the object in space as well as the way it shown.
Object	Objects are containers of multimedia content. Valid media objects include: images, text, audio, video and 3D objects (3D shapes).
Reference Image	This image displayed in the Preview Canvas Window offers a workspace context for the placement of media objects and serves as a static preview.
Simple Content	Simple content are images, text, audio and video. They are two-dimensional, static and allow no interaction with the student. The Teacher provides them during design time.
Phenomena Representations	Phenomena representations are 3-D objects, which show visually the phenomenon and its mechanics being examined. They are dynamic in that they change with the changing state of the exhibit.
Variable Representations	Variable representations are meters showing the value of exhibit variables. These magnitudes are showing through arrows (vectors), cylinders (bars) and numerically (through text).
Educator	Any person taking it upon themselves to teach science to a learner
Learner	The learner is the person being taught via the CONNECT pedagogical process.

Appendix I: EVALUATION QUESTIONNAIRES

SEMANTIC DIFFERENTIAL

Pre vi sit version:

Below are descriptive pair of words relating to “studying science in my class”.
The words in every pair are opposite in their meaning. Please mark an X in one of the squares between the words that mostly expresses your attitude towards the two words.

Studying science in my class has been:

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



Immediately after Visit version:

Below are descriptive pair of words relating to “visiting the exhibit _____ “. The words in every pair are opposite in their meaning. Please mark an X in one of the squares between the words that mostly expresses your attitude towards the two words.

Visiting the exhibit _____ was:

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



INTRINSIC MOTIVATION INVENTORY

Dear student,

This test contains a number of statements about science. You will be asked what you yourself think about these statements. There are no right or wrong answers. Your opinion is what we want.

Please put a mark in a box of each row. Rate aspects of the course on a 1 to 7 scale, 1 equals «strongly disagree» and 7 equals «strongly agree». 1 represents the lowest and most negative impression on the scale, 4 represents an adequate impression, and 7 represents the highest and most positive impression.

	1 definitely disagree	2	3	4	5	6	7 definitely agree
After working at this activity for a while, I felt pretty competent.							
I am satisfied with my performance at this task.							
I think I am pretty good at this activity.							
I was pretty skilled at this activity.							
This was an activity that I couldn't do very well.							
I think I did pretty well at this activity, compared to other students.							
I didn't put much energy into this.							
I didn't try very hard to do well at this activity.							
I put a lot of effort into this.							
It was important to me to do well at this task.							
I tried very hard on this activity.							
I thought this was a boring activity.							
This activity did not hold my attention at all.							
I enjoyed doing this activity very much.							
This activity was fun to do.							
While I was doing this activity, I was thinking about how much I enjoyed it.							
I thought this activity was quite enjoyable.							
I would describe this activity as very interesting							



	1 definitely disagree	2	3	4	5	6	7 definitely agree
I believe this activity could be of some value to me.							
I think that doing this activity is useful for learning about science and technology							
I think this is important to do because it can improve my skills							
I would be willing to do this again because it has some value to me.							
I think doing this activity could help me to learn quicker than using other media							
I believe doing this activity could be beneficial to me.							
I think this is an important activity.							



KNOWLEDGE TEST

AEROFOIL EXHIBIT

Your name:

Dear student,

this Quiz contains Questions about lift and the aerofoil model in general. The questions might be very difficult to answer. Don't be frustrated, but try your best to answer them. For every task there is exactly ONE correct answer. Please cross the options, of which you mean that it is the right answer. If you are not sure, you may cross the option "don't know".

1. Which of these forces is not involved in normal flight?

- ☐ Weight
- ☐ Lift
- ☐ Thrust
- ☐ Magnetic
- ☐ Don't know

2. Which force remains constant for a given aircraft?

- ☐ Lift
- ☐ Thrust
- ☐ Weight
- ☐ Drag
- ☐ Don't know

3. What does the fan represent?

- ☐ A windy day
- ☐ The forward speed of the aircraft
- ☐ The temperature
- ☐ Air humidity
- ☐ Don't know

4. What forces are represented by the Augmented reality?

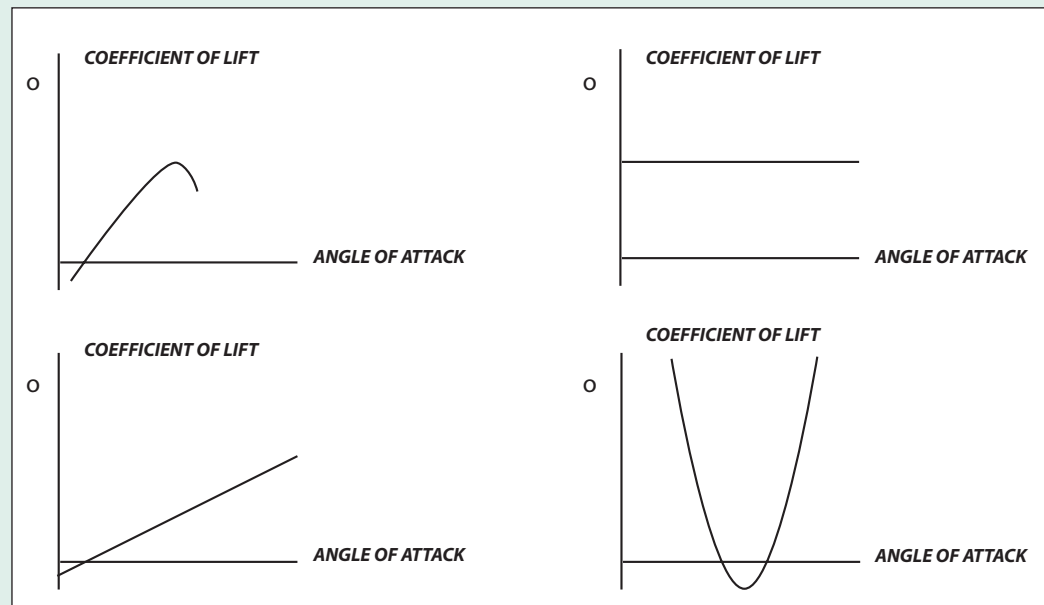
- ☐ Drag, weight
- ☐ Lift, thrust
- ☐ Lift, weight
- ☐ Drag, thrust
- ☐ Don't know



5. What happens to the lift force as the wing is rotated through 90° ?
- ☐ It increases as the wing is rotated from 0° - 90°
 - ☐ It decreases as the wing is rotated from 0° - 90°
 - ☐ It increases as the wing is initially rotated, and then drops to zero at angles greater than approximately 18°
 - ☐ It decreases as the wing is initially rotated, and then increases from 18° - 90°
 - ☐ Don't know
6. What happens to the weight as the wing is rotated through 90° ?
- ☐ It stays constant
 - ☐ It decreases as the wing is rotated from 0° - 90°
 - ☐ It increases as the wing is rotated from 0° - 90°
 - ☐ It rises and falls as the wing is rotated from 0° - 90°
 - ☐ Don't know
7. What happens to the ping-pong balls as the wing is rotated through 90° ?
- ☐ They bounce up and down
 - ☐ They rise up, and fall back down again
 - ☐ They don't move at all
 - ☐ They all rise up, and once risen, stay up
 - ☐ Don't know
8. Which of these does not affect the lift force?
- ☐ Cross sectional shape of the wing
 - ☐ Velocity of the aircraft
 - ☐ The weight of the aircraft
 - ☐ The angle the wing makes with respect to the oncoming air
 - ☐ Don't know
9. Which of these definitions best describes the angle of attack?
- ☐ The angle of the wing with respect to the horizon
 - ☐ The angle the wing makes with respect to the oncoming air
 - ☐ The angle the pilot sits at during take-off
 - ☐ The angle the wing makes with respect to the main body of the aircraft
 - ☐ Don't know
10. Which two factors together determine the coefficient of lift?
- ☐ The shape of the wing and the angle of attack
 - ☐ The shape and density of the wing
 - ☐ The shape and size of the wing
 - ☐ The angle of attack and the shape of the aircraft
 - ☐ Don't know



11. Which graph represents how the co-efficient of lift depends on angle of attack?



☐ Don't know

12. What do the red lines represent?

- ☐ Angle of attack
- ☐ Air pressure
- ☐ Forces
- ☐ Air speed
- ☐ Don't know

13. What happens to the airflow as the wing is rotated?

- ☐ The air disappears
- ☐ The air pressure changes
- ☐ The air combusts
- ☐ The air changes composition
- ☐ Don't know



14. Which of these would you not use to model how the air flows across an aircraft?

- ☐ A computer simulation
- ☐ An augmented reality headset
- ☐ A telescope
- ☐ A wind tunnel
- ☐ Don't know

15. Your class are doing an experiment to test which type of paper aeroplane design allows the aeroplane to travel the furthest distance. Before carrying out the experiment you were asked to vote which of three designs you thought would give the best results. You were being asked to...

- ☐ Make an observation
- ☐ Carry out a fair test
- ☐ Make a prediction
- ☐ Record your results
- ☐ Don't know

16. In the above experiment you want to test how different shapes will fly. Which of the following would be a 'fair test'?

- ☐ Make different shaped aeroplanes, with different types of materials and launch them in different ways
- ☐ Make different shaped aeroplanes, with the same type of material and launch them in different ways
- ☐ Make different shaped aeroplanes, with the same type of material and launch them in the same way
- ☐ Make aeroplanes with the same shape but with different materials and launch them in the same way
- ☐ Don't know

17. Birds use flight in different ways, some, like hummingbirds flap their wings at high speed while others, like hawks soar, glide and dive. What do you think are the most important factors in determining how a bird will fly?

- ☐ The bird's size and wing shape
- ☐ The length of the bird's legs and beak
- ☐ The colour of the bird
- ☐ The age of the bird
- ☐ Don't know

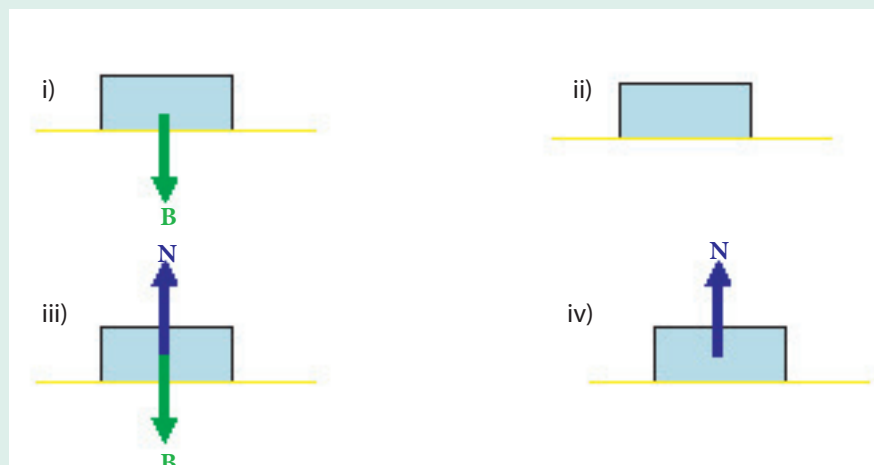


AIRTRACK EXHIBIT

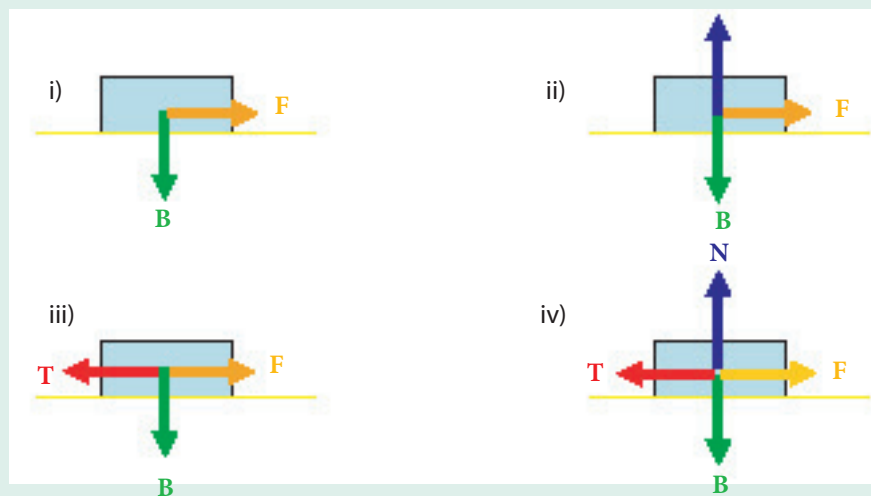
Το όνομά σου:.....

ΕΠΙΛΕΞΤΕ ΤΗ ΣΩΣΤΗ ΑΠΑΝΤΗΣΗ

Ένα σώμα ισορροπεί (δεν κινείται) σε οριζόντιο επίπεδο. Υπάρχουν δυνάμεις που ασκούνται σε αυτό και αν ναι, ποιες;

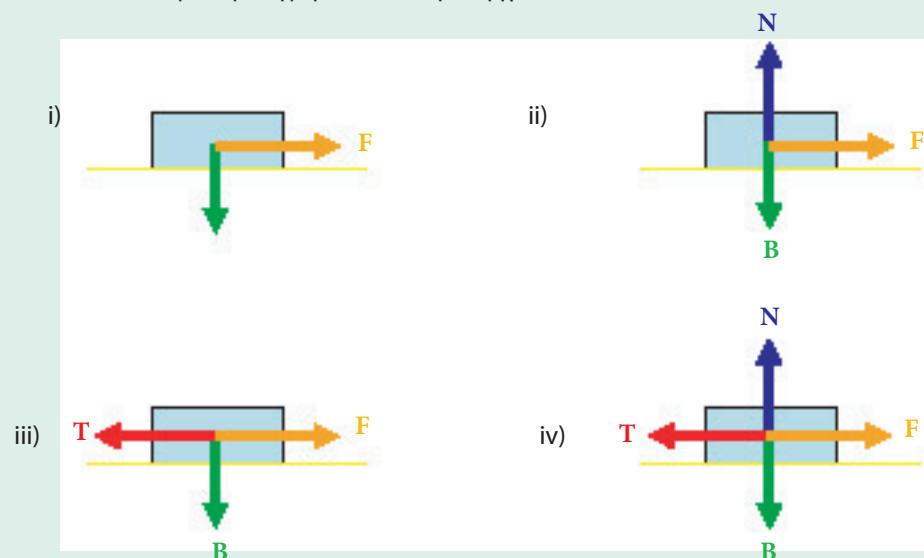


Ασκούμε στο σώμα οριζόντια δύναμη F . Το σώμα παραμένει ακίνητο. Ποιες δυνάμεις ασκούνται σε αυτό;

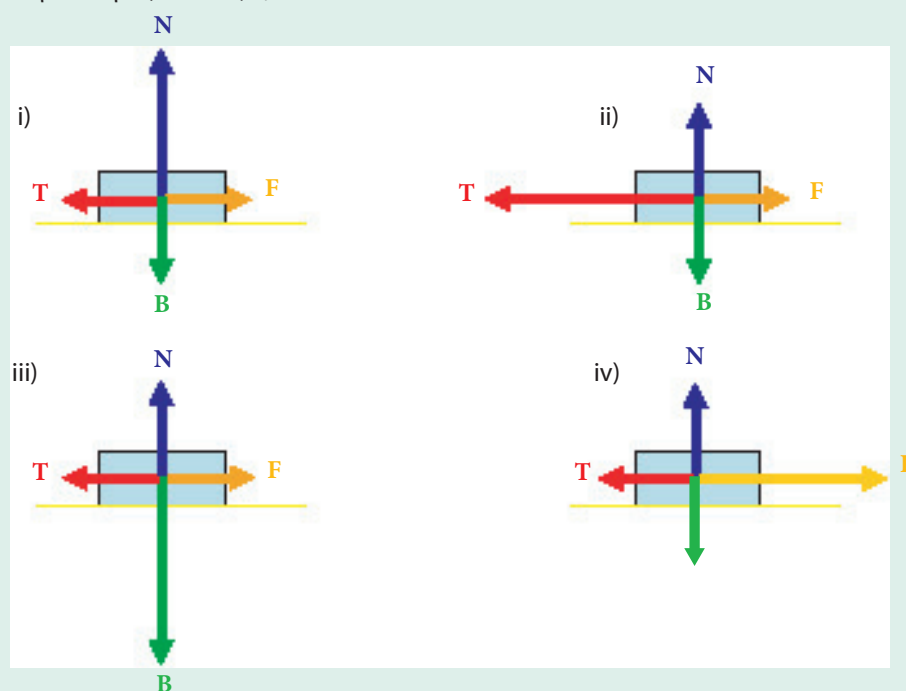




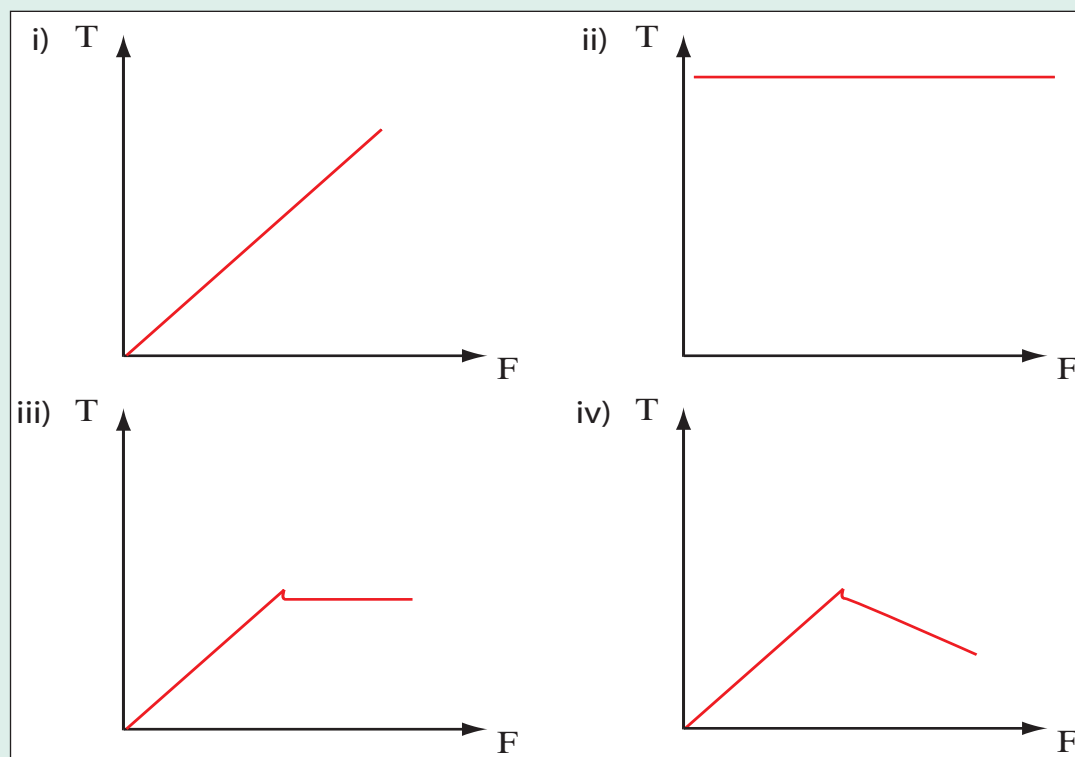
Ασκούμε οριζόντια δύναμη F , το μέτρο της οποίας αυξάνεται σιγά-σιγά ώσπου το σώμα αρχίζει να κινείται. Ποιες δυνάμεις ασκούνται στο σώμα τη στιγμή που το σώμα αρχίζει να κινείται;



Ποιο από τα παρακάτω σχήματα περιγράφει σωστά τις σταθερές δυνάμεις που δρουν σε ένα σώμα όταν αυτό κινείται επιταχυνόμενο προς στα δεξιά;



Ένα σώμα αρχικά ήταν ακίνητο. Στο σώμα ασκείται οριζόντια δύναμη F , το μέτρο της οποίας αυξάνεται σιγά-σιγά ώσπου το σώμα αρχίζει να κινείται. Ποιο από τα παρακάτω διαγράμματα αναπαριστά την τριβή σε σχέση με την οριζόντια κινητήρια δύναμη;



(T : τριβή, F : οριζόντια δύναμη)

Περιέγραψε με δικά σου λόγια τι συμβαίνει με τη τριβή (στατική, οριακή και ολίσθησης).

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Από τι εξαρτάται η στατική τριβή;

- i. Από τη φύση των επιφανειών που βρίσκονται σε επαφή.
- ii. Από την αντίδραση του δαπέδου και την οριζόντια δύναμη που ασκούνται στο σώμα.
- iii. Από τη φύση των επιφανειών που βρίσκονται σε επαφή και την οριζόντια δύναμη που ασκείται στο σώμα.
- iv. Από τη φύση των επιφανειών που βρίσκονται σε επαφή, την αντίδραση του δαπέδου και την οριζόντια δύναμη που ασκούνται στο σώμα.

Ποια είναι η μαθηματική έκφραση για την τριβή ολίσθησης;

- i. $N = \mu B$
- ii. $F = ma$
- iii. $T = \mu F$
- iv. $T = \mu N$

(N: κάθετη δύναμη, μ : συντελεστής τριβής, B: βάρος, F: οριζόντια δύναμη, m: μάζα, a: επιτάχυνση, T: τριβή)

Είναι η τριβή απαραίτητη στην καθημερινή λειτουργία μας;

- i. Όχι, η τριβή είναι πρόβλημα στην καθημερινή λειτουργία μας, γιατί μας σταματά όταν κινούμαστε, περπατάμε, κινούμαστε με το αυτοκίνητο, κλπ.
- ii. Όχι, η τριβή δεν είναι απαραίτητη, αλλά μερικές φορές είναι χρήσιμη όπως όταν φρενάρουμε ή κατεβαίνουμε μία πλαγιά με σκι.
- iii. Ναι, χωρίς τριβή δεν θα μπορούσαμε να περπατήσουμε, να κάτσουμε, κλπ., γιατί όλα θα γλιστράγανε και θα πέφτανε.
- iv. Ναι, γιατί η τριβή διευκολύνει τις κινήσεις μας.

Έχουμε τριβή στο ανθρώπινο σώμα;

- i. Όχι, γιατί δεν υπάρχουν κινούμενα μέρη μέσα στο ανθρώπινο σώμα.
- ii. Όχι, γιατί τα μέρη του ανθρώπινου σώματος κινούνται αργά.
- iii. Ναι, γιατί η τριβή αναπτύσσεται πάντα όταν δύο επαπτόμενες επιφάνειες τείνουν να κινηθούν ή κινούνται η μία σε σχέση με την άλλη.
- iv. Ναι, γιατί η τριβή αναπτύσσεται πάντα όταν δύο επαπτόμενες επιφάνειες κινούνται αργά η μία σε σχέση με την άλλη.

Τα hovercraft πετάνε μόλις δύο εκατοστά πάνω από κάθε επιφάνεια, επιτρέποντας να πλοηγούνται με ασφάλεια σε νερό, ξηρά, πάγο, χιόνι, ή έναν συνδυασμό αυτών. Οι κινητήρες του hovercraft ωθούν τον αέρα προς τα κάτω, για να

- i. αυξήσουν τη δύναμη της βαρύτητας.
- ii. μειώσουν τη δύναμη της βαρύτητας.
- iii. αυξήσουν τη δύναμη της τριβής.
- iv. μειώσουν τη δύναμη της τριβής.



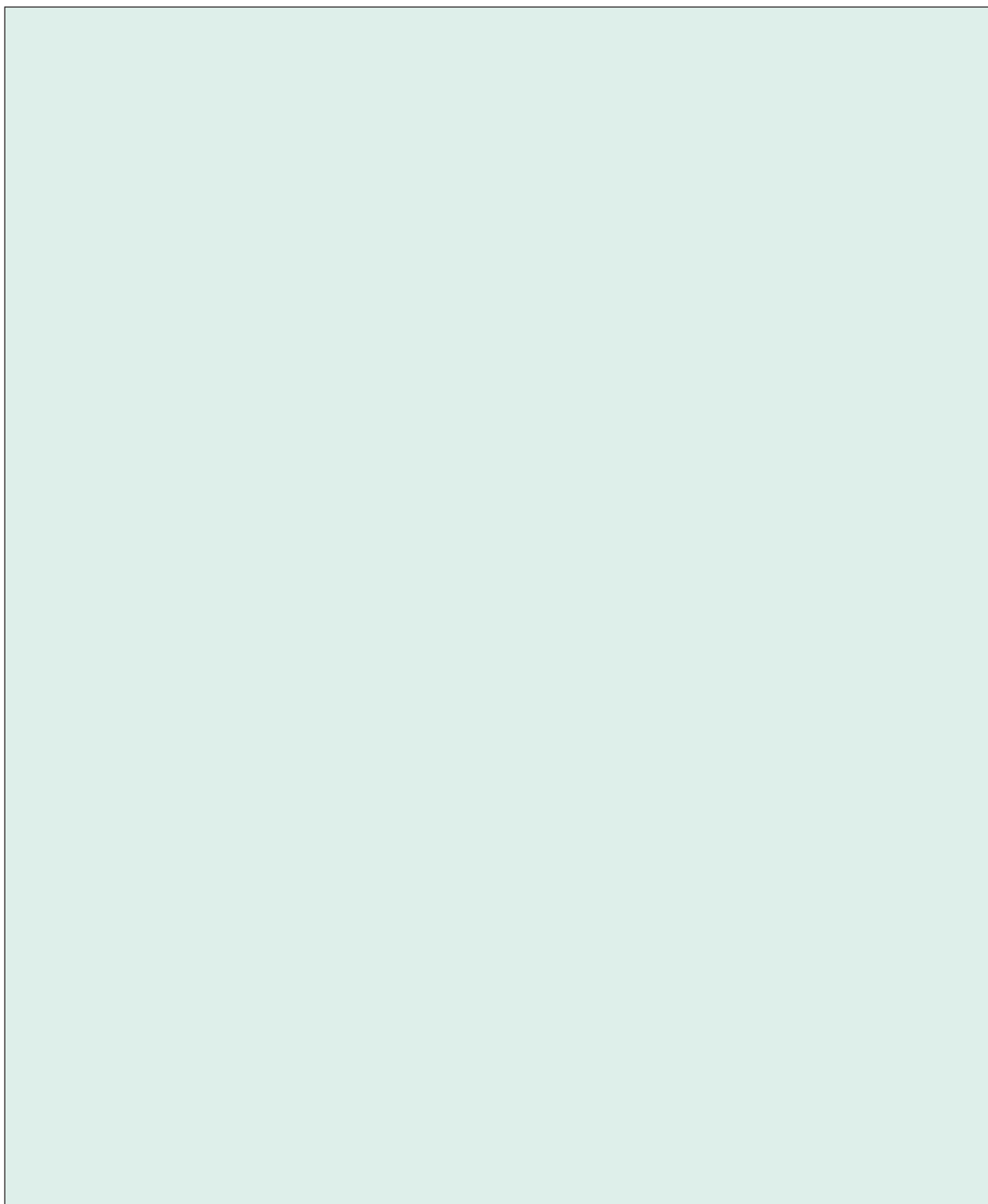
Ένας μαθητής κατεβαίνει την πλαγιά ενός βουνού με το snowboard. Προτιμά να κυλάει πάνω στο χιόνι (το χειμώνα) αντί πάνω στο γρασίδι (το καλοκαίρι). Εξήγησε γιατί.



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HOT AIR BALOON EXHIBIT

Etunimi:..... Sukunimi:.....Koulu:.....
Jupperi Luokka:.....synt.vuosi:.....

1. Mikä seuraavista on kooltaan pienin? Which one has the smallest size?

- a) piste= dot
- b) pilkku = comma
- c) atomi = atom
- d) molekyyli = molecyle

2. Kappaleet putoavat alaspäin (esim. kirja pöydältä lattialle). Tärkein syy tähän on
Object do fall down (for example a book from the table to floor). The main reason for this is

- a) voima = power
- b) paino = weight
- c) maan vetovoima = gravity
- d) nopeus = speed

3. Missä kolmessa olomuodossa aineet voivat esiintyä? Nimeä olomuodot!
Which are the three different elements in which the material can exist? Name it!

.....
.....
.....

4. Ilmapallon kuminen kuori painaa yksinään 120 grammaa.

Kun ilmapallo täytetään puhaltamalla täyteen ilmaa, sen paino on tämän jälkeen

The rubber cover of the balloon weights 120 g.

Then the balloon is filled full by briefing air into it. The weight of the balloon is now

- a) alle 120 grammaa = less than 120 g
- b) tasan 120 grammaa = exactly 120 g
- c) yli 120 grammaa = more than 120 g
- d) noin 90 grammaa = about 90 g



5. Lämmitetyssä saunassa on 3 lämpömittaria: A, B ja C. (Katso kuva alapuolella!) The heated sauna has 3 thermometers: A, B, C. (See the picture on the right)

Keskimmäinen lämpömittari B näyttää lukemaa 80°C .
In the middle, the thermometer B shows the figure 80°C .

Lämpömittari A:n todennäköisin lukema on
The most probable

1. 90°C
2. 80°C
3. 70°C
4. 60°C

Lämpömittari C:n todennäköisin lukema on

1. 70°C
2. 80°C
3. 90°C
4. 100°C

6. Miksi kuumailmapallo nousee ilmassa ylös? = Why does the "hot air balloon" go up?

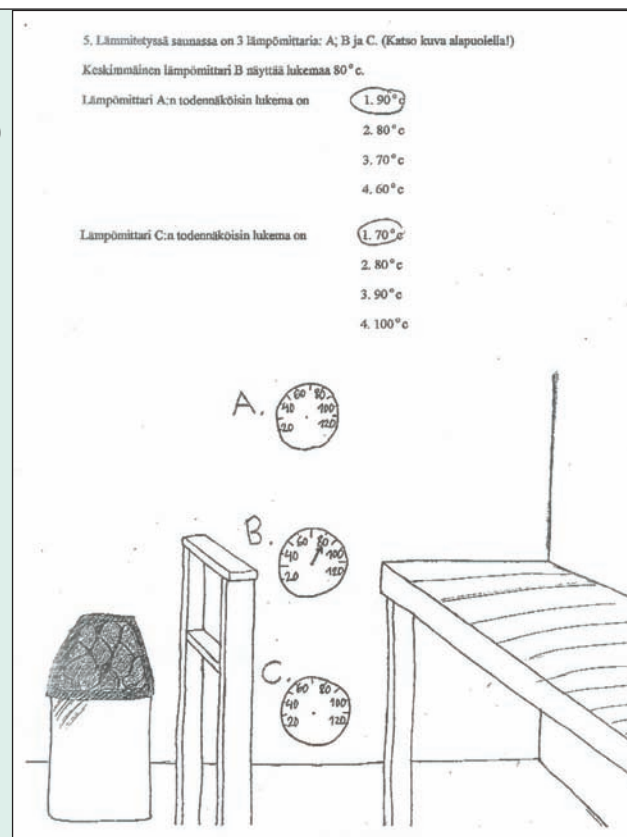
- a) Koska pallon puhalletaan lisää ilmaa = Because more air is blown into the balloon.
- b) Koska se on tehty erittäin kevyestä alumiinifoliosta = Because it is made of ultra light aluminiumfolio.
- c) Koska pallon sisällä on tyhjiö = Because there is a vacuum inside the balloon.

d) Koska lämmitin tekee ilman pallon sisällä lämpimämmäksi kuin ilma sen ulkopuolella = Because the heater is making the air inside the balloon warmer than outside it.

e) Koska lämmitin muuntaa ilman kaasuksi pallon sisällä = Because the heater is changing the air inside the balloon into gas

7. Kun kuminen ilmapallo täytetään Helium-kaasulla, tämä pallo nousee ylöspäin. Syy tähän on:

When the balloon made from rubber is filled with Helium-gas, it will rise up. The explanation is:



Kuva - Picture



- a) helium on kaasu ja ilma ei ole mitään = helium is a gas and air is nothing
- b) helium atomit ovat vahvempia kuin ilma ja voittavat = helium atoms are stronger than air, and the are winning
- c) $x = \text{helium} + \text{ilma} + \text{painovoima} = x = \text{helium} + \text{air} + \text{gravity}$
- d) helium kaasun atomipaino on ilmaa suurempi = the atom-weight of helium is bigger than the atom-weight of the air
- e) koska heliumin ja pallon yhteinen paino on ilmaa kevyempää = because the total weight of the helium gas and the balloon is lighter than the air
8. Tasan 100 cm pitkää metallitanko on huoneessa, jonka lämpötila on 20 ° c. Tämän jälkeen metallitanko lämmitetään 80 ° c kuumaksi. Mitä tangolle tapahtuu? = The 100 cm long metal stick in in a room having the temperature of 20 ° c. Then the stick will be heated to the temperature of 80 ° c. What will happen for the stick?
- a) se haihtuu ilmaan = it vanishes into air
- b) sen pituus lisääntyy = it becomes longer
- c) sen pituus lyhenee = it becomes shorter
- d) se pysyy täsmälleen samanmittaisena = it stays exactly in the same length
- e) siitä tulee noin 90 cm pitkä = it becomes approximately 90 cm long
- (additional questions)
9. Aineessa olevat atomit ja molekyylit = The molecules and atoms existing in the material
- a) liikkuvat jatkuvasti = are moving all the time
- b) liikkuvat mutta pysähtyvät lepoasentoon silloin, kun aineeseen ei kosketa
are moving, but they stop in resting position when no-one is touching the materia
- c) pysyvät paikallaan atomipainonsa vuoksi
they stay in one spot because of their own atom-weight
- d) tiede ei osaa selittää tätä ilmiötä
science and research cannot explain this phenomenon



10. Kun ainetta lämmitetään, niin siinä olevat molekyylit

When any materia is heated, the molecyles inside it

- a) liikkuvat entisellä tavallaan = are moving in the same way as earlier
- b) alkavat liikkua aiempaa nopeammin = start to move more faster than earlier
- c) alkavat liikkua aiempaa hitaammin = start to move more slowly than earlier
- d) pysähtyvät paikalleen = stay on one spot

BIOTUBE EXHIBIT

- 1) What factor were you able to change during your experiment?
 - a. Humidity
 - b. Oxygen
 - c. Light intensity
 - d. Carbon dioxide
- 2) What molecules are represented in 3D in the Biotube?
 - a. Humidity
 - b. Oxygen
 - c. Light intensity
 - d. Carbon dioxide
- 3) Which parameter was represented in your predictions?
 - a. Rate of Oxygen over time
 - b. Rate of temperature over time
 - c. Rate of Carbon dioxide over time
 - d. Rate of humidity over time
- 4) What are the 3 components that plants use in the photosynthesis process?
 - a. Oxygen, light, water
 - b. Glucose, light, water
 - c. Carbon dioxide, light, water
- 5) What 2 substances are produced by photosynthesis?
 - a. Oxygen, Water
 - b. Carbon dioxide, Nutrients
 - c. Light, Oxygen
- 6) What is the energy source of the plant?
 - a. Oxygen
 - b. Carbon dioxide
 - c. Sun light
- 7) Why is CO₂ necessary in the photosynthesis process?
 - a. It is needed to split the Water
 - b. It is needed to make Glucose
 - c. It is needed to transport the minerals
 - d. It is needed to produce chlorophyll
- 8) At what time can the plant take in big amounts of CO₂?
 - a) Night
 - b) Day
 - c) Day and night



9) Explain your answer:

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10) Pick a shape that represents the effect of exceeding CO_2 on biomass production, keeping in mind that there will be enough water, light and nutrients.

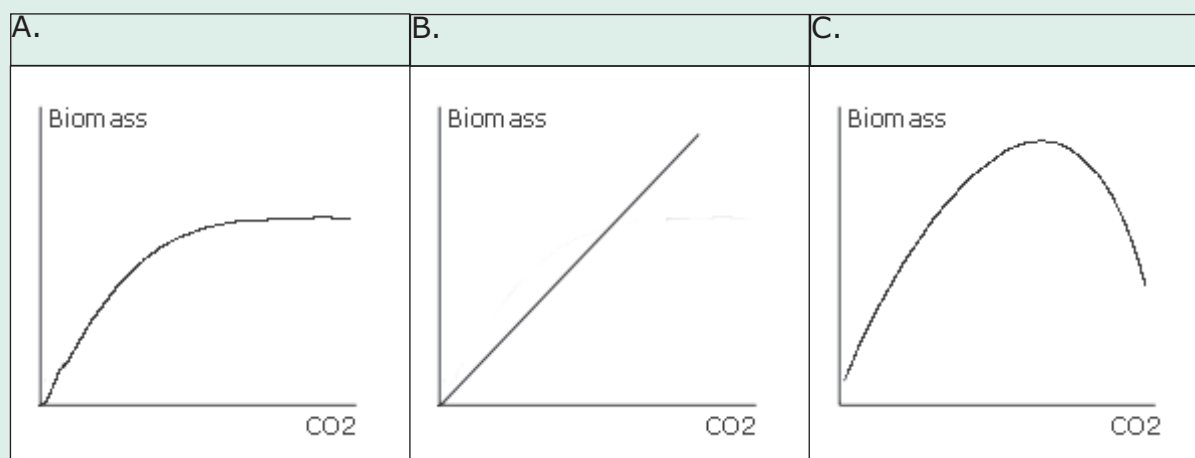
Experiment Conditions:

Dependent Variable: Biomass

Independent Variable: CO_2

Experiment length: 100 days

Other Factors: constant



11) Give reasons for this effect :

.....

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12) Pick a shape that represents the effect of 24 hours of light per day on a plant, keeping in mind that there will be enough water, CO_2 and nutrients.

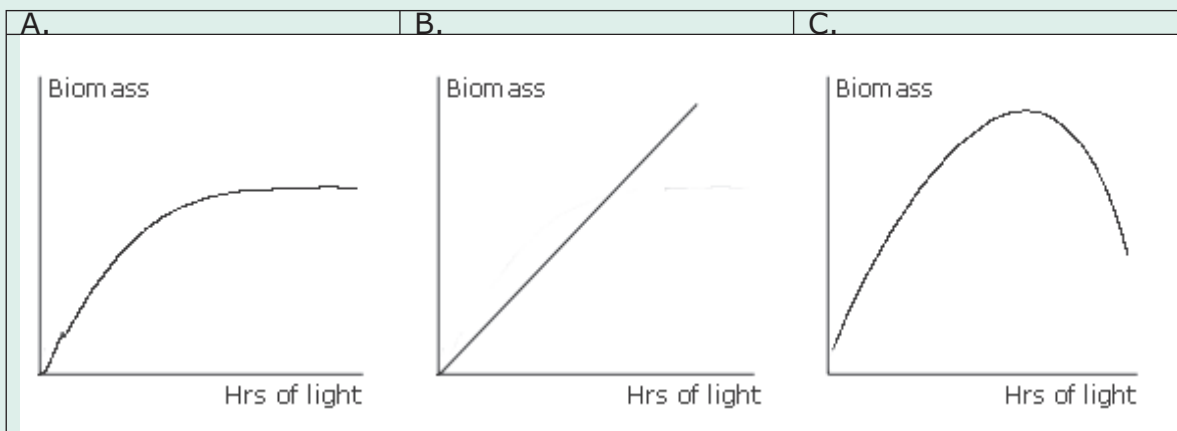
Experiment Conditions:

Dependent Variable: Biomass

Independent Variable: hours of light

Experiment length: 100 days

Other Factors: constant



13) The following graph represents a prediction for an experiment result. Please formulate a research question and hypothesis that fits to the graph below.

.....

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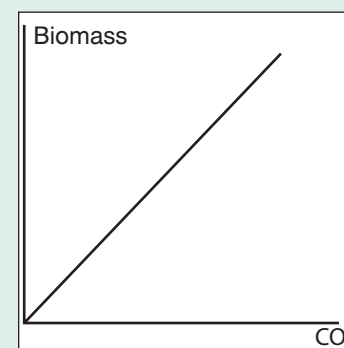
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Experiment Conditions:

Dependent Variable: Biomass
 Independent Variable: CO_2
 Experiment length: 30 minutes
 Other Factors: constant



Research Question:

Hypothesis:

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- 15) Maria collected the gas given off by a glowing piece of charcoal. The gas was then bubbled through a small amount of colorless limewater. Part of Maria's report stated, "After the gas was put into the jar, the limewater gradually changed to a milky white color." This statement is
- a. An observation
 - b. A conclusion
 - c. A generalization
 - d. An assumption of the investigation
 - e. A hypothesis
- 16) Biomass can be defined as:
- a. Energy from the wind
 - b. Hydroelectric energy
 - c. Electricity
 - d. Chemical energy from plants and animals



TEACHER'S QUESTIONNAIRE

Dear Teacher,

Thank you for taking part in the CONNECT Test Run. We would like to ask you to take a few minutes to provide us with some information which will help improve the CONNECT system, as it evolves to take on its final shape. Your comments and suggestions about your class' visit are very important to us. Please write a short comment about the following.

Name of Teacher _____ Grade _____ School _____

A. Pre-Visit Stage

1. Are you teaching the subject matter of this exhibit in your classroom?
☐ Yes ☐ No

If so, was the visit well-timed within the timeframe of your teaching unit?

- ☐ Yes ☐ Too early
☐ Too late ☐ Timing didn't matter

2. What learning objectives did you wish to achieve by visiting the science museum?

3. What other objectives did you wish to achieve by visiting the science museum?

4. What pre-visit activities did your class perform? _____

5. How much class-time was taken up by the pre-visit activities?

- ☐ About half a class period ☐ Between half and a full class period
☐ One to two class periods ☐ More than two class periods

6. How did the pre-visit activities help to prepare the students for the visit? _____



B. Visit Stage:

Regarding your students’ visit to the museum, to what extent do you agree with the statements below? Please check off the appropriate boxes below:

	I Agree Very Much	I Agree a Little	I Disagree a Little	I Disagree Very Much
1. The museum visit was well-organized.				
2. My learning objectives were met during the museum visit.				
3. The visit did <u>not</u> encouraged student teamwork.				
4. Students were given the chance to exercise free-choice while using the exhibit.				
5. The museum visit did <u>not</u> improve my students’ attitude toward the subject matter.				
6. The museum visit improved my students’ attitude towards science in general.				

Please add any other comments you’d like to make, about the visit. _____

6. When you used the AR-related set-up with the exhibit, which activities did you use? Circle one or more the following statements:
- a. I used an existing template
 - b. I modified and used an existing template
 - c. I created my own activity

Please explain your answer: _____



C. Post-Visit Stage

1. What post-visit activities did your class perform? _____

2. How much class-time was taken up by the post-visit activities?

☐ About half a class period

☐ Between half and a full class period

☐ One to two class periods

☐ More than two class periods

3. To what extent did the museum visit improve the students’ understanding of the subject matter? Please explain: _____

4. To what extent did the visit improve the students’ attitude toward the subject matter? Please explain: _____

5. To what extent did the visit improve the students’ attitude toward the science center? Please explain: _____

6. If your class used the AR system, do you think this new technology provides better opportunities for learning and teaching?

☐ Yes

☐ Not sure

☐ No

Please explain your answer _____

7. What do you think are the limitations or potential problems in using this technology?_____

Please feel free to add any comments or further suggestions that will help the CONNECT team to improve the museum experience for your students and yourself. _____

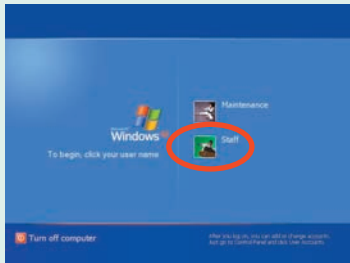
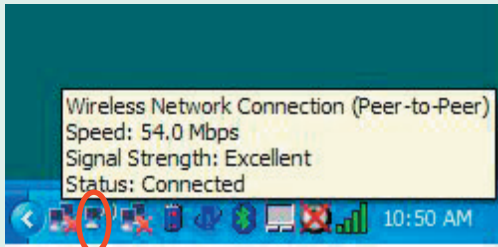
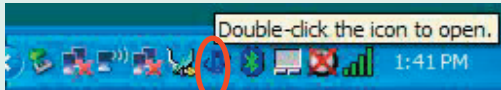
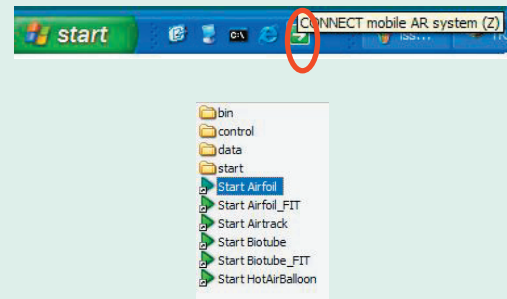
Thank you for your cooperation,
 -- The CONNECT Team



Appendix II: AR System Starting Procedure

The following steps have to be performed both on the exhibit AR system and on the mobile AR system(s), unless specified explicitly. You should start with the exhibit AR system, as the file server and synchronization server are located there.

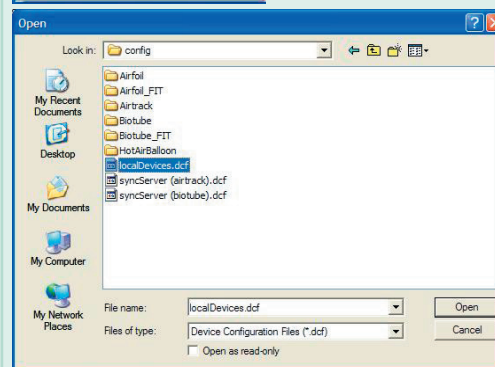
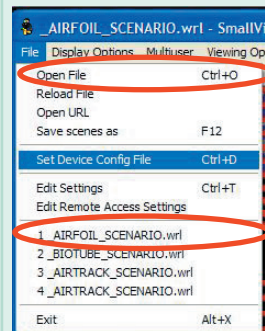
Startup Exhibit and Mobile AR System

Step	Description	Screenshot
1	Switch on components: • Boot laptop/wearable/PC • Switch on wireless mouse • Switch on display (if applicable) • Plug in power supply of data acquisition system (if applicable)	
2	Log in as user “Staff” • To enter password it may be required to switch to English keyboard layout by pressing SHIFT-ALT.	
3	Check WLAN connection: • Hover over W-LAN network connection symbol in taskbar to check that the system is connected to the wireless network ‘connect’ at 54.0 Megabits per second.	
4	Check InterSense tracker (if attached): • The blue InterSense icon in taskbar should have a green ‘i’. If not, refer to the Appendix Troubleshooting.	
5	Access Workspace: 1. From the quick launch section in the task bar choose the ‘Connect Mobile AR system’ shortcut (icon: white arrow in front of green background). Info: This is the root directory. It is associated with network drive Z. Physically it is located on the exhibit AR system. 2. Choose the shortcut leading to the start sub-folder of the specific exhibit, e.g. ‘Start Airfoil’.	

6	Start audio connection to classroom (if desired): On mobile AR system start Skype and call classroom user (there is a shortcut for every classroom).	
7	Convert CVD scenario to 3D scenario: On the exhibit AR system execute the batch file 'A-EM-ConvertCvdScenario.bat'. Info: A: step 'A', EM: execute on 'Exhibit or 'Mobile system).	0-EM-StartViewer.bat 0-EM-StartViewerDebug.bat 0-E-StartSyncServer.bat 1-E-StartAirfoilTracking.bat 1-M-StartUserTracking.bat 2-E-ConnectAirfoilTracking.bat 2-M-ConnectUserTracking.bat 8-E-LaunchTracking.bat 8-M-LaunchTracking.bat 9-EM-TerminateTracking.bat A-EM-ConvertCvdScenario.bat B-E-LaunchExhibitSystem.bat B-M-LaunchMobileSystem.bat C-EM-TerminateSystem.bat exhibit system
8	Launch AR software components: - On the exhibit AR system execute 'B-E-LaunchExhibitSystem.bat'. - On the mobile AR system execute 'B-M-LaunchMobileSystem.bat'.	0-EM-StartViewer.bat 0-EM-StartViewerDebug.bat 0-E-StartSyncServer.bat 1-E-StartAirfoilTracking.bat 1-M-StartUserTracking.bat 2-E-ConnectAirfoilTracking.bat 2-M-ConnectUserTracking.bat 8-E-LaunchTracking.bat 8-M-LaunchTracking.bat 9-EM-TerminateTracking.bat A-EM-ConvertCvdScenario.bat B-E-LaunchExhibitSystem.bat B-M-LaunchMobileSystem.bat C-EM-TerminateSystem.bat exhibit system 0-EM-StartViewer.bat 0-EM-StartViewerDebug.bat 0-E-StartSyncServer.bat 1-E-StartAirfoilTracking.bat 1-M-StartUserTracking.bat 2-E-ConnectAirfoilTracking.bat 2-M-ConnectUserTracking.bat 8-E-LaunchTracking.bat 8-M-LaunchTracking.bat 9-EM-TerminateTracking.bat A-EM-ConvertCvdScenario.bat B-E-LaunchExhibitSystem.bat B-M-LaunchMobileSystem.bat C-EM-TerminateSystem.bat mobile system
9	Open files in SmallView: Load scenario main VRML file (starts with an underscore '_') from one of the data\scenes\<exhibit> sub-folders (CTRL-O, File menu -> Open File), e.g. 'data\scenes\Airtrack\CvdDefault\ _AirtrackScenario.wrl'. Alternatively you can choose the last file loaded from the File menu by sequentially typing ALT, F, 1 or by selecting 3 _AirtrackScenario.wrl.	Untitled - SmallView 0.9 beta (built...) File Display Options Multuser Viewing Options Open File Ctrl+O Reload File Open URL Save scenes as F12 Set Device Config File Ctrl+D Edit Settings Ctrl+T Edit Remote Access Settings 1 _AIRFOIL_SCENARIO.wrl 2 _BIOTUBE_SCENARIO.wrl 3 _AIRTRACK_SCENARIO.wrl 4 _AIRTRACK_SCENARIO.wrl Exit Alt+X Open Look in: 1stPrototype My Recent Documents Desktop My Documents My Computer My Network Places AIRFLOW media AIRFOIL_SCENARIO.wrl AIRFLOW.wrl AIRFOIL_GHOST.wrl AIRFOIL_GHOST_2 BACKWALL_AIR_VO BACKWALL_FRAME.wrl BACKWALL_PLANES.wrl EXPLANATION.wrl EXPLANATION_BERNOULLI.wrl EXPLANATION_FRAME.wrl EXPLANATION_WHY_PLANES_FLY.wrl INIT_MENU.wrl MANAGE_MENU.wrl MENU_MANAGER.wrl PILLAR_GHOST.wrl PLYWOOD_GHOST.wrl TABLE_GHOST.wrl Type: VRML File Size: 13.7 KB Date Modified: 10/23/2005 3:26 PM File name: _AIRFOIL_SCENARIO.wrl Files of type: Open Cancel scenario file

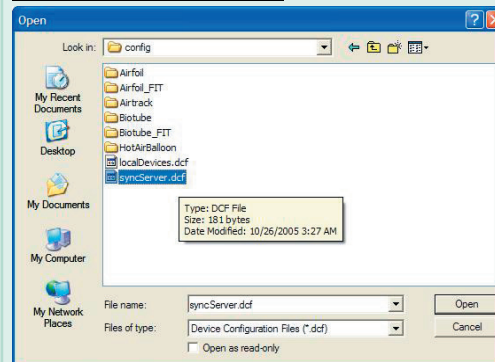
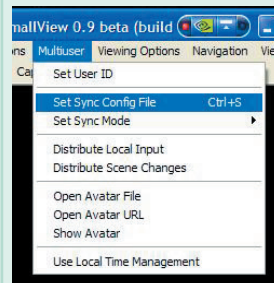


2. Connect to hardware devices by opening the device configuration file 'data\config\localDevices.dcf' (CTRL-D, File menu -> Set device config file)



device file

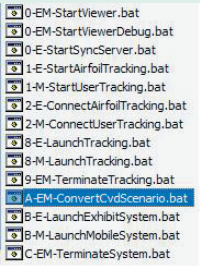
3. Synchronize exhibit and mobile AR systems by loading the sync config file 'data\config\syncServer.dcf' (CTRL -S, Multiuser menu -> Set sync config file)



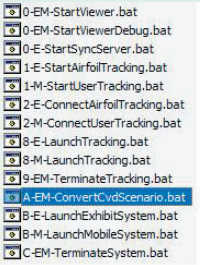
synchronization file

4. Switch to full screen by pressing F10. Attention: Don't maximise the window, as this interferes with full screen mode. Only use F10.

Now the system is operational. To load a new scenario created by the CVD, it has to be transmitted to the exhibit AR system first (not described in this section). Then it can be converted and loaded as follows.

Load New Scenario		
Step	Description	Screenshot
1	Convert CVD scenario to 3D scenario: On the exhibit AR system execute the batch file 'A-EM-ConvertCvd-Scenario.bat'.	
2	In SmallView reopen VRML file (CTRL-R File menu -> Reopen) or through the menu of the CONNECT user interface.	

After using the AR system it is shut down as follows.

Shutdown exhibit and mobile AR system		
Step	Description	Screenshot
1	Terminate the system by executing the batch file 'C-EM-TerminateSystem.bat'.	
2	Close audio connection to classroom (if available): On mobile AR system close Skype.	
3	Switch off components: - Shut down laptop/wearable/PC - Switch off wireless mouse - Switch off display (if applicable) - Unplug power supply of data acquisition system (if applicable)	



4	Charge battery packs: • Plug power supply into laptop/wearable • Charge batteries in wireless mouse (if applicable) • Plug battery pack of display to charging facility (if applicable)	
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If a restart is required because of problems with the data acquisition system or the tracking, this has to be performed before starting the system again. Components that are not affected, like the laptop, display or audio connection, can remain as they are.

