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1. Executive Summary

The aim of this report is to present a series of case studies illustrating the work of the 14 pilot projects, whereupon comparisons of common features or experiences may be made. This in turn leads to a set of generalised findings or conclusions about the nature of museum/science centre relationships with schools. Thus, whilst this report provides an assessment of each pilot project (acknowledging the local context in which the projects operated), the emphasis is on the identification of effective practice which may inform future projects which seek to support and strengthen the bridge between formal and informal learning.

The EU-funded Pencil project provided practitioners, policy makers and researchers with a unique opportunity to examine, in detail, the manner in which science museums and science centres may integrate their activities and resources with those of local schools. The project promoted a series of initiatives in which science museums and science centres worked closely with teachers to develop practices which exploit the learning opportunities provided by both contexts. These initiatives included, among other developments, discussions about the use of informal teaching methodologies which aim to enhance student motivation; the involvement of stakeholders – such as teachers and students – in the design of museum and science centre exhibits and programmes; and approaches for enhancing both teachers and students understanding of the nature of contemporary science.

Each of the 14 Pencil projects was led by a pilot project coordinator (PPC) who was responsible for planning the projects and building partnerships with local schools. The pilot project coordinators were also responsible for conducting the internal evaluations of their projects.

Although the 14 pilot projects varied in content and approach, all the projects sought to explore ways to strengthen the relationships between formal and informal learning contexts. In this way, Pencil created of a network of institutions across Europe and Israel each sharing a common goal. Twice yearly face-to-face meetings, and weekly online chatroom discussions supported communication across the network with the intention that, despite differences in the local context, the lessons learnt in one country would be relevant to the work planned, and ongoing, in another.

2. Background

2.1. Aims

This report addresses the following aims:

- To assess the nature, practice and outcomes of pilot project activities
- To identify key factors in determining the success, or otherwise, or pilot project activities
- To summarise the factors for success and areas needing improvement emerging from the assessment of pilot projects in order to inform future developments

2.2. The 'assessment' of pilot projects

In acting as external evaluators to the Pencil pilot projects, the role of the two academic teams – King's College London and the University of Naples – was to advise the projects on their use of evaluation, and to document the varied practices and processes with which the 14 projects engaged. As each project is a function of its local context, it is impossible to conduct a direct comparison of project outcomes, or indeed offer a 'score' for project practices. Furthermore, it may be argued that only the project staff (and other key stakeholders) are really in a position to assess the impact of their initiative in light of local needs, constraints and opportunities.

However, in reviewing all 14 projects, it is possible to conduct a cross-comparison of the ways in which projects conducted their activities across a set of common parameters or dimensions. It in is this way that we have conducted an 'assessment of the pilot projects' and have derived factors for success and areas for improvement,

3. Methods

3.1. Data gathering

The 14 Pencil pilot projects were planned and conducted in a variety of contexts – national, local and political. In managing the projects, the pilot project coordinators (PPCs) would respond in different ways to particular problems according to the educational traditions of their country / institution. As it is impossible for any group of researchers to fully understand the nature of such varied contexts and traditions, our research data can only consist of the reports from the PPCs regarding project processes and lessons learnt, together with our own professional understanding of informal and formal learning based on the academic literature and our own experiences. In order to gather data from the PPCs, an interview protocol was developed and lengthy interviews (between 2 and 3 hours) with the PPCs were conducted. In some instances, teachers who worked with the project were also interviewed.

In the course of conducting these studies, we also offered advice and suggestions to the PPCs about the best ways to develop their activities and plan their evaluation processes. In addition, we helped in the identification and resolution of key issues, and shared the experiences of other Pencil projects in order to prompt consideration of alternatives and also to strengthen the wider European Pencil network.

3.2. Interviews

The interview protocols and overarching evaluation framework was discussed and agreed with all pilot projects in advance. The protocols explored a number of themes such as the processes involved in decision making, or steps taken to reduce gender inequity. (see Annex A and B for interview protocols). The interviews were conducted during two visits to each of the 14 museums and science centres. Each visit – the first of which was conducted at the end of Year 1, the second at the end of Year 2 – lasted 1-2 days. During this time, the researchers were also able to talk informally with the PPCs, and where possible, observe some of the Pencil project activities. The Year 1 interviews examined the involvement of teachers, university researchers and internal staff within the Pencil project. They also explored decision making processes and plans for the activities and evaluation thereof. The Year 2 interviews focused on barriers to success, the added value of projects, connections with the wider Pencil network and the nature of completed evaluation protocols. Interviews were conducted in English and audio recorded with permission. Transcripts were made in full, and were used in analysis alongside field notes of the visit. The logs from monthly chat rooms sessions hosted by the Xplora-EU web portal (http://www.xplora.org/) were also collected. These chat-room discussions, designed as part of a Pencil community-building exercise, were attended by Pencil staff from each project and consisted of discussions between the project staff and researchers regarding both practical considerations of running projects, and aspects of educational research such as the choice of evaluation methods. Other sources of data for our assessment included unpublished Pencil projects documents, brochures, teaching materials and the internal evaluation reports produced by the Pencil staff.

Once both sets of interviews were completed, we were able to begin our data analysis. In the first instance we grouped factors and issues which the pilot projects reported to be important in determining the success or otherwise, of their projects. This led to the development of a set of eight parameters which structured our analysis and case study descriptions. The parameters, as dimensions of analysis, are described below:

3.3. Dimensions of analysis

3.3.1 Relationship between key players

This parameter examines one of the key premises of Pencil: the extent to which key players interact to sustain a partnership between museums and science centres with local schools.

Whilst museums and science centres have long worked with schools, producing materials and resources to suit schools' needs, rarely have institutions established long-term partnerships with schools wherein schools and the institutions both contribute to the design of educational activities over an extended period of time.

The Pencil funding, however, has provided an opportunity for museums and science centres to establish such partnerships and to develop new and innovative ways of working. By examining the nature of the relationships within the Pencil project, it is possible to comment on the ways in which future partnerships between formal and informal environments may be best supported.

This parameter also considers relationships developed with other players, such as internal museum staff, or academic researchers from local universities. Such relationships are influential in enabling the success or otherwise of the pilot projects.

When considering the internal and external relationships, the impacts of strategic or political decisions on the emerging relationships are examined. When considering the relationship with schools and teachers, both practical issues which impact on the relationships (such as how do people work together, plan together, and communicate?), and also pedagogical issues (such as how are differing models of teaching and learning discussed and applied?) are considered.

3.3.2 Use of educational (and other) research

This parameter considers the extent to which the pilot projects were built upon established educational, or visitor studies, research. If prior research findings are not examined, pilot projects run the risk of trying to invent the wheel each time they wish to develop activities in a new direction. In this context, educational research includes findings on aspects of how the teaching of science may be supported and enhanced, and how particular environments may enable or constrain learning opportunities. To a certain degree, actions considered here are also examined under other parameters, such as models of practice of teaching and learning, and the nature of evaluation.

3.3.3 Models and practice of teaching and learning

This parameter examines the espoused models of teaching and learning, as held by science centre/museum staff, and by partner teachers. Furthermore, it examines, where possible, the implementation of such models in practice. It also considers the models of science held by various individual educators involved in the project. The findings within this parameter will highlight any differences between the pedagogical perspectives held by the museum or science centre and those held by the partner schools, or by the educational system more broadly.

3.3.4 Use of evaluation tools

In this parameter the perception of evaluation expressed by the various pilot projects is considered. For example, the choices made by pilot projects in determining the aim of their evaluation projects, and in identifying evaluation tools to use, are examined. This parameter primarily examines the methods of evaluation, but when available will also address the results of evaluation. (Note – see the internal evaluation results of each pilot project for the full set of findings.)

3.3.5 Professional development of museum / science centre staff

This parameter examines the extent to which the pilot projects resulted in the professional development of museum or science centre staff. Where possible, the personal and professional development of teachers (and other players) is also commented upon, but given that the main locus of the Pencil project was the informal institution, it is the development of museum or science centre staff that is primarily analysed.

3.3.6 Emphasis on issues of gender equity and social justice

This parameter explores the extent to which the project attempted to serve the widest possible audience (thus enabling greater sustainability of the project). Gender equity refers to the extent to which girls are afforded opportunities to engage in science activities to the same extent as boys, and vice versa. Social justice refers to the notion that museums and science centres, as publicly funded institutions and mainstays of popular culture, should seek to ensure that all members of society, regardless of ethnic, or social background, and physical ability, should be able to benefit from the resources available in the informal institution.

3.3.7 Involvement in, and fostering of, wider network

This parameter considers a secondary aim of the wider Pencil project – that is, the extent to which a collection of museums and science centres may share insights and practices by operating as a network at the local level with education providers, or more widely with other informal science institutions.

3.3.8 Sustainability of the initiative

The final parameter combines aspects of the other seven in order to comment on the extent to which the innovation of the Pencil funded initiative will be embedded in institutional practices in order to support and enhance science learning. This parameter also affords insights into the ways in which projects are planned and implemented and thus the findings constitute valuable advice for future projects.

4. Overview and structure of this report

4.1. Structure of this report and connections to other deliverables

In this report we present a series of case studies describing the development processes, activities and outcomes from the 14 pilot projects. These case studies are structured according to the parameters as discussed above. Where appropriate, we include quotes from the interviews, but given that English was not the first language of many of our respondents, comments have generally been summarised rather than quoted verbatim

Six of the pilot project case studies were completed by researchers from King's College London, and eight were completed by researchers from the University of Napoli, The case studies follow the same framework, but vary in style. In order to check our interpretations, key findings were shared with the individual Pencil pilot projects to confirm their validity. In this way, we were able to resolve any outstanding questions, and address any gaps in the data.

As a conclusion to each case study, we identify the key practices employed by players in the project to build stronger bridges between the formal and informal environments. The identification of such practices or key features are supported by our professional understanding of and extensive experience in evaluating formal and informal learning.

Such practices are further discussed in D31 and D28 wherein recommendations for future projects, and criteria of innovation are also presented.

4.2. Reporting conventions

In the whole text of this report, the following conventions are used:

- PPC(s) indicates the Pencil Project Coordinator(s) - those members of the museum or science centre staff who were responsible for the pilot project in their institutions.
- The references for specific quotes from PPCs refer to interviews conducted by the university researchers.

5. Case studies

5.1. National Marine Aquarium, (UK) – Marine issues with climate change

5.1.1 Summary description of The National Marine Aquarium pilot project

The NMA project used the uncertainties and disputes in the scientific debate about climate change to present science as a dynamic process as opposed to a collection of static facts.
By enhancing understanding and awareness of climate change and its impact on the oceans and the environment, the project's primary objective was to stimulate students' interest in studying science and help them to become scientifically literate, responsible citizens.

The pilot project activities were connected to the opening in March 2006 of a new permanent exhibition named *ExplorOcean*. This exhibition may best be described as a small science centre devoted to an interactive presentation of ocean technologies. The space includes (among other things) a *Climate Lab*; a large tank containing real remote-controlled underwater equipments; and a 3-D theatre to virtually explore the depths. In particular the pilot project was connected to the *Climate Lab*, a section of the exhibition which explores the ways climate changes are affecting the oceans with respect to temperature, chemical composition, sea level and sea life. The *Climate Lab* exhibit, together with an online *Climate Lab* (developed as part of the PENCIL pilot project) were used, in partnership with local schools, to develop cross-curricular educational pathways.

The *Climate Lab* exhibit contains:

1. hands-on exhibits related to key issues (such as ocean levels, ocean acidity, ocean currents and so on).
2. a *Climate Kitchen*. Inspired by the huge popularity of TV programmes about cooking and famous chef, a kitchen is used to represent the earth. Different ingredients (fossil fuels, deforestation, etc.) are used to "cook" natural disasters. Visitors read information panels about the ingredients and watch a short video modelled on TV programmes except that the chef proposes recipes for disasters rather then recipes for food.
3. *Climate news*. The visitors watch TV-like news about climate changes.

The website offers tools for understanding and delivering the subject at a variety of levels and provides access to real information for manipulation and appraisal. It also offers access, through web links, to working scientists within a number of relevant disciplines to encourage debate, and to put users in touch with "cutting edge" climate change studies. A prior web survey allowed the PENCIL team to identify existing provision in the area of climate change with specific reference to marine issues and to assess links with the school curriculum. Where relevant, good quality resources were identified, and have been included in the links of the website. The website also features a teachers' area with curriculum advice, downloadable support materials and ideas for class demonstrations of basic concepts.

The pilot project involved six primary and six secondary schools (with students aged between 9 and 15 years old). Eight of the schools were located near the aquarium, whilst two of the primary and two of secondary are located elsewhere in the UK.

Local context
Compulsory education in the UK is divided in primary (4/5 to 11 years old pupils) and secondary (11 to 16 years old) schools. A new, more flexible, curriculum covering the last three years of secondary school is currently being trialled. This new curriculum gives school managers greater

freedom to add supplementary courses to the mandatory topics. Furthermore, pupils have greater freedom to choose their own projects for study. This reform provides museums and science centres with the opportunity to build long-term relationships with schools.

In primary schools, science is taught by one teacher. In secondary schools, one teacher is responsible for each different scientific discipline (maths, physics, biology, chemistry). To qualify as a teacher, individuals must have a degree in education, or have completed their postgraduate certificate in education (PGCE).

5.1.2 Case study

I. Relationships between key players

As part of the pilot project internal evaluation strategy, an initial scan of the National Curriculum was carried out in order to identify key areas for the potential inclusion of climate change in teaching. The intention was to ensure that pupils and teachers were correctly targeted with relevant and useful resources. Science, Geography and Citizenship were assessed to be the most appropriate topic areas in the curriculum on which to make connections.

Teachers were also asked about what they wanted from the resources created. Their answers were mainly concerned with establishing connections between the resources and the National Curriculum. In addition, teachers expressed a need for the development of a coordinated approach across subject areas to deliver teaching about climate change issues. Teachers also expressed a desire for a set of resources that were targeted at specific subject areas but with the flexibility to be incorporated into school-wide projects. With regards tools and resources to be used, teachers noted preferences towards:

- students panels/debates
- worksheets
- computer based animations and applets
- virtual tours / links to Aquarium visits
- videos / videoconferencing
- guest speakers
- online experiments
- databases / scientific data with tools for analysing

The *Climate Lab* website was designed and built by an external partner, working with National Marine Aquarium project staff. The partner produced a graphical concept for the site together with a set of proposals for student activities and teaching resources. A website consultation group was then set up which consisted of National Marine Aquarium project staff, a university student conducting a project on informal learning, a group of four partner teachers and two pupils from a partner school's "laptop group"[1].

A set of initial ideas were presented in a meeting of the consultation group and a number of changes were identified (for example, a reduction in the amount of cartoon characters as they were felt to be off-putting to a teenage audience). The teachers in the group also made a number of suggestions to make the student activities connect with the curriculum. In a subsequent meeting the final prototype of the website was presented to the group. All teachers were satisfied with the development of the website and in particular with the good balance of technical and non-technical vocabulary. The reduction in cartoon characters was felt to be beneficial. Further work was

[1] The "laptop group" is a group of selected pupils who use laptop computers for the majority of their learning in school

required to improve the teachers' area and included the implementation of concise, straightforward instructions with links to extension texts. Suggestions for improvements also revolved around more resources to be linked to the Aquarium visits.

Following this meeting, the external contractor and National Marine Aquarium made a number of amendments to the final design and the website was went live in December 2006. This date was three months later than originally scheduled, largely because of the number of changes identified in the first meeting. This had a detrimental effect on the final outcome as teachers were unable to find time to use the website until after the exams in June.

II. Use of educational (and other) research

A number of external research partners were involved in the design and carrying out of the Pencil pilot project activities and evaluation strategy, including the Plymouth Marine Laboratory, the Marine Biological Association of the UK, the Faculty of Science at the University of Plymouth, the Tyndall Centre at the University of East Anglia, the Association for Science Education in the UK and the Environment Agency in the UK. The content composition of both the *Climate Lab* exhibition and website were based upon a programme of academic research and information gathering on the causes and effects of climate change in marine systems. This information gathering included building working relationships with local research scientists and fishermen.

The National Marine Aquarium has also developed a link into the *Euroceans* network of excellence dedicated to the science of marine climate change.

III. Models and practice of teaching and learning

The intended learning outcomes of the pilot project included:

- increased knowledge of the causes of climate change and the impacts upon ocean systems;
- enhanced understanding of the role of the individual in contributing to climate change and alleviating the effects;
- increased understanding of the role of scientists in investigating climate change and the use of predictive modelling; and
- enhanced appreciation of the complex systems approach to understanding climate.

In order to achieve these outcomes, the website aimed at prompting users to create links between their personal behaviour (what they eat, what resources they consume, how they get around), with environmental processes and impact on marine systems (water temperature, volume, chemistry, global movement). The website presented a range of materials which varied in approach from investigative learning to discussion; some activities were learner-centred, others were led by a facilitator. All the activities were intended to stimulate ideas and debates in class. Each activity and the associated learning outcomes were self-contained but by combining several activities, the aim was to empower students with an in-depth holistic view of marine issues relating to climate change. This flexible approach also created opportunities for pupils to develop projects in their own way. Indeed, one group of pupils created their own website[2], to communicate with other pupils and may be considered an example of peer-to-peer teaching/learning.

IV. Use of evaluation tools

Beginning in January 2006, a front-end and formative evaluation study was carried out to assess the preferences of teachers and pupils with respect to the contents and style of delivery of the two *Climate Labs* – ie the physical exhibition, vs. the online resource. Unfortunately, the results of the evaluation were too late to affect the design of the *Climate Lab* exhibit, although the online

[2] Visit http://www.bideford.devon.sch.uk/climatelab to see the website created by the students.

version was readily modified in response to the comments from the target group. A summative evaluation study was then set up to assess the relative value of different learning programmes with respect to a visit to the science centre only, the use of the website only, and the combination of the two.

As discussed above, the front-end evaluation study consisted of the web survey, a schools survey, academic survey and science centre survey in which several evaluation tools were used including questionnaires and focus groups. The formative evaluation study also investigated the suitability and accessibility of the website for its target audience, through an iterative design process involving consultation between National Marine Aquarium staff, web designers, teachers and pupils.

The summative evaluation study assessed the efficacy of the website in classroom teaching, and examined the absolute and relative value of science centre visits and website use in terms of learning outcomes. Methods used to conduct this study included concept mapping and pre/post knowledge tests. Concept maps were chosen because they offer a simple but potentially effective method of allowing pupils to demonstrate their level of knowledge and awareness about the myriad issues involved in a complex topic as climate change. Knowledge tests covered a broad range of principles and facts that demonstrate the degree of understanding resulting from the project as a whole.

V. Professional development of museum / science centre staff

The main results achieved with respect to the professional development of Aquarium staff are related to the design and implementation of the evaluation strategy, and the collaborative work with teachers. For example, the consultation group established to conduct the formative evaluation provided NMA staff with the opportunity to work in partnership with teachers rather then developing a resource without end-user input. Such a collaboration could be described as the starting point for building further long-term relationships with schools aimed at sharing a common vision of science learning/teaching and a common approach for the assessment of learning outcomes.

The pilot project coordinator at NMA also expressed the intention of developing a teacher training activity to be carried out in the first month of the next school year to encourage a more comprehensive use of the *Climate Lab* website.

VI. Emphasis on issues of gender equity and social justice

Differences in student performance due to gender were collected by recording gender on questionnaires and concept mapping exercises. The evaluators from the University of Napoli also suggested that it would have been useful to perform observational studies of the Aquarium visits and to encourage teachers to provide observation data on classroom activities with regards to students' gender.

However, issues of gender were not specifically discussed in the pilot project internal evaluation survey, as relevant data was passed to Heureka for the Pencil Motivation Study work package.

VII. Involvement in, fostering of, wider network

Most of the issues about networking reported by the pilot project staff at NMA were related to the interaction with the evaluators from the University of Napoli. For example, the PPC welcomed the input of the academic researchers, saying that "We need support in terms of coordinating what we are doing, and insuring that what we are doing fits into the aims of the overall project."

During the two evaluation visits, an extensive discussion about the science teaching/learning models used in the pilot project was carried out. The focus was on the use of the complex systems approach as a general framework to refer to when dealing with subjects such as climate change, in order to allow the integration of qualitative reasoning and quantitative modelling and simulation. This open and collaborative discussion resulted in the development of a support page especially designed for the NMA pilot project, available on the Resource Centre website[3].

VIII. Sustainability of initiative

As the PPC at NMA declared: "The National Marine Aquarium is dedicated to becoming a leader in the communication of climate change issues to the public. Climate change will affect us all over the next century and tough choices may lie ahead for politicians and society as we struggle to come to grips with the potential for our actions to impact on climate systems. A public fully engaged with the scientific arguments and processes will be necessary to ensure that society makes informed choices. Effective science communication is therefore a key part of the process". The Pencil supported *Climate Labs* are thus seen as playing a central role NMA's mission of effective science communication. Indeed, activities that involve pupils creating their own films about climate change for use on the website have been trialled and are being added to the C*limate Lab* in order to extend the programme and impact of the original pilot project.

5.1.3 Conclusion of National Marine Aquarium case study

The Pencil Pilot Project at NMA was successful in attaining its objective of creating a resource, developed in partnership with teachers and students, to promote understanding around issues of climate change and its impacts on the world's oceans. Such success is mostly due to the implementation of a formative evaluation programme which involved a number of key players: teachers, students, NMA staff, researchers and members of professional associations. This programme resulted in an educational resource which is innovative and well suited to its target group's needs and expectations. Secondly, the materials produced support cross-curricular resources (both real on on-line) thus helping to embed the use of pre visit materials and the interactive website across several school subjects. In short the NMA Pencil pilot project offers a good example for other science centres with respect to developing a collaborative partnership with schools in the development of teaching and learning resources.

Unfortunately, however, the summative evaluation programme did not yield any clear findings with respect to the impact of the three variations of study – the website alone, the exhibit alone, or the combined programme. Furthermore, whilst the website was designed to provide resources for teachers, no evaluation of their use has been conducted. This deficit has already been recognized by the NMA PPC and further steps to address this lack have already been planned.

In summary, the National Marine Aquarium pilot project offers innovative resources and experience with respect to collaborating with the scientific research world and with teachers on highly topical and contemporary scientific issues.

[3] http://www.pencil.unina.it/pilotProjects/nma/support.php

5.2. IMSS, (Italy) – (Online) access to history of science objects

5.2.1. Summary description of pilot project

The pilot project at IMSS explored two approaches for supporting student understanding of aspects of Galileo's physics set against the historical context in which he developed his revolutionary thinking. The project involved the development of a multimedia application (see www.imss.firenze.it) and a practical workshop activity designed for secondary school aged students. Both activities were based upon historical materials held by the museum and explored new ways of presenting the content to engage the interest of young people. In this way, the project, and lessons learnt, may be considered to constitute a valuable model for other museums with historical collections who wish to develop innovative learning materials.

5.2.2. Case study

I. Relationship between key players

The concept for the IMSS Pencil activities was developed by IMSS staff in consultation with a historian of science. However, the Pencil pilot project coordinator (PPC) spent a considerable amount of time recruiting teachers whom she thought would be enthused by the project. Due to the emphasis on commitment and enthusiasm, only a relatively small number of teachers were recruited, although they represented the different types of school in Italy, and were responsible for different age groups.

Two meetings were organised prior to the practical activity – the first to discuss the experimental research of Galileo, and the second to continue to explore the contexts in which Galileo worked and to discuss how to run the sessions with the students. The teachers welcomed learning more about the content, in advance of planning the session as this provided them with a greater understanding about how the activity could be conducted, and supported back in school. A final meeting with teachers was held following the sessions to review the activity and gain feedback.

Interestingly, several of the teachers were accompanied by colleagues responsible for literature and the humanities as these teachers were also intrigued by the concept of exploring the context in which Galileo developed his ideas.

In summary, the success of the activity seems partly due to the close working relationship, and trust, which had developed between the teachers and PPC and historian of science.

II. Use of educational (and other) research

The Pencil project benefited from expertise offered by the historian of science in terms of the content for the activity. As a professor, he had organised similar ventures with college and high school students previously, and understood how to introduce the activity to appeal to younger students.

Whilst the PPC did not mention specific resources with respect to educational theory, she did comment that she valued the materials circulated by the university teams regarding the nature of evaluation. She also noted that she had gained insight from working alongside the other PPCs in the Pencil network.

III. Models and practice of teaching and learning

The activity offered as part of the IMSS Pencil project involved students exploring principles first demonstrated by Galileo using the objects and technology (and ways of thinking) that were available in his day. In this way, the project may be described as following an experiential or discovery learning approach to science content.
In giving the student materials but no explicit instruction, the aim was to "try, as it were, to nudge them without actually giving them the final answers to find out for themselves" (DM200008 page 2) and to "replicate the initial discovery process" (DM20008 page 3).

In addition to the discovery learning approach, the IMSS team wanted to encourage students to think for themselves: "We want to encourage experimentation, questioning authority, give license to fee thinking" Furthermore, IMSS wanted students to learn something of the nature of science and the social practices of science: "We want to give the idea that science is not a linear process but is something that develops, often with faults, and involves many different ideas" (DM200008 page 8).

In providing the teachers with additional context in the pre-session meetings, the IMSS team sought to integrate an experiential approach and an emphasis on the history of science into school learning. Some materials were produced to help contextualise the activity in advance of the museum visit. In addition, a short warm-up activity prior to the main session was designed to prepare students for the practical elements of the activity, and the practice of working cooperatively in groups. This involved students experimenting with a series of instruments in order to prime their skills of coordination and to allow other members of the group to become aware of the relative competencies of others.

The PPC's interpretation of the students' behaviour during the workshop session was that the assessment-free environment, in conjunction with the activity, prompted free experimentation and hypothesising. The atmosphere also promoted greater collaboration amongst students rather than a sense of competition.). One teacher also said that she felt the activity (and by association IMSS) 'legitimated her own view of teaching.' (DM200007 page 8)

Whilst no explicit follow up activities were organised, the web-based activities also designed as part of Pencil served to extend the learning experience. The IMSS coordinator noted that "it is really interesting that they [teachers and students] used the multimedia tool to deepen their understanding of the objects" (DM200008 page 3). Notably, the web-based resources were found to be well used – indeed the IMSS staff had not expected to see such a level of use and interaction. Comments were received about the content, but also about the interface for navigation and graphics. In this way, the web-based activities supported learning in web-based design whilst contributing to the overall learning objective of using interactive learning approaches to support students' understanding of Galileo's scientific endeavours.

IV. Use of evaluation tools

The evaluation procedures employed by the IMSS focused on observation of activities with teacher feedback. Given the experimental nature of the activity, the PPC did not wish to examine any knowledge gain on the part of students (with respect to physics, or an understanding of the social history of science). Instead she wanted to know how the activity was received – whether it was enjoyed, and whether it had potential as an educational tool. To this end, the PPC and the historian of science simply wished to observe the impact on the participants.

To support this approach – i.e. an emphasis on the process of the activity, rather than the outcome – the Pencil evaluators suggested several other evaluation strategies that could prove useful. These included focus groups; the use of stimulated recall, wherein a recording with students taking part in the activity is played back and the students discuss what they were thinking; and using other records of the events – such as the video and photos made by students accompanying the class to the museum – in order to see how others perceive the process of the activity.

V. Professional development of museum or science centre staff

The professional development of museum staff was not an explicit focus for the IMSS Pencil project. However, it was noted that the skills of the workshop facilitators did develop over time, and that they modified the sessions to suit the needs of the audience and as such may be considered to have developed professionally as museum educators.

VI. Emphasis on issues of gender equity and social justice

The IMSS Pencil project did not explicitly address issues of gender or social justice, although the PPC did comment that the practical aspects of the activity might have appealed to the more extrovert nature of boys.

VII. Involvement in, and fostering of, wider network

The IMSS PPC welcomed the opportunity offered by the wider Pencil network to meet other people, to listen to what they do, and to get a different point of view. However, she also noted that since the project topics were so very different, the greatest opportunity offered by the network was the chance to learn about ways of communicating, rather than specific educational practice. Within the context of communication, she also expressed a personal preference regarding the importance of meeting in person rather than via a chat room. In a similar vein, the PPC commented that it was important to meet and discuss ideas with teachers, and that web-based materials on their own were not enough:

VIII. Sustainability of initiative

IMSS would like to continue to integrate the different functions of the museum – visits, multimedia, experimental activities – and use the Pencil model to explore other topics in the history of science. Some of the IMSS activities have already been adapted for use within the INDIRE format, thus ensuring that a wider audience benefits from the project.

The Pencil evaluators noted that the basic idea of the IMSS Pencil activity - exploring the work and experimental thinking of [historical] scientists - could be applied in other museums and informal spaces. In addition, they noted that the activity was predicated upon the expertise of the museum, and as such demonstrates the way in which other historical museums may offer a beneficial learning experience.

Finally, the PPC commented that the Pencil project had provided staff with an opportunity to experiment, meets lots of different people with different ways of thinking, work within different types of relationships and be part of a wider context.

5.2.3. Conclusion of IMSS case study

The Pencil project at the IMSS may be considered successful as a result of several key factors. Firstly, the museum built on its body of established expertise – for example, the web-based materials were enriched by enabling access to the museum's unique collection of historical objects, whilst the ideas for the workshops were made possible by the expert knowledge of the museum's education staff and associated colleagues. In developing a programme of activities based on the history of science, and the study of historical objects, the IMSS has demonstrated that (contrary to popular conceptions) historical museums can offer compelling educational experiences.

Secondly, the success of the project activities may also be attributed to the strong relationships built with the teachers who partnered in the initiative. These teachers welcomed the new approach and were excited by the support that the museum offered to them.

However, whilst the project was clearly a success, with the ideas having since been shared more widely, the evaluation of the original project could have been stronger, with results providing greater guidance to future developments. For example, little attempt was made to capture student's views and changes in understanding as a result of the workshop activity. Although the comments of teachers are useful, student responses are invaluable for gauging the success of an activity and for providing data for potential benefactors of future initiatives. Equally, the evaluation of the web-based materials was minimal, although feedback from students was collected.

In building further activities, it is recommended that more thought be paid to the design of evaluation procedures to ensure that the interests of the museum (in designing new activities) and the interests of teachers and students (in capturing the impact of the experience) are met.

5.3. Explor@dome (France) – Middle school students' use of ICT in science learning

5.3.1. Summary description of pilot project

The Explor@dome pilot project was based on an existing activity, the Explor@mobile programme, which is a combination of science and multimedia activities designed for middle school students and delivered directly into the classrooms via the travelling science van Explor@mobile. The programme is an outreach activity with an underlying philosophy which is aptly summarized in the following statement by Brigitte Zana, the former director of the museum: "We therefore decided that, besides the 30 interactive environments conceived and developed at the Exploratorium, the public of the Explo@dome was going to have free access to a further multimedia environment connected to the Net. The underlying principle of the Explor@dome was indeed that of combining the real and the virtual worlds to favour the acquisition of scientific knowledge, and for this purpose we decided to compound the above-mentioned interactive and multimedia environments with activities that were to be carried out in pedagogical workshops under the guidance of animators and myself"[4].

The standard Explor@mobile programme consisted of 12 weekly workshops (one and an half hours each) presented at schools by two Explor@dome educators over a three-month period. Half of the workshops were based on hands-on exhibits together with lab and exploratory activities focused on a variety of scientific topics (physics, astronomy, optics, meteorology, environment, maths, etc.), while the remaining sessions were devoted to multimedia activities designed to support and reinforce what was learned in the "scientific" workshops. The objective of the whole programme was for students to develop a multimedia product (slide-show presentation, website, exhibition panels or video) as an educational resource for other students at the same school level. The Explor@mobile is thus equipped with a number of hands-on exhibits, educational kits and laptops supplied with open source software.

Examples of projects carried out in the participating schools included:

- production of a CD-ROM investigating the links between art and mathematics, covering optical illusions, paving, and geometric constructions (pupils aged 12)
- creation of an illustrated novel and an exhibition on pinhole photography (photographs were taken using a pinhole camera made out of a tin can) (pupils with learning difficulties aged 12)
- design of exhibition posters about energy (pupils aged 15)
- production of a scientific documentary on DVD (pupils aged 13 with learning difficulties).

Over two years the pilot project involved 27 middle schools (in the Paris district of Val d'Oise), approximately 500 students (aged between 11-16 years old) and approximately 50 teachers.

In keeping with the framework of Pencil, the main objective of the pilot project was to evaluate the effectiveness of the teaching approach on which the Explor@mobile workshops were based and as a result develop necessary revisions. The evaluation was mainly focused on assessing the differential impact of the whole programme, and of the multimedia activities alone, in terms of changes in pupils' knowledge and perceptions of science.

[4] Brigitte Zana, *History of the museums, the mediators and scientific education,* **JCOM 4 (4)**, December 2005

Local context

The educational departments of the local administration (the Council of the Val d'Oise) have strong relationships with a number of out-of-school educational partners. At the beginning of every school year the Council publishes a *Guide of educational activities for Collèges*, which presents a series of activities offered by different associations and institutions and divided in general thematic areas. The science and technology section of the *Guide* includes, for example, thematic areas such as Environment; Scientific and Technologic Ateliers; and Use of ICT in Teaching. The weekly timetable of the Collèges includes two hours of "free time" designed to enable teachers to choose extra-curricular educational programmes among those contained in the *Guide*.

The French school system is structured in 5 grades of primary school (with students aged 6 to 10 years old), followed by 6 grades of Collège (with students aged 11 to 16 years old). Some children stop school at 16 and instead attend 2 years of work based practical studies (as a plumber, baker, etc.). Pupils from 16 to 18 years old attend Lycée, which ends with the final exam – the "Baccalauréat". The time prescribed for maths and science in Collèges is: maths 4-4.5 hours per week; physics and chemistry 1.5 hours; biology and geology 1.5 hours; and, technology 1.5 hours.

In the Collèges there is one teacher for each discipline (maths, physics and chemistry, biology and geology, technology). Science teachers have an academic background related to the subject they teach. After 3 years at university, the students pass a competitive entrance exam to enter IUFM (*Academic Institute for Teacher Training*), which lasts two years. During the second year, they begin to work at school and continue to study. The IUFM is also in charge for the in-service teacher training which is organized in three-week workshops (in collaboration with external partners). During a teacher's participation in these workshops their responsibilities at school are taken on by IUFM students.

5.3.2. Case study

I. Relationships between key players

Every school year the educational offer of Explor@dome is included in the above-mentioned *Guide of educational activities for Collèges* published by the Council of the Val d'Oise. During the two years of Pencil pilot project activities, the Explor@mobile programme as included in the *Use of ICT in Teaching* thematic area of the *Guide*. The recruitment of the teachers participating in the pilot project was therefore "mediated" by the *Council*, who distribute the *Guide* to all the schools in the district. The final cohort of teachers were selected by the Explor@dome. The pilot project coordinator (PPC) at Explor@dome offered this rationale for selection: "Many teachers are not willing to participate in the activities, they just ask us to do something and during the workshops they do not make any contribution. But some of them are willing to make interventions and modify the programme they carry out at school. We always try to select this kind of teacher".

The Explor@mobile programme offers many different kinds of workshops and the choice about subject, timing and modality of intervention were discussed in meetings with each teacher, in order to arrange activities to suit her/his curricular needs. The first meeting took place in the science centre, after which the informal educator responsible for the activity and the teacher kept in constant contact to coordinate their work. The evaluators from the University of Napoli had a chance to participate as observers to one of those preliminary meetings which was structured as follows:

- agreement about the timing of intervention: the teacher expressed preference for the first semester so to have time left in the second to build on the experience of his pupils (13 years old);

- the educator from Explor@dome explained to the teacher what Explor@dome could offer his class in making use of the multimedia products developed by classes participating in the programme during the previous school year;
- agreement about the topic to be presented was delayed because the teacher wanted to decide about it together with his pupils, after showing them the above mentioned multimedia products;
- detailed discussion about the (open source) software to be used in the multimedia activities
- agreement about the weekly schedule of intervention (according to the above mentioned "free time" in the school schedule) and about their next meeting.

The evaluators had the feeling that, depending on the participative attitude of the teacher, the coordinated planning of the activities could result in the Explor@mobile programmes being essentially made-to-measure. This feeling was confirmed by direct observations of the school activities and discussions with teachers made during the evaluation visits. The evaluators from the University of Napoli also had a chance to interview one of the PENCIL teachers, who commented: "I use the Explor@mobile programme as a tool to enhance the reasoning and communicating skills of my pupils [all with cognitive and language difficulties] and I'm very satisfied of the impact it has on their capacity to communicate what they are learning".

II. Use of educational (and other) research

The Explor@dome Pencil pilot project profited from its collaboration with the CDDP92 (*District Centre for Pedagogical Documentation - Hauts de Seine*)[5] resource centre. Through libraries, online resources and consultants, the CDDP offers teachers direct support on any aspect of their teaching practice, from information about existing activities to educational research materials. The PPC explained that "these support activities, which in principle are offered to any teacher who requests them, are mainly exploited in the framework of educational projects in which teachers are involved together with out-of-school institutions". During the Pencil project, teachers were encouraged to make use of the resource centre to satisfy their needs and questions connected to the programmes they were developing together with the Explor@dome educators.

The Explor@dome also collaborated with the University of Paris X – Nanterre and in particular with the Laboratory for Cognitive Psychology, which was involved in Pencil as external evaluator (see Section 4.)

III. Models and practice of teaching and learning

The Explor@mobile programme had many educational objectives, which can be summarized as follows:
- enhance pupils' motivation towards learning science
- stimulate pupils' working in group
- let the pupils discover and practice the use of ICT tools
- enhance pupils' communication skills with the aim of helping students reinforce their knowledge gained by communicating it to their peers.

The approaches used by Explor@dome educators to attain these objectives depended on the huge variety of scientific topics, curricular needs and audiences. Nonetheless a common teaching/learning model was shared among the educators (and the teachers).

As already mentioned the programme was based on two parallel sets of activities, and thus involved tackling the scientific subjects via two different approaches. The scientific workshops

[5] www.crdp.ac-versailles.fr/cddp92.

consisted of debates involving the whole class in answering the educator's questions while observing experiments and manipulating and constructing objects (i.e. a model of our solar system). The model underlying these hands-on workshops can best be described as enquiry-based learning.

These activities were then supplemented with activities involving the use of multimedia tools with the aim of letting the pupils discover new ways of communicating what they have learnt in the scientific workshops. Multimedia workshops consisted of an initial training about the use of specific software which were then used to produce multimedia materials, through which pupils communicated aspects of science to their peers by video interviews, demonstrations, and photos. The model of learning underlying this part of the programme can be described a peer-to-peer learning.

In summary, the overall pedagogical approach was constructivist, in that pupils developed their own solutions to scientific problems, and their own ways to represent those solutions using ICT.

IV. Use of evaluation tools

Explor@dome collaborated with an external evaluator (the cognitive psychology research group of the University of Paris X – Nanterre) to conduct the evaluation protocol. As already discussed, this evaluation study was the main objective of the pilot project and was designed to evaluate the differential impact of the Explor@mobile programme on pupils' learning.

After a first phase consisting of direct observations of classroom activities, the researchers designed a study divided in two parts: the first one aimed at exploring the impact of the series of 12 workshops (including the multimedia activities) on a group of 12 year old pupils; the second aimed at studying the impact of the just multimedia workshops on a group of 14 years old pupils. Despite well-developed prior planning, some problems occurred with the first study due to the difficulty of finding classes of the same grade to act as the target and control group. As a result, the pre-test was administered when some of the Explor@mobile workshops had already been carried out.

The first study was conducted on two classes: one exposed to the Explor@mobile programme and the other not participating in the programme but studying the same subjects (mathematics and "arts plastiques") with the same teachers, thus constituting the control. The tools used for the study (all with a pre-post administering strategy) comprised a questionnaire concerning pupils' perceptions about science and science teaching (interests, motivation, difficulties) and two cognitive tests (knowledge and skills concerning symmetry and proportions). The results of this first study showed a clear impact of the programme on the knowledge of pupils, while pupils' perceptions seemed to be only slightly affected by the programme on a long-term basis. (For a more detailed analysis see the Explor@dome's internal evaluation report). The study also showed evidence of gender differences in the results, which will be outlined in Section IV.

The second study was performed on three groups of pupils from two classes: one exposed to both a scientific and a multimedia Explor@mobile workshop; the second only to the scientific workshop and to an activity (lead by their teacher) aimed at developing an "exhibition"; and the third to the scientific workshop only. Pupils' knowledge about energy was evaluated using pre / post tests, and audio recordings of all the sessions were then analyzed. The multimedia session was also analyzed via screen-capture software, which records the pupil's actions and presents, on screen, the progression of activities. The results of this second study showed that the multimedia workshop alone did not produce any particular effect on pupils' knowledge, as the responses of the "multimedia group" and the control group were completely comparable. Interestingly, the responses of the "exhibition group" were systematically lower than those of the other two. The hypothesis advanced by the researchers to explain this difference included to a lack of motivation (the activity was carried out in the end of the school year): and the activity being perceived as particularly "boring".

Since the evaluation was mainly focused on the impact of the programme on pupils' learning, teachers and educators were only examined using "validation" questionnaires, with results indicating a general appreciation of the interactive and innovative methods. The evaluators from the University of Napoli, however, suggested that it would have been interesting to investigate the impact of the Explor@mobile on teachers' practice. Staff from both the Explor@dome and from the University of Nanterre agreed with the point, but unfortunately the suggestion came too late and there was no time left to organize a suitable strategy to perform this study. This could be a further step of analysis to be carried out in future months, along with an evaluation of the Explor@mobile educators' self-perception of their work and of the model of teaching/learning that they employ. This last issue was also discussed during the second evaluation visit following findings from the questionnaire administered to the educators. The PPC commented: "They interpreted the questionnaire only as an extra-load of work. Maybe they could have been more motivated if we had asked more interesting questions".

V. Professional development of museum / science centre staff

Although the pilot project was focused on evaluation and the concrete involvement of both teachers and educators in the evaluation process, the professional development of the staff was not an explicit objective of the project. Nevertheless, in being informed about the results of the in-depth evaluation study, performed for the first time as part of PENCIL, has proved to be a positive stimulus for educators. Possible further steps in this process have been outlined in the previous section.

VI. Emphasis on issues of gender equity and social justice

It is worthwhile noting that many of the involved classes included students with learning difficulties. The target group was also very heterogeneous with respect to social and economic background.

In the first evaluation study carried out by the University of Nanterre an analysis of gender differences was also completed. Whilst this analysis didn't indicate any evidence of a gender-biased impact as a result of the Explor@mobile programme, some interesting elements emerged from both the target and control group. In the "Explor@mobile" class there was an improvement in performances regardless of gender, although this improvement was more marked in boys especially in geometry. Furthermore, the programme produced a greater positive affect in girls' perceptions of science more than it did for boys.

In the control group, the pre-test performances of boys and girls was equal, while in the post-test, boys' performances were very much lowered. This may be connected to a change in girls' perception of science and self-perception of their capabilities which were both developed positively over the course of the school year, while boys' perceptions, together with their perhaps overstated initial self-perceptions remained unchanged.

VII. Involvement in, fostering of, wider network

The Explor@dome staff did not feel at all involved in the wider network of Pencil except for the direct and personal relationship with the evaluators from the University of Napoli during the two evaluation visits. Communication strategies among the network (chats, mailing list, meetings) were felt to be ineffective.
In contrast, the Explor@dome Pencil project did help to establish a local network of teachers (and indeed used existing administrative networks to advertise the resource).

VIII. Sustainability of initiative

The Explor@dome pilot project was based on an existing initiative, which will continue to operate in future years. The main objective for the pilot project was the evaluation of this initiative: the results being important in allocating future funding specifically devoted to further developments. As summarised by the PPC, "PENCIL was important for us because we had money and therefore time to plan the evaluation, reflect on our actions and produce materials".

5.3.3. Conclusions of Explor@dome case study

By working closely with their academic partners from the University of Paris X – Nanterre, the Explor@dome Pencil project was able to achieve their stated objective of evaluating their Explor@mobile programme. The extensive evaluation yielded interesting results which will inform the continued developed of this initiative. Furthermore, in building on an existing programme, the Pencil project at the Explor@dome benefited from internal support from the science centre's management and infrastructure. The pedagogical basis of the project – that of enquiry learning – was also well developed and understood by project staff. Nonetheless, the recommendation made by the University of Napoli researchers, that the perceptions and practices of project staff should also be studied in any evaluation programme was well made.

Finally, the Pencil project was ensured success by using existing networks to establish strong relationships with target teachers, and in working with schools from a mix of areas, was able to provide learning opportunities for students with a broad range of educational needs.

5.4. Heureka, (Finland) – Chemistry for primary schools

5.4.1. Summary description of pilot project

The main aim of the Finnish Pencil pilot project was to revise the chemistry-based laboratory activities offered by Heureka by employing a cyclical process involving the implementation of new and refined activities, followed by observation, and critical reflection. The revisions focused on establishing better links between the activities and the primary school curriculum, in which science was introduced for the first time during the year the project was conducted. The programme included five different activities: Bubbling Chemistry; Colourful Chemistry; Water Analysis; Rock Analysis; and From Large to Small. The project involved fifteen primary schools. Teachers were able to select several lab-sessions during the course of the school year according to topics being taught at school. Connections between the activities and the school curricula were discussed with the teachers during the project development. Follow-up web-based interactive activities were also developed for the pupils to carry out back at school or at home.

The laboratory activities were designed for groups of at most 24 pupils. Pupils worked in pairs under the guidance of Heureka explainers. The five activities addressed the requirements of different age groups, and varied in their levels of complexity, as described below.

Bubbling Chemistry was designed for younger children. The main aim of the activity was for pupils to learn about substances (names and properties) and to introduce laboratory methodologies. Pupils performed simple experiments using tools, materials and substances to conduct chemical reactions. Such reactions had "spectacular" results including changes in colours, vapour formation, and the production of gases leading to 'explosions'.

Colourful Chemistry explored the properties of substances in greater detail. The experiments included mixing acid and alkaline substances with red cabbage juice, which is used as a pH indicator. Using felt tip pens, pupils then made their own pH colour chart on a preset form by noting the colours of mixtures against known pH values. Then they used the colour chart to determine the pH of familiar household chemicals.

In Water Analysis pupils simulated a real laboratory analysis of water characteristics with the aim of understanding the physical and chemical properties of good drinking water. The whole activity was aimed at enhancing pupils' awareness of the importance of protecting natural water from pollution. The pupils brought with them various samples of water – tap water, lake water, river water, rain water, melted snow – and examined the smell, colour and turbidity of the samples. They also measured the temperature, conductivity, iron concentration and hardness using semi-professional lab equipment. The characteristics were then compared with tabulated reference values in order to determine the quality of the samples.

Rock Examination aimed at underlining the importance of minerals in human activity by observing and measuring some relevant physical and chemical properties of samples. The activity was targeted at pupils from the last grades of primary schools, but could be adapted to different age groups by performing the same analysis on fewer samples and by explaining the significance of the measurements in a less detailed manner. The following sample properties were observed or measured with semi-professional lab equipment: lustre, hardness, magnetism, colour of powder, conductivity, solution in hydrochloric acid, fluorescence, and specific weight. The relevance of each property was explained during the course of the measurements.

From Large to Small was aimed at describing the function of cellular components and involved the extraction of DNA from an onion sample. The function of the different cell components was explained using analogies with well known every day life objects or devices. For example the membrane structure was compared to a plastic bag, the chloroplast to a solar cell, chromosome pairs to cassettes and so on.

With reference to the national school curriculum, the PPCs designed preparation and follow-up activities for the teachers to carry out at school in order to complement the laboratory activities run by museum explainers in the science centre. To ensure complementarity, laboratory programme manuscripts were developed for the five activities to be used by both the teachers and the museum explainers. The manuscripts thus shared a common structure and contained the following sections: Teaching observation; The laboratory programme as part of the school work; Links to the curriculum; Background of the activity; Preliminary work before the activity; Carrying out the activity; Follow-up work; Links to related educational material on the Internet; and Development of the laboratory programmes in the science centre.

Local context

The Finnish school system is structured in nine grades of basic education (primary and secondary school) followed by three grades of high school. Primary school covers the first six grades and contained no chemistry until 2005, the first year of the Pencil pilot project. The new science curriculum prescribes two hours per week for a cross-disciplinary subject named after the acronym FIKE, which includes Physics, Chemistry, Biology and Geography. The school curriculum has a high degree of flexibility. Only the broad objectives and core contents of instruction are defined by the National Board of Education, while specific contents can be chosen locally by each school.

While secondary school teachers must have a specific academic background in the subject they teach, primary school teachers are "class teachers", teaching all subjects. Their education is based on a two-year long training course covering all the different subjects. Primary school teachers are usually not familiar with chemistry laboratory-based activities.

Notably, out-of-school learning is traditionally valued in Finland. Two days of visits to the Heureka science centre are included in the national teachers training programme.

Heureka is the largest science centre in Finland, and is run by a non-profit foundation involving the Finnish academic community, private companies and public administration. The permanent exhibition contains over 200 hands-on exhibits divided in seven thematic areas (Thought and Mathematics; The Universe and the Laws of Nature; The Changing Environment; The Structure of Life; The Global Village; Languages and Cultures; and Energy and Production) wherein the general principles of disciplines such as physics, mathematics, philosophy, linguistics, and archaeology are illustrated. Particular attention is also devoted to new technologies and their applications. The contents are organized according to a “spotlighting” method aimed at stimulating the visitor to explore the scientific content of the exhibits further following their visit. The philosophy of the science centre is focused on enhancing visitors’ motivation as a key step in the learning process.

Heureka receives around 100,000 visiting pupils each year. Around 60% of these are primary schools pupils - thus constituting a large fraction of the total number (300,000) of primary school pupils in Finland.

Having developed chemistry-based laboratory activities from its inception (in 1984), Heureka has accumulated a considerable experience in the area.

5.4.2. Case study

I. Relationships among key players

The pilot project was developed in cooperation with the University of Helsinki, the local City School Administration and the National Chemical Industry Foundation. The pedagogical background was provided by both the University of Helsinki and the City School Administration, which also supported the project team by helping to foster connections to teachers.

130 teachers from 15 primary schools were involved in the pilot project. With the laboratory-based activities being led by science centre explainers, the main role of the teachers was to provide feedback on the programme and the manuscripts. In particular, teachers were asked to comment on the links of the activities with the school curriculum.

The relationship between the designer of the activities and the science centre explainers who were appointed to carry out the activities with the pupils was also crucial to the development of the project. Being in direct contact with the target audience, the explainers were - together with the teachers - the main source of feedback for the revision of the activities and programme manuscripts.

II. Use of educational, and other, research

In designing the pilot project, a partnership with experts from the University of Helsinki was established to ensure that the activities were grounded on research and a strong pedagogical basis.

The project also benefited from the specialist knowledge of the main PPC, who as, head of the Research and Development Department of the Science Centre and a professor of Cultural History at the University of Helsinki, had previously conducted research focusing on informal learning, the role of motivation in learning process, and the nature of exhibitions as open learning environments.

The educational philosophy of the project was informed by the literature on enquiry-based and free-choice learning, and also constructivist theories. The methodologies adopted in the companion motivation study commissioned for Pencil built upon established tools such as the Deci et al test for pupil motivation (1991), and the Raven test (see Salmi 2003) for assessment of reasoning level.

III. Models and practice of teaching and learning

The project's pedagogical basis sought to emphasise the process of science and aimed to familiarise pupils with the nature of observation, data collection and analysis in terms of mathematical quantities.

Both the laboratory activities and accompanying manuscripts stressed the experimental nature of science. For example, the text in one manuscript reads as follows: "An observed phenomenon is different to knowledge or the correct answer to a question. An observation can conflict with what has been learned, but it's important to trust one's own observations. Much new scientific knowledge is the result of an unexpected observation and its careful further analysis".

A further approach was to highlight connections to pupils' everyday lives. The PPC stated that "we ask the pupils participating in the water analysis activity to bring water samples from lakes or rivers in their own neighbourhoods. This effectively raises their involvement and motivation". Finally, the PPCs also observed that having the pupils work in pairs at the activities helped to portray science as a collaborative process and also developed pupils' cooperation skills.

IV. Use of evaluation tools

Questionnaires were administered to teachers as part of front-end evaluation process in order to identify teacher needs. Based on the original programme manuscripts, teachers were also asked to give feedback on the expected impact of the activities and the consistency with school curriculum. Unfortunately, the result of this process was unsatisfactory as teachers were uncritical in their responses and simply expressed generic appreciation for the proposed activities, with comments such as: "It seems very good", "I like it very much".

With regards the proposed lab-based activities, no evaluation was conducted as, according to the PPCs “the efficacy of the labs is something that doesn’t need to be evaluated anymore, because it is the result of years of work and evaluation studies” (HK03-2).

Finally, a motivation study was carried out in conjunction with the project in order to assess the impact of the programme by comparing changes in pupils involved in laboratory activities only; laboratory activities in conjunction with and web-based activities; and web-based activities only. The results of this motivation study are presented in the Motivation Study.

V. Professional development of museum / science centre staff

Chemistry laboratories have been part of the educational offer of the science centre almost from the beginning. The Water Analysis activity, for example, was first designed in 1989. By being both designers and leaders of the activities, the science centre educators are in direct and constant contact with their target audience, which enables them to update and revise their programmes accordingly. Nonetheless, the PPCs reported that being involved in Pencil resulted in a unique opportunity to "work in a different way than usual. We had much more time for studying, reading, documenting, and revising the programme manuscripts. We have learned a lot and I'm sure we can use what we have learned in our future work as well" (HK02-2).

VI. Emphasis on issues of gender equity and social justice

The Finnish pilot project did not include an explicit focus on issues of gender and social equity. However, based on their observations, the PPCs reported that "laboratory learning offers an opportunity especially for the girls to have contact with science [...] just before they reach the age when 'science' becomes a more male oriented topic. Girls’ intrinsic motivation tended to be at a higher level [as a result of the activities]" (HK04-2).

VII. Involvement in, fostering of, wider network

In order to disseminate their work to a wider network, the Finnish Pencil pilot project team used the Xplora science education portal. The programme manuscripts in Finnish, Swedish and English were thus made available to be downloaded via the portal. In addition, the laboratory activities were presented at the 2005 Ecsite Annual Conference held at Heureka and at the final Pencil teachers’ conference held in Mechelen in 2007.

With respect to any benefit gained from being part of the Pencil network, the PPCs commented that internal communication and coordination were a problem within the network: "Maybe Pencil had just too many partners. The Internet chats were a difficult tool for us and the one-day consortium meetings seemed too short to address all the emerging issues" (HK02-2).

Nonetheless, the PPCs also said that they had "learned much about working together with different science centres and academic partners" (HK02-2). They also noted that "everyday work in a science centre strongly limits the possibility of putting new ideas into practice. Pencil has stimulated us to do things that we wouldn't have done otherwise" (HK03-2).

VIII. Sustainability of initiative

The activities included in the pilot project's educational programme have been part of the science centre's offer to the public for many years. The revised activities will remain available to all school groups visiting in the future and the availability of programme manuscripts available in Finnish, Swedish and English (via the Heureka and Xplora websites) ensures that the project has a wide and continuing impact.

5.4.3. Conclusion of Heureka case study

The success of the Finnish Pencil pilot project may be attributed to two key factors. Firstly, the project built upon the established expertise of the Heureka science centre by basing the initiative on a programme of tried and tested lab-based activities, which were hosted within the science centre. By linking the activities to the new primary school curricula, and modifying them as necessary to suit the target age groups, the project was able to support schools in the teaching and learning of the newly-introduced discipline of chemistry.

Secondly, the project was able to use the academic expertise of the lead PPC, and links with the local university, to ensure that the project was strongly grounded in theories of learning and motivation, whilst emphasising the nature of science. For example, by introducing primary-aged students to laboratory based activities – which included dramatic events, and linked processes to everyday issues or experiences – both the process of science, and its role in wider society were explored. Furthermore, the novelty of the lab-based experience, together with the enthusiasm of the explainers leading the classes will have had an impact on the students' interest in and motivation towards science.

The pilot project may also have benefited from the perception of Heureka as a valuable resource – indeed, as discussed above, all teachers visit Heureka as part of their teacher training, and thus are likely to be familiar with the centre and its expertise. However, it is a little disappointing to note that teachers were not more actively involved in the development and design of the Pencil programme. Although their opinion of the draft manuscripts was solicited, it appears that they were not involved with the original selection of activities, or the initial drafting of the supporting materials. In this way, there is a risk that the science centre is seen as the 'expert', rather than an equal partner with teachers in supporting students' learning.

By working closely with teachers and involving them into the development and delivery of programmes, science centres have the opportunity to learn from the pedagogic and behaviour management expertise of teachers (and to understand more fully the constraints under which teachers operate). The teachers, meanwhile, have an opportunity to learn more about science content from science centre staff, and to continue their own professional development by observing informal teaching practices which they may then employ in their own classrooms. In short, working more closely with teachers and establishing genuine partnerships with schools is a recommendation for this and other similar projects.

5.5. NEMO (The Netherlands) – The science centre at school

5.5.1. Summary description of pilot project

The programme developed at NEMO involved 8th grade primary school classes (11-12 year olds) in the construction of interactive exhibits made out of cheap, easily accessible materials. The project was tested during a pilot phase in the first semester of school year 2005-2006, which in the Dutch primary school is crucial for determining the subsequent educational path of the pupils. In this first phase, which was intended as a formative stage with results informing the programme in the following year, Pencil pilot project staff worked with ten classes from ten different schools. The activity, which was scheduled over 8 half days, was carried out at school, except for the first half day, which consisted of a visit to NEMO in order for the pupils to become familiar with the exhibits in the science centre. In particular, pupils had a chance to see the professional versions of the exhibits that they would be constructing in action. Teachers and pupils then received a booklet of recipes for building the exhibits, the "Exhibit Design Book" (Edb). The Edb contains the description of 20 well known, easy to build exhibits (featuring for example, soap bubbles, an electrical cell, an electrical motor, leaf recognition, the Bernoulli effect, mirrors, sounds from straws and so on).

The activity was structured as follows. Day 1: the school visit NEMO: pupils learn what exhibits are, and what makes a good exhibit. They evaluate a few exhibits in NEMO. Day 2: pupils choose two exhibits out of the Edb, that they would like to build. They make sketches of what they think it is going to look like and explain their motivation for their choice. They send the sketches to NEMO. NEMO chooses the best design. Day 3: pupils research, via books and the Internet, content question relating to their exhibit topic. Day 4: pupils make a technical drawing of their exhibit. Day 5/6: they actually build their exhibit. Day 7: they make a presentation of their exhibit. They make 5 labels outlining with the name of the exhibit; instructions for the visitor; the science behind the exhibit; the technical drawing of the exhibit; and information about themselves as makers of the exhibit. Day 8: the school's science centre opens to other pupils and parents. Pupils explain to visitors how their exhibit works and why it works that way.
Following an evaluation of the pilot implementation, the research activities of Day 3 were then delayed to day 5/6 when the pupils constructed the exhibit.

The aim of NEMO and the Institute for Mathematics and Science Education of the University of Amsterdam (Amstel) with which NEMO cooperated for the development and evaluation of the pilot project was to set up an inquiry-based model for science education appropriate for primary schools. However, since, Dutch primary school teachers do not attend specific university courses, and may not have been exposed to the nature of science, the pilot project also included a two-day training session for teachers, in which the inquiry-based approach and the activities of the programme were presented.

Local context

Until 2004 the Dutch primary school curriculum (8 grades from 4 to 12 year olds) contained no science at all. In 2004 the government promoted the 'Science is Primary' conference, with the aim of discussing the introduction of science into primary schools. This conference was hosted by NEMO. Now there are approximately 20 minutes of science per week in primary school. On the contrary, maths is an important topic and it plays a fundamental role in the final primary school test.

NEMO, the biggest science centre in The Netherlands, is primarily aimed at 6-16 year olds. It is located in a big green building in the shape of a ship designed by architect Renzo Piano and located in the very centre of the town. More than 300.000 people visit every year. The name NEMO refers to "a no man's land, a world between fantasy and reality where fantasies suddenly seem to become real" (NM01-1). The main space is divided in different exhibition areas, namely Water Worlds; Code Name DNA; NEMO's Wonder Lab; Journey through the Mind; Why the World Works; Amazing Constructions; and the digital playground Studio Bits & Co. The science centre also hosts a scientific theatre, a chain reaction show and a temporary exhibition area. The next temporary exhibition, *Teen Facts,* starting April 2006, deals with the science behind adolescence: hormones, brains, sex, self-esteem and risk taking.

NEMO has been asked by the Dutch government to play a leading role in the school reform that is currently being developed in the country. It has been cooperating with the Amstel Institute in the development of a new science curriculum for primary schools and is involved in the national teachers training programme.

Since the average time dedicated to science is just 30 hours per year, the schools involved in the Pencil pilot project have effectively doubled the amount of time devoted to science teaching. Indeed, the programme alone takes 20 hours of school time. This was possible because the Dutch school curriculum is based on very open key objectives and the schools are left with great deal of freedom. In order to implement the programme in other countries it would be necessary to make the content more specific, according the local curriculum or to relate it to different disciplines.

5.5.2. Case study

I. Relationship between key players

To develop the pilot project, the project team cooperated with the National Association of Technical Teachers, the Foundation for Curriculum Development, the Institute for Mathematics and Science Education (Amstel) and the Education Faculty of the University of Amsterdam. The role of these partners in the pilot project was to evaluate the lesson materials produced throughout the project. This evaluation was used by the PPCs in order to revise their programme after the pilot phase.

Teachers involved in the pilot phase were chosen among those previously known to the science centre staff as being particularly willing and enthusiastic. A two-day training session was carried out at NEMO to introduce the learning by making and learning by design approach to science teaching. During the training, teachers were presented with the project activities and engaged in the construction of the exhibits.

Whilst teachers were not involved in the design or the activities, they were responsible for leading all the activities in the classrooms. A Teacher Manual was prepared by the project team for the teachers, who were also given the Exhibit Design Book before the start of the programme. As the PPC explained: "In this project the process – and not the end product – is most important. Therefore, guidance by the teacher focuses primarily on acquiring an investigative attitude and technical skills" (NM04-4).

At the end of the programme, teachers were invited for another meeting in the science centre, in which the activities were discussed and feedback was collected for the evaluation and revision of the programme. During the meeting teachers were presented with the results of the evaluation of the impact of the programme on the pupils. Based on the feedback received by the teachers, PPCs proposed four points for possible improvements to the programme for the teachers to choose from.

With regards relationships with other players, NEMO welcomed the input from the academic partners, including the evaluation team from the University of Napoli, and commented that they would not have conducted as extensive an evaluation programme (or focussed on the differences between the behaviour of boys and girls) without the guidance from the academic partners.

II. Use of educational (and other) research

The pilot project has been inspired by previous experiences and activities in the field of science education. One of these was the La main a la Pâte initiative, a programme launched in France in 1996 promoted by Georges Charpak, Nobel Prize winner in Physics 1992, and by the Académie des Sciences with the aim of fostering science teaching in primary school. A further inspiration was the project run at the American School in The Hague, with which the pilot project has many similarities. Representatives of the project team visited the school together with an expert from the Amstel institute.

The theoretical basis on which the project is grounded is inspired by the research reported at the Science is Primary conference and on the report “Vision of science and technology in primary education” produced by the Expert Group in Science and Technology Primary Education, a committee of experts appointed by the Dutch government in 2005.

The exhibits included in the Exhibit Design Book are inspired by the Snackbook, the handbook for the construction of hands-on exhibits with cheap materials developed at the leading US science centre, the Exploratorium in San Francisco.

III. Models and practice of teaching and learning

The project activities are grounded in the constructionist theories of learning, according to which learning occurs through making something, for example building an artefact, writing computer programs or painting. In the constructionist vision students who create their own solutions to problems engage in an experience altogether different from simply memorising the achievements of others. The more empowered students feel, the more they enjoy their classes, and the more they begin to take charge of their own learning process. Thus learning is fostered when students get the opportunity to explore the world on their own, but in a guided environment. When students actively construct things in the physical world it helps them build knowledge in their minds. This new knowledge enables them to create ever more sophisticated solutions, resulting in more skills, more knowledge, and more solved challenges in a self-reinforcing cycle.

The programme developed by the project team includes a visit to the science centre, and activities at school. The pupils are involved in the design of a hands-on exhibit, in its actual construction, and in a process of research about the science behind the exhibit. At the end pupils are asked to present their exhibits to school mates and visiting parents. In this way, pupils develop team-work skills by working in pairs and are confronted with both abstract and practical problems when designing and constructing the exhibits. Peer learning is also involved when pupils work together to find solutions and when they present their work to their school mates. The latter activity also has the role of fostering pupils’ communication skills and increasing their motivation to learn. The PPCs reported that having to present their exhibits to others made the pupils want to learn more about the work they had done and to be confident in their understanding of the scientific bases of the exhibit.

IV. Use of evaluation tools

The evaluation strategy planned by the project team included direct observation of the activities, questionnaires for the pupils and for the teachers involved, and discussion groups. Some of the teachers were interviewed as well. The main objective was to evaluate the impact of the programme in terms of changes of pupils perception of self with regards to science and technology; measure gains in appreciation resulting from the single activities included in the programme; and to assess the value of the learning and teaching materials prepared for pupils and teachers.

Teachers were also asked to comment on the pupils' learning and understanding throughout the programme, and to express their willingness to repeat the programme in the future.

The project was run twice over two school years. The first implementation involved ten schools and was used as pilot experience in order to refine the programme for the subsequent year. In the programme for the second year, some of the activities were modified, and an oral presentation to peers included, as a result of the experience and feedback in year one.

In working together with teachers and pupils during the research phase of the programme, the PPCs noted that there was a lack Internet resources in Dutch offering information on science and technology. This led pilot project staff cooperating with teachers to design a new project aimed at filling this gap (see section VIII).

The educational materials were also revised after the pilot phase, and the training for the teachers was reviewed. Teachers most valued being involved in building the exhibits themselves before working with their pupils – they wanted to "Find out for ourselves so we are able to help the pupils properly" (NM05-2).

The analysis of the collected questionnaires showed that the project was highly appreciated by pupils. On a 0-10 scale, pupils gave the project an average score of 8.5 The phase of the programme pupils valued the most was the building of the exhibits (9.4), with comments such as: "because you don't often get to do things such as sawing; I like that kind of thing" and "because – once it's finished – you can see if it works". Showing the exhibits to other children and parents was also given a high score (8.7) with the following sorts of explanations: "because you're happy with what you've made and you can show it to other people" and "because some people just couldn't believe it and were thinking 'how do they do that?' " (NM05-3). Upon the suggestion of the evaluation team from the University of Napoli, the PPCs included a gender check in the questionnaires for the pupils. The findings for this questionnaire are discussed in section V1.

Teachers also expressed an appreciation for the programme. "I found the children more enthusiastic than I had expected. That also applied to myself." (NM06-6). Teachers mostly appreciated the richness coming from the variety of the different phases: building, the research, presenting, etc. "The active components and the presentation by the children made it a very rich experience" (NM06-6) Like their pupils, the teachers valued the building phase the most. Working in pairs was also considered a success factor in the activity: "Many pairs worked very well together. They inspired each other, brought each other ideas..." (NM06-7).

For both pupils and teachers the drawing and design phase did not score highly. For example, one student said "I found making the sketches a bit difficult and an outline was already in the Exhibit Design Book. Moreover, making the construction drawings was terrible" (NM06-7). Teachers gave the research phase the lowest scores (6.0 in average) after having expected this phase to be useful. Comments included: "The background information is not accessible for children. It takes too much time and provides limited results" and "a lot of reading work, too much to select from and sometimes cumbersome books or sites. Not child-friendly language" (NM06-7). However, when asked if they would want to run the programme again the following year most teachers (7 out of 8 answers) responded positively.

V. Professional development of museum / science centre staff

Whilst the professional development of NEMO staff was not an expressed objective of their pilot project, the PPCs commented that their interaction with the evaluation team from the University of Napoli had increased their professional understanding of the role of evaluation in the development of an educational programme.

Being involved in PENCIL also raised project staff's awareness of the value of interacting with academic partners (both at the local and wider level) and thus benefiting from each other's experiences. Project coordinators said they now "definitely see the value of cooperation with other players [researchers]" (NM03-2) and that they are going to continue their cooperation with partners such as the Amstel Institute in future projects.

As a consequence of the evaluation of the programme, project coordinators worked together with a teacher in writing a proposal for a project for developing educational resources on scientific subjects in Dutch to be published on the web. The proposal was successfully developed and the project was granted public funds.

VI. Emphasis on issues of gender equity and social justice

The NEMO pilot project involved schools located in different areas of Amsterdam, from both the wealthy central areas and from the suburbs. The project team did not note any particular difference in attitudes, behaviours, perceptions or impact of the activities on pupils of the different schools. However, interesting findings relating to gender emerged from the evaluation of the data. Firstly, boys and girls had different preferences with regard to the exhibits they chose to build. For the boys, the most popular exhibits were those about batteries and electric circuitry, whilst the girls liked exhibits involving human interaction such as the magic mirrors and the exhibit involving a quiz to guess to learn the names of leaves.

Secondly, interesting results were also found when looking at boys and girls perceptions of self with regards to science and technology. Project staff asked pupils "how technical" they would say they were. They asked this same question both before and after the programme. Before the programme most of the girls (65%) said they were "not very technical", while most of the boys (52%) said they were "rather technical". Following the programme, only 30% of girls considered themselves to be 'not really technical', and the vast majority considered themselves to be competent. In contrast, whilst a small percentage (6%) of boys subsequently decided that they were only 'technical', as opposed to 'rather technical', in general, their self-estimation of skills remained high. Finally, it is interesting to note that following the programme, there was a 43% increase in the number of girls electing to study nature and technical studies in the next stage of their education. However, it is important to note that any correlation between the effect of the programme and the subject choice on the part of girls was not confirmed, and other factors may have played a significant role in such choices.

VII. & VIII. Involvement in, fostering of, wider network/ Sustainability of initiative

To support the workshop programme, the NEMO pilot project team designed a new website specifically for the project. The site includes all necessary information for both pupils and teachers. All the lesson materials tested in the project are available in Dutch and in English and can be downloaded for free. Furthermore, teachers can order the necessary materials and tools for the project through the website. Finally, pupils may find numerous links to online resources containing background information about the project exhibits. In this way, the project may be replicated by others in Holland or beyond.

In addition, PPCs are planning to build a network with local science centres in order to spread their programme. 30-50 school classes should be involved in the next implementation of the programme with the support of smaller science centres nearer to each partner school.

PPCs have also proposed including the project activities in the national teachers training curriculum, and the project team is currently planning to present the programme on national TV, where the project manager already runs a show on science experiments.

Finally, it is important to note that the NEMO Pencil project won the NOT Innovation prize 2007 in the category Education and Learning – General. The prize was conferred by the Minister of Education at the 2007 National Education Fair (NOT). The deciding factors for the jury included the following: integration of different school subjects promoting the coherence in education; Lesson materials for schools and online; the pupil as co-designer of exhibits; teachers being trained; support offered by a science centre.

5.5.3. Conclusion of NEMO case study

The Pencil pilot project led by the team at NEMO has proved to constitute a successful approach for promoting student engagement in aspects of science and technology. Furthermore, the project has led to the development of strong relationships between teachers and NEMO staff, and highlighted the potential of science centres, such as NEMO, to support science learning.

The project's success was due in part to three main factors. Firstly, the flexibility of the Dutch curriculum allowed teachers space and freedom to adopt the NEMO Pencil programme and test it with their students. NEMO's role in recent policy decisions regarding the inclusion of science in the primary curriculum may have also helped to secure teachers' confidence in the potential of the activity.

Secondly, the Pencil team at NEMO built upon their institution's expertise as designers of exhibits and communicators of science, in order to develop an activity which would help foster such skills in primary aged students. Although the planning of this activity took considerable efforts (for example, in recruiting partner schools) NEMO was able to rely on existing reference materials as guidance for exhibit construction, and furthermore, knew many of the pitfalls relating to designing and building exhibits and thus were able to cater for these.

Thirdly, the programme itself constitutes a clear model of the practices involved in technological developments. For example, the workshop phases completed by the students involved proposing an idea, developing a prototype, testing the prototype, constructing the finished model, and then communicating the benefits of the object/piece of technology to a broader audience.

To improve the programme in future years, or as guidance to other institutions considering a similar programme, it would be worth exploring ways of involving teachers in the development stage of an idea, rather than just the delivery stage. With this in mind, it is interesting to note that the Pencil pilot project has led to a teacher working in partnership with NEMO on a project designed to address the lack of Dutch language materials available on-line for students of science and technology. Thus it is clear that such close involvement is possible.

Finally, large projects such as this provide useful contexts for exploring the impact of complex issues such as gender, ethnicity, or social class upon science learning. And, whilst NEMO did attempt to assess gender impact (upon advice from the University of Napoli), more studies in such areas could have been conducted as part of the evaluation protocol.

5.6. Deutsches Museum, (Germany) – Mobility issues with climate change

5.6.1. Summary description of pilot project

The Pencil project at the Deutsches Museum (DM) involved three main elements: the development of an exhibition space focussing on traffic and the environment; the enhancement of an existing gallery with the introduction of new interactive elements and up-to-date information about climate change; and an extensive school programme exploring issues related to traffic and pollution and their impacts upon the global climate and ecosystem. All three elements were specifically targeted at students aged between 11 and 16 and were designed to encourage young people to become more engaged in issues of climate change, and to understand how they, as individuals, may contribute to both the problem and the solution.

A key aspect of the school programme involved the development of new pedagogical approaches to enable active engagement on the part of students in the issues. These involved role play activities whereby students were firstly given the opportunity to research particular aspects by using the new exhibitions (and additional materials) before then developing role plays with their peers in which they highlighted the arguments for and against particular environmental or economic initiatives relating to climate change, and issues of traffic and pollution. These role-playing skills were also developed when students attended debate events organised by the DM to which experts in the field either attended or sent their particular points of view. In this way, students were given the opportunity to develop skills in communication, argumentation and ethical decision making – all of which are key skills for responsible citizenship in modern society.

5.6.2. Case study

I. Relationship between key players

With schools, teachers and students

As is the case for most museums and science centres, schools traditionally visiting the DM tend to be the end-users of services rather than co-creators. Thus they choose to visit if they see that an existing activity connects to their curriculum, rather than work with the museum to create a new activity. However, the Pencil project at the DM has prompted a change in this relationship.

For the Pencil pilot project, the DM PPC sought to build relationships with individual teachers. Letters were sent to the head teachers of schools asking that they then forward the information to German language teachers, foreign language teachers, ethics teachers and religious studies teachers. Usually, letters would be sent to physics teachers only.

The PPC targeted teachers from local gymnasium and technical schools. Groups from the technical schools do not usually visit the museum, and thus Pencil afforded a new opportunity in extending the school audience base of the DM. The final group of teachers were split evenly between these school types, although teachers from the technical schools were initially a little apprehensive about joining a project with their counterparts from the (more academic) gymnasium schools,

In designing the project, the PPC felt that teachers' needs had to be addressed as much as students'. She argued that "the visit to the museum has to be a good experience for the children, that is the first thing. But it has also got to be a good experience for the teachers. And if they are involved more strongly [in planning the activity] then that will improve the experience" (DM200011 page 12).

Internally
Internal relationships were also important in ensuring the success of a project at the DM. The PPC had a good relationship with the curators of the environment gallery and was able to use this to develop the Pencil project. The Pencil funding was seen as an opportunity to experiment in connecting the content of two galleries. Such an initiative had been considered previously, but there had been no funds to do this.

Externally
The PPC (and the wider education department within the DM) already had a relationship with academic researchers from local universities. These researchers were appointed to design and conduct an evaluation programme for the project.

II. Use of educational (and other) research
The PPC did not have time for an extensive review of the literature on educational research and specific methodologies, but she did manage to read key articles (in both English and German), and exchange papers with Pencil colleagues. For example she found the work of Falk and Dierking (1992) and Roberts (1997) to be very useful. Her prior training in education had already introduced her to the work of Montesorri, Kechensteiner and Piaget.

The PPC also commented that she would have appreciated greater sharing of academic papers and guidance materials for practitioners, particularly with respect to evaluation, in order to prevent reinvention of the wheel.

III. Models and practice of teaching and learning
The PPC saw her role as one of working with teachers to help respond to students' needs. Her view of museum education was that one should support teachers in their role, but not to teach for them: "I think we just make teaching easier for the teachers. We don't have to tell them how to teach – they're perfect teachers" (DM200009 page 11).

She also believed that it is important not to replicate the school experience, but instead develop programmes that complement the learning that occurs in schools. This approach is also recommended by contemporary education researchers (Griffin 1994; Griffin & Symington 199:, DeWitt & Osborne 2007)

However, the PPC also acknowledged that a teacher's perception of a visit may be different from a museum educator's: many teachers tend to view a visit in terms of cognitive outcomes, and are concerned about administrative and disciplinary issues, whilst museum educators tend to regard a visit as an experience which may enhance motivation, and provide interesting teaching and learning opportunities. With respect to visits to the DM, however, this perception on the part of teachers does appears to be changing: "many teachers still come with expectations that when children come out of the museum they will have learnt fact 1, fact 2 and fact 3. But there is also a change and many teachers see the visits to the museum as something motivating and as something providing interest and deepening something they have already talked about in school" (2000011 page 8).

In supporting teaching and learning, the PPC said that her role was one of building a 'golden bridge' between the expectations of teachers and the learning opportunities offered by the museum. This involves explaining what resources are available and how to use them, so that teachers are confident in using the materials on display.

Building such a bridge can require considerable effort on the part of a museum practitioner. Whilst PPC accepted that teachers may not have prepared their students, she also explained that she cannot change the galleries to suit individual needs. This, therefore sums up the pedagogical role (and practical headache) of a museum educator – the need to find a way to communicate and negotiate between the ideas and expectations of the visitor with those of the museum.

With regards to student learning in museum, the DM PPC believes that: “students need to be active. But they learn more if they follow their own interests, if they get a chance of asking questions and getting answers by experts” (DM200004 page 22). Given this, the PPC noted that museums can help learners follow their own questions, rather than stick rigidly to a curriculum. She explained that “we don’t have to work from A – Z, we can work the other way round if it helps people” (DM 200005 page 10). She also believes that museums offer an opportunity for hands-on engagement, and commented that the German word for ‘getting the idea of something’ or ‘understanding something’ is ‘begriefen’, which literally means to touch.

In supporting learning, the DM, like many other museums, favours an enquiry approach, wherein learners are encouraged to explore questions for themselves, and continue their learning outside of the museum: “We should instil questions from children [that enables] enquiry, research, [that] they can do by themselves. And if they go out and say ‘look this was quite interesting, but I don’t know enough about solar cars’, they can go to the next library and read more, and this is an even better outcome.” (DM 200011 page 19). Thus in the design of the role playing-activities – designed as part of the school programme – students were firstly asked to develop their own questions about the topics of climate change and traffic and then to research the answers using the museum’s exhibitions and other resources (provided by the museum, and identified by the students themselves). Once this period of enquiry was complete, the students engaged in role-play whereby they discussed key issues from different points of view. In this part of the activity, the theoretical perspective underlying the learning is one of argumentation whereby individuals come to understand the content matter by developing opinions grounded in evidence and engaging in discussions with others to explore and assess other points of view.

In addition to enquiry and argumentation models, the DM PPC also expressed a clear view on the nature of science (and the presentation thereof) as indicated by the statement: “I don’t think that the museum should offer the one perfect answer to any scientific question”(DM2000011 page 19). Whilst this philosophy of education can promote learners to question ideas more deeply, there is an inherent danger that this approach leads to a relativist view of the world, with the content of the museum, and the knowledge of the curators being undervalued. In the academic literature, it has been argued that museums need to explain why they view content/knowledge in a particular way, and then invite learners to make up their own minds based on evidence (Hein 1998).

Whilst the argument for one particular view on the part of the museum is not advocated by the Pencil PPC, she did agree that the museum could play an important role in fostering evidence-based decision-making. This point is made on three occasions in three separate interviews:

“The Museum’s position cannot be the one to judge right from wrong. It can just be the source of information. And we shouldn’t try to be or provide anything more or less, just quality and factual information. And encourage people to go further, but *we* should not go further than that” (Page 18 DM200010 page 18)

“I don’t think the museum is in a position to say this is right or this is wrong about scientific or technological development. It’s up to everybody to decide and make up their own minds. But our role is to instigate that making up of their minds.” (DM20009 page 8)
“I would like to make them see that science and technology has advantages and has potential and I would also like them to get a feeling that there can be threats and disadvantages. I would like to

bring them into a state that they can make their own decisions on what they think about issues" (DM200011 page 13)

IV. Use of evaluation tools

The Pencil PPC at the DM, in partnership with a researcher from a local university hired to support the programme, conducted extensive front-end evaluation studies exploring student and teacher knowledge and interest in the proposed topic of climate change and its relationship with traffic. The front-end questionnaires (one for teachers, one for pupils) asked: what do you know about climate change and traffic? What would you expect to see in an exhibition? What do you like at museums? What would you like to see?

The results of the questionnaires indicated that students wanted activities on catastrophes, weather and pollution. They also wanted to do experiments, detective work and free (unstructured) activities. Teachers wanted topics on renewable energy, global warming, with the activities comprising tours and questionnaires (which could be marked and assessed later).

A prototype activity based on the formative evaluation was then developed in order to identify problems and weaknesses in the activity. This was then used with a few selected school groups, and the subsequent discussions were recorded, and the activity modified as appropriate.

Throughout the full programme of activities, observations of students were made, with foci of looking at satisfaction, interest, learning and motivation of students. At the end of the activity, a series of focus groups were conducted. In addition, post-project questionnaires were also sent in order to measure change in motivation to particular topics. This process was in concordance with the usual evaluation practice at the DM. A standard protocol is used so that the tools may be readily applied by all education staff.

The King's College London evaluators, however, questioned whether the evaluation protocols were really addressing the aim of the project – that is a change in behaviour. The evaluators proposed using concept maps pre- and post- the experience as a way of making sense of student's change regarding the bigger picture. In response, the Pencil team at the DM argued that they wanted to understand the manner in which the audience see the bigger picture – i.e. ethical aspect or political aspect – and they believed that this outcome was more likely via focus groups.

V. Professional development of museum and science centre staff

The professional development of museum staff was not an explicit focus for the DM Pencil project.

VI. Emphasis on issues of gender equity and social justice

The DM Pencil project sought to extend the profile of schools visiting the museum. They did this by explicitly targeting the non-gymnasium schools – which tend not to visit museums. Since the proportion of gymnasiusm and non-gymanasium schools was roughly 50:50, this objective was clearly met in full.

The DM Pencil project did not attempt to address any issues of gender.

VII. Involvement in, and fostering, of wider network

The DM PPC played an active part in the Pencil chat room discussions, offline discussions, and during the wider project meetings. She welcomed the opportunity to discuss and defend the ideas behind her project with other Pencil colleagues: "I think being part of a network forces you to really rethink your position more clearly. If others ask about what you're doing then you really have to formulate it" (DM 20005 page 7)

However, the PPC would have appreciated more opportunities to get to know her other Pencil colleagues in order to jumpstart the communication process. She described the network as not fully operational: "If you have this image of a network, then you have strings and they meet at certain points. And I think we're still in the process of finding those points at which we can meet and exchange experiences and then work into different directions from there" (DM20005 page 3).

As a mechanism for enabling the development of the network, the DM PPC proposed publishing the analyses of front-end evaluations from across the Pencil projects. This would have the dual effect of sharing findings about the knowledge and interests of a target audience, or the design of a project, and also help to promote the value of evaluation.

VIII. Sustainability of initiative

The Pencil project at the DM has helped to establish new relationships with teachers from the non-gymnasium schools who previously rarely visited the museum, and cement relationships with the gymnasium teachers who visited more regularly.

Following the completion of the project, the DM staff are now exploring ways of seeing how the materials generated for the Pencil project could be used by other schools in the future. In addition, the Head of the Education Department proposed running a training course for teachers who are not involved in the project in order to continue the initiative once Pencil funding stops.

However, it is important to note that the DM is a large institution, and thus any change in organisational practice inevitably takes time. Hopefully, the results of the Pencil initiative have proved positive and as such changes have will become embedded at an institutional level.

5.6.3. Conclusion of Deutsches Museum case study

The Pencil project at the DM may be considered an effective model of practice on several counts. Firstly, the programme of school activities was underpinned by a strong theoretical perspective which advocates active engagement – by way of enquiry, or engagement in role-play/argumentation events – to support learning. Secondly, the PPC specifically targeted schools who would not normally visit the DM in order to serve a more mixed group of students. Thirdly, an evaluation protocol was followed which enabled the DM staff to develop materials which would serve both teachers' and students' needs and expectations.

However, it can be argued that by sticking to the existing evaluation protocols, DM staff were not able to measure their expressed objective of prompting long-term change in student behaviour and attitudes. Whilst the pre- and post-activity questionnaires and small focus groups helped to establish the original and final views of students (and teachers), the reason for the changes, and any long-term changes in behaviour were not captured. The former could have been achieved by observations of activities; asking students to keep diaries of their days in the museum; or the use of stimulated recall. The latter could have been achieved by interviews conducted with a small number of individuals at six months, or year following the museum activity, although admittedly, this is a difficult process to organise.

As one final comment on the DM Pencil project, it is worth noting that whilst the success of the project was partly due to a good working relationship between the PPC and the gallery curator, internal workings on the museum may also limit the extent to which the initiative becomes imbedded within institutional practice. In such a large organisation, existing structures, systems and practices are difficult to change, and thus it may take several more innovative projects in the educational department before such ways of working (i.e. developing close relationships with target stakeholders) become mainstream across the museum.

5.7. Experimentarium, (Denmark) – Xciters

5.7.1. Summary description of pilot project

The overall aim of the Experimentarium's pilot project was to increase middle school students' interest in and motivation towards science. The project pioneered a technique of peer-to-peer teaching whereby older students became science communicators for younger students. The older students, known as 'Xciters' attended a training programme led by Experimentarium staff. 'Learning by teaching' activities were designed to support these students in acquiring knowledge and skills in science, and also confidence and expertise in communication. To support the Xciters in their interactions with their peers back at school, a set of boxes containing resources for use by students was developed by the Experimentarium. Experimentarium staff also liaised closely with teachers in the selection on students to be trained as Xciters and in the delivery of the peer-to-peer sessions in classrooms.

In reviewing the Experimentarium's Pencil pilot project, it is important to understand a few key features that characterise the educational context in Denmark. Firstly, (as in many western European countries), students tend not to favour science subjects, preferring instead courses in communication or the arts. Thus motivation towards, and interest in, science is seen as a pressing national problem.

Secondly, the Danish school system is regarded as more flexible than many other European countries. For example, teachers commonly work in teams and explore themes, which may run across several days, rather than topics that are confined to set timetabled lesson slots. In this way, the introduction of new activities, such a peer-to-peer teaching, are not necessarily hampered by curriculum constraints, although other issues (such as teacher reassignment or illness) do of course affect the success of any initiative.

5.7.2. Case study

I. Relationships between key players

With schools

In aiming to recruit and train students to become peer teachers, the Experimentarium worked closely with teachers in selecting students, in organising appropriate training timetables and in managing the activities of students back in school. Teachers were also invited to attend the training sessions so that they would understand the communication approach and have time to reflect on how to support the students back in the classroom. The PPC thus explicitly acknowledged the need for the Experimentarium to communicate the benefits of the proposed activity in order to attract teachers and students.

As the peer teaching occurred in schools, rather than at the science centre, the Experimentarium needed to build strong relationships with the schools in order to ensure that the peer teaching activities were indeed supported. Such relationships were cemented with preparatory planning and a mid-point review workshop. To support communication between the schools (teachers and students) and the Experimentarium, the PPC developed a blog in which students could make comments and raise questions thus ensuring that any confusion or outstanding issues were clarified quickly.

Externally

The Experimentarium benefits from a long-standing relationship with education researchers from a local university who have expertise in pedagogy and evaluation. For the Pencil project, staff were also fortunate to have links to a popular TV presenter who helped to lead the workshops in science communication. Finally, the programme was well publicised resulting in various commendations from policy makers and a large amount of funding from a private consortium to ensure that the project continues in future years.

Internally

The PPC benefited from strong support and advice from her institution's management. In addition, contacts with schools developed by the Experimentarium in the past were shared with the PPC, and these past relationships helped to secure the implementation of the peer-to-peer initiative.

II. Use of educational (and other) research

The PPC and the team at the Experimentarium benefited from their close connections with academics from the education departments at local universities in terms of planning and managing the internal evaluation programme. Unfortunately, as with many staff working in museums and science centres, the PPC found little available time to personally keep up-to-date with new research, or initiatives being undertaken at other institutions.

A possible solution to this problem may lie in the implementation of discussion groups comprising academics and science centre staff to explore contemporary research, in addition to working with academics on evaluation projects.

III. Models and practice of teaching and learning

The model of learning underlying the Experimentarium project is that of 'learning by teaching'. This approach is built upon an understanding that in order to teach, an individual needs to understand the content to such an extent that they also understand how others may make sense of the concepts involved. Shulman (1986) conceptualised the skills of a teacher as comprising three categories of knowledge: content knowledge, pedagogical content knowledge, and curricular knowledge. He argued that teachers need a thorough grasp of the content in order to explain how a particular proposition or idea is warranted, why it is worth knowing, and how it relates to other ideas (content knowledge); that they need to understand how and when to use particular forms of representations for the ideas and concepts in the given subject areas (pedagogical content knowledge); and that they need to be aware of the full range of materials that may support learning, and the indications and contraindications for their use (curricular knowledge).

In the context of the Experimentarium project, however, the students as teachers were not expected to gain a thorough content or curricular knowledge, or a detailed pedagogical content knowledge, but instead it was hoped that the Xciter process would afford a knowledge of science communication, and would result in increased confidence. Indeed, in response to a worry on the part of several female students that one ought to know everything before they teach, the workshop leader assuaged such doubts by explaining that effective presentation involves supporting learners to engage in a dialogue, rather than reciting facts. In later informal conversations with the teachers of the Xciter students, meanwhile, it was clear that the ability of a student to stand up and present aspects of science, and the inspirational impact that this had on their peers, was valued more highly that the accurate transfer of content.

Thus the model of practice which underpins the Xciter programme at the Experimentarium is one which emphasises the importance of students thinking for themselves, developing communication skills, and in so doing gaining some content knowledge, but more importantly, confidence in engaging in science. In addition, the activity results in younger children seeing fellow students in a position of expertise. This in turn has an aspirational impact and helps to embed the approach into the regular curriculum.

This model of practice also supports the secondary aim of the Experimentarium project, which is to promote students' motivation towards science by emphasising the importance of communication skills in peer-to-peer teaching. Thus in the training programme, the Experimentarium staff (with help from TV science presenters) sought to help students understand the ways in which scientific content can be imbued with stories and questions and associations with the everyday lives of their target audience.

As a final comment, it is interesting to note that whilst some teachers were initially unsure about the project and its objectives, they were subsequently very impressed and are continuing to use it in their classrooms.

IV. Use of evaluation tools

The Experimentarium PPC employed an evaluator from the local university to conduct the internal evaluation of the project. This evaluation comprised focus group interviews (structured around key questions) and the use of questionnaires. In commissioning the evaluation, the PPC hoped to determine whether students' attitudes towards science had changed in the sense that they were more interested or intrigued as indicated by the way they would talk about the Xciter process.

In focussing on student reactions to the Xciter project, the Experimentarium primarily examined the results of the project. To extend an understanding of the way in which students engaged in the project (i.e., to examine the process), the King's evaluators suggested asking the Xciters to keep a record of their experiences (which could also be used at a later date to prompt reflection). The PPC acknowledged these suggestions and devised a logbook on the website for Xciters to record their feedback. She also conducted a few short feedback sessions with the Xciters following the aspects of the training programme as a way of gaining a commentary on the process. One interesting finding here, however, was that the students were not used to, or confident in, giving feedback, or engaging in reflection about processes. In addition, whilst the PPC did not ask the teacher to lead the discussion/reflection session (in fear that the teacher would prevent honest and open feedback), she did not consider that the students may not feel able to be open with her. In such cases an independent and external evaluator will often gain more objective feedback that someone who in intimately involved in the project.

Finally, the PPC commented that the Experimentarium would have liked to have conducted more evaluation studies, but did not have the money to do so. She also welcomed hearing more about evaluation, and suggested sharing more about the evaluation methods and concepts used by other projects.

The reported results of the evaluation highlighted the following:

- The crucial role of the teacher in encouraging children to interact during peer-peer activities.
- An enhancement of teacher interest in including scientific topics as part of the curriculum
- The notion of teachers 'discovering' the potential of their own students for communicating/explaining aspects of science.
- The opportunity for students to engage in hands-on activities, ask questions and develop answers in co-operation with others; explore a particular topic in depth; and share their experience with peers
- The need for separate tasks being given to teachers (to engage and intrigue them in the principle) and to students (to be used to communicate science to others)

V. Professional development of museum or science centre staff

In working on the Pencil pilot project, the PPC noted that she has gained a heightened sense of awareness of how to develop activities. However, the greatest impact had probably been on the 'pilot' staff of the museum that had helped to develop the project, and led the workshops training the student Xciters. The PPC noted that the 'pilots' liked the additional responsibility and the involvement in a project's design. She also commented that this development in their role and attitude will be sustained after the project ends.

VI. Emphasis on issues of gender equity and social justice

The Pencil pilot project at the Experimentarium was designed to target girls but also intended to appeal to boys. The notion being that if the communicative aspect of science teaching were to be emphasised, this would appeal to girls, whilst the practical element (the hands-on demonstrations) involved in the activity would appeal more to boys.
A gain in confidence (especially for girls) was a particular aim for the project. This aim in the most part was achieved. The PPC offered the following explanation of the differing approaches of boys and girls: "I think that a lack in confidence is one of the main reasons girls don't enter into science…We have girls saying time and time again saying 'oh, we can't be part of this. We are not so knowledgeable in science'. On the other hand, boys have confidence that even if they don't know the content, they can still explore the topic"

VII. Involvement in, and fostering of, wider network

With regards the wider Pencil community, the PPC at the Experimentarium gained advice and guidance from other partners. However, she would have also welcomed hearing more about the provisional results of other projects – what went well, what did not – so that she would not replicate the same mistakes.

VIII. Sustainability of initiativee

The Experimentarium has received funding from a large corporate sponsor in Denmark that will enable them to carry on with the Xciters project for a few more years.

The Pencil team have already begun to reflect on how they partnered with schools and what they can offer schools in the future to complements school based learning. They are also keen to retain and extend the existing relationships: "we want to make sure that we tell other teachers about it".

In addition, they are keen that the pilots at the Experimentarium will also be involved in new developments. Furthermore, they have considered developing an area of the website to be written and used by Xciters as a place to propose suggestions for workshops etc.

5.7.3. Conclusion of Experimentarium case study

The success of the Pencil pilot project at the Experimentarium – as indicated by student and teacher feedback, and underscored by the receipt of private funding to continue the initiative – is arguably due to a number of key features.

Firstly, the Experimentarium played to its own particular strengths in the sense of developing a programme for school students which echoed the practice of key floor staff, the 'pilots.' At the Experimentarium, the 'pilots', which tend to be students or young adults, are employed to help visitors interpret the science exhibits on display. They do this by interacting on a one-to-one basis with visitors, and by communicating to large groups in specially designed hands-on workshops. The Xciter programme trains students to develop skills in communicating science phenomena during a hands-on workshop or demonstration in order to support learning (both their own, and that of their audience). In training the Xciters, the PPC was able to use the expertise of the pilot staff and other colleagues in the science centre. The pilots were thus instrumental in helping the students to explore ways of communicating particular phenomena.

Secondly, the Xciter programme was grounded upon a strong model of science. This model holds that in order to teach, an individual must have an understanding of both the discipline's content, and ways to communicate such content in an interesting manner. By enabling students to act as teachers for their peers, the Xciter programme not only helps the individual Xciter to become confident in science content and communication, but in addition, the subsequent Xciter-led demonstrations prompt content learning on the part of the audience, and can have an inspirational impact as exemplified by comments such as "I want to be like that Xciter".

From discussions with the PPC and other key players in the Experimentarium project, it is clear that the primary expectations from the Xciter programme were an increase in confidence and communication skills on the part of Xciters, and enhanced interest and aspiration on the part of the peer audience. The acquisition of content knowledge was a secondary objective, as the limited training time (and relative experience of the students) meant that the development of an extensive conceptual knowledge was impossible.

Thirdly, the Pencil pilot project worked hard to establish strong relationships with the local schools, which became partners in the project. Once these schools were recruited, the PPC then developed a close rapport with individual teachers, and responded to their needs and suggestions (such as the creation of a resource box), in order to ensure the success of the programme. However, it is clear that this initial expenditure of effort on the part of the science centre paid off, as several partner teachers have now embedded the Xciter philosophy into their own classrooms and also act as strong advocates for the initiative in their communications with other teachers.

Finally, the Experimentarium Pencil project benefited from the input of academic researchers (from their local university, and the Pencil evaluators from King's College London) in terms of developing effective mechanisms for capturing the experience of the Xciter programme such that improvements, where necessary, could be made. Recommendations from the academic researchers included a focus on the process as well as the outputs, which led to the creation of a blog, and the use of independent researchers to collect data to ensure a more objective picture of events.

In reviewing the Xciter initiative, however, it is clear that the Experimentarium and the PPC could have benefited from a greater understanding of educational research and practice: a number of studies would have informed, and enriched, the development of the peer-to-peer teaching programme and thus saved effort and expense on the part of Experimentarium staff. For example, the work of Shulman (1986) would have been useful for understanding the nature of expert knowledge required by a teacher; whilst research conducted by McCallie et al (in press) offers guidance on enabling conversation and debate about scientific topics. By reviewing such studies, both Experimentarium staff, and the students themselves, would have been saved from re-inventing the science communication wheel.

In summary, the Experimentarium Pencil pilot project proved highly successful in developing an innovative approach to science learning and science appreciation. The approach, which explicitly sought to target both boys and girls, and appeal to both students and teachers, has now become embedded in many of the partner schools, and is being supported at the Experimentarium by a private benefactor. Thus the project has proved to be both popular and sustainable and constitutes an effective model for other informal institutions, or school systems, to adopt in order to support motivation towards, and learning in, science.

5.8. Ciência Viva / Pavilion of Knowledge, (Portugal) – Ludo-mathematics

5.8.1. Summary description of pilot project

The Ludo-mathematics project at the Ciência Viva aimed to support the learning of mathematics by encouraging students to design museum exhibits and classroom activities that present mathematical concepts in interesting ways. Formats for such resources could include games, gadgets or hands-on activities.

The students were supported in their activities by visits to the Ciência Viva, resources and guidance from the science centre, and following the initial low response and feedback on the part of schools, dedicated Explainers who worked with the teachers in schools and helped in the running of the Ludo-mathematics activities.

The project also aimed to develop an on-line discussion forum, and whilst this did not prove fully operational, other new networks (with schools and national associations) emerged to support the project.

To provide further context to the Ciência Viva Pencil project, it is worth noting that there are currently 13 science centres in Portugal (all of which have been set up in the last few years in order to promote public engagement with science). The Pencil PPC project was previously involved in establishing the centres. The relationship between these centres remains strong, and thus if a venture is successful in one setting, there is a strong likelihood that it will be replicated at the other centres across Portugal thus raising the numbers of students reached by an initiative. It is also relevant to note that the school system in Portugal is currently undergoing change. Concurrently, parents are increasingly realising that children can learn from places beyond schools and the home environment.

5.8.2. Case study

I. Relationship between key players

With teachers and schools

The Pencil pilot project at Ciência Viva was built on a clear understanding that the aim was to find new ways of working with schools. The notion of Pencil was thus welcomed at Ciência Viva, as staff had long realised that school visits to the science centre were generally short and rarely planned to connect to the curriculum. In this way, the visits were not providing long-lasting learning opportunities, and as such the experience for Ciência Viva was also unsatisfactory.

The Pencil funding enabled Ciência Viva to establish relationships with schools and to work directly with teachers. On the whole, the teachers welcomed the invitation from Ciência Viva, although the PPC noted that it was often necessary to 'push' schools in order to find new ways of working together.

In attempting to build relationships with schools, staff from Ciência Viva shared many experiences with other museums and science centres, in the sense that the teachers who book visits and agree on the activities, or galleries to be visited, may not be the members of staff who either teach the class, or even accompany the class on the day of the visit. (Interestingly, however, in the case of Ciência Viva, the PPC notes that maths teachers are more proactive in booking visits for their own classes than teachers of other disciplines). It is also worth noting that the Portuguese teachers (and parents) of students in year groups facing an important exam do not welcome extra curricular visits to museums as these are seen to be distracting.

In an attempt to establish a stronger relationship, thus embedding the Ciência Viva experience into school learning, two Explainers were appointed to work closely with teachers, to find out more about what teachers needed, and to match these needs with the services that the science centre could offer. This decision was taken as it was clear that schools were not volunteering to take part in a project, and it was realised that the Ciência Viva had to be the more assertive and thus send staff out to the schools.

The PPC described the rationale for the project thus: “..unless some care is taken to establish a relationship with a school, unless you have some kind of new interaction and new ways of doing things, a visit will be a one-time event… I’m not saying that schools coming here is not enough but a lot more can be done and we need to change ourselves in order to fulfil that role that schools are expecting from us”.

Once contacts were made, Ciência Viva asked the schools to define their own projects, and to outline the ways in which the science centre could help. But this strategy was unsuccessful as schools tended to expect guidance and leadership from the science centre, rather than the other way around. This notion of expecting the science centre staff to ‘teach’ was also found to be prevalent in course of school visits. Teachers expected a guided tour – they did not think that they would have to do any work. In addition, some teachers expressed a lack of confidence with respect to teaching in the context of an informal science centre.

However, the PPC was reticent to allow the relationship to develop in this manner. In interviews, he repeatedly stressed that science centre staff can never take the place of teachers. He also noted that whilst his Explainers may feel that they know more about teaching and making science ‘fun’ than teachers, this is not appropriate. He said “Some of our Explainers are not in a better position than some teachers. A lot of teachers are tired or they don’t have the opportunity or the practical stuff they need, so the last thing we should do is pitch ourselves as the ones who have the solution” .

Finally, with regards the practicalities of maintaining relationship, both the teachers and Ciência Viva staff noted that communication was difficult: emails are not read, and the proposed forum between teachers and Ciência Viva staff did not truly get off the ground. Maintaining relationships with teachers was further complicated by the Portuguese education system, whereby teachers are often reassigned to new schools during the summer break.

Externally
In addition to schools, the Ciência Viva Pencil project also worked with the Portuguese Teachers Association. This partnership was considered fundamental to the success of the project. They also worked with the Portuguese Association of Mathematics. For purposes of evaluation, the Pencil project also worked closely with researchers from the Sociology Research Institution.

II. Use of educational (and other) research
Sociological perspectives on evaluation were provided by researchers from the Sociology Research Institution. This organisation had previously worked on projects exploring the public’s perception of science and so they were well grounded in the issues faced by Pencil.

Whilst not articulated explicitly as a particular position or point of view, the PPC’s comments suggest that his understanding of informal learning environments was consistent with those in the research literature. For example, he repeatedly stressed the necessity of teacher-led pre- and post-visit activities (Griffen and Symington 1997); an active role played by teachers whilst in the informal setting (ref); and the importance of reflexivity on the part of museum educators (Tran and King, 2007).

III. Models and practice of teaching and learning

With respect to a model of teaching and learning in informal settings, the PPC and his staff acknowledged the importance of pre-visit preparation on the part of schools and have thus encouraged teachers to visit in advance of their class trip. Unfortunately, even though teachers may enter Ciência Viva free of charge at any time, few rarely do so to prepare for their visits. Furthermore, although the Ciência Viva staff run open evenings with invitations addressed to individual teachers of science, history, maths and music, most visits are still booked as standard by school administrators.

In terms of working, the PPC believes that Ciência Viva should work with teachers, rather than directly with students. Whilst some of the Explainers are qualified teachers, he would not want them to work with students unless they discussed this with the teachers first.

In terms of the project content, the PPC noted that maths goes from being a favourite subject (in younger children) to a hated one (in secondary school children). He wondered whether this could be due to a lack of practical (real world) context. The aim of Pencil project, therefore, developed from this original question to an activity whereby concepts in maths and science could be turned into practical exhibits – in this way the abstract concept becomes more concrete. The emphasis was still to be on the teacher in leading the learning process, although science centre staff would be available to help teachers (and students) in the practical design of exhibits. The theoretical framework underlying this activity may thus be described as learning by teaching: in developing 'fun' materials related to maths for others to appreciate, the individual students learn about mathematical concepts by thinking about how to communicate particular aspects and recognising that some features may be more complicated (and thus harder to understand) than others. In reflecting deeply on the nature of the content and thinking about how to present it, the students are, in a sense, gaining pedagogical content knowledge (i.e. learning how to teach) as well as content knowledge (Shulman 1986).

With regards to the role of the science centres in supporting attitudes to science and maths more generally, the PPC noted that student attitudes towards these subjects were generally poor, and thus science centres had an important role to play in making such subjects more appealing. By engaging students in the science centre process of designing exhibits which must appeal to a broad audience the Ciência Viva Pencil project helped students to understand the role of science centres and other informal resources as adjuncts to school. As a result the students also developed opinions about the use and usefulness of particular approaches and consequently began to appreciate the problems faced by teachers.

IV. Use of evaluation tools

The PPC offered a personal view of evaluation as 'what worked, and what didn't, and what the problem was'. He also commented that the initial Pencil meeting in Barcelona was useful in highlighting the potential of evaluation. From interview data and other discussions, he clearly recognised the important role of evaluation in improving learning opportunities at Ciência Viva. To help him to conduct the evaluation, the PPC worked closely with the Institute for Sociological Studies in Lisbon.

In planning the evaluation, the PPC noted that it would be difficult to compare the experiences of the project group with a control group, as there would be too many variables i.e. different teacher, different situation. He was also aware that the project schools were trying a lot of new things, but that they were not recording them in any way..

In order to document the activities of students and teachers, a researcher from the Institute of Sociology made extensive observations of the classes involved in the Pencil project. She noted that that more instances of cooperation, imitation, and description were discernible than were evident in traditional science classroom.. These observations were primarily made from an ethnographic rather than a design-based or interventionist perspective. Nonetheless, the PPC was later able to review this data and propose changes in practice.

In terms of receiving feedback from teachers, some difficulty was experienced. Initially teachers' responses were all positive, as if they were reluctant to point out any shortcomings. The PPC tried to encourage a more reflexive approach on the part of teachers. He also hoped to establish a forum for regular comments and reflection, but this was not successful. Following the first stage of the project, the PPC also commented that he intended to continue conducting small scale studies and small surveys in the coming year, but that these would be done more systematically.

From the results of the evaluation, the PPC noted that the project – both its content, and its emphases on evaluation – constituted a major change in the way that a science centre should act and interact with the formal learning environment. He also noted that the project had had a significant impact on teachers. A typical comment from teachers was 'we don't feel that we really did anything new, but in a way this would never have happened [without the Pencil project]'.

V. Professional development of museum or science centre staff

Museum Explainers formed a central part of the Ciência Viva Pencil project. Following their partnership and close working with teachers, the PPC made the following statement: "There's a very significant change in attitude from the Explainers that were involved in Pencil. They understand much better the difficulties experienced by teacher: why the teachers sometimes don't prepare…and why they don't always apply good ideas at school. So Explainers now understand the problems that teachers face in schools in terms of space, in terms of money, in terms of time". Elsewhere in the interview process, the PPC noted that Explainers working in Pencil are now more assured, and they have a theoretical framework for developing new work. The Ciência Viva Explainers who had attended the first Teachers Conference in Geneva had also benefited from the opportunity to network with others and to develop new ideas/ways of working.

VI. Emphasis on issues of gender equity and social justice

Issues of gender and social justice were not explicit aims of the Ciência Viva Pencil project.

VII. Involvement in, and fostering of, wider network

The PPC very much welcomed the possibility of learning from other colleagues in the Pencil network. He commented that he had tried to develop discussions with various pilot projects (namely IMSS and Bloomfield) but technical difficulties in maintaining communication (together with busy workloads) limited such relationships.

The PPC noted that the project meetings in which all the partners attended had been very useful for sharing ideas, experiences and difficulties. He commented that a lot of practical problems were discussed and resolved through informal conversations at such meetings.

For Ciência Viva, the lessons learnt by the process were particularly important. Indeed the PPC stated that he would have welcomed a website wherein projects could share their formative experiences. In this way, other science centres could benefit from the knowledge and insight that had been amassed in other settings.

VIII. Sustainability of initiative

The length of Pencil project has meant that the Ciência Viva staff could witness the advantages of working intimately with schools over time. Many Explainers have since expressed a desire to work in a similar way on different topics with other teachers. The partner schools have also been keen to continue with the relationship. The PPC commented that a “good indicator of success is that everyone wants to go on, and to enlarge on things”. In addition, other schools have shown interest (following details on Teachers Association newsletter), with some schools replicating the projects to try the initiative for themselves.
In short, the Pencil project at Ciência Viva has achieved its aim of creating impact locally.,.

Ciência Viva now plans to disseminate the lessons learnt with other science centres across the country, particularly with respect to the role of Explainers. They also hope that the mathematics and teaching associations will spread the format of practice more broadly.

5.8.3. Conclusion of Ciência Viva case study

The Pencil project at Ciência Viva may be considered innovative in several respects. Firstly, project staff are notable for ways in which they genuinely reflected upon the service that they were offering and sought to improve the experience for participating schools. This led the second innovation (at least with respect to the Portuguese context) of sending Explainer staff out to schools, with the dual purpose of providing support for schools in the development of their project ideas and to learn, at first hand, about the constraints and difficulties under which teachers must perform their roles. This experience ensured that Ciência Viva staff leant to respect teacher knowledge and expertise and to no longer assume that science centre staff always know best in terms of teaching science.

The interest in evaluation, and the partnership with research colleagues from the local Institute of Sociology may also be considered an innovative move with respect to Ciência Viva. This partnership led to detailed studies, and recommendations for future practice which included the continued close involvement of Explainer staff in supporting learning. However, it should be noted that the evaluation mainly comprised qualitative observations of activities, and more quantitative assessment of impacts were not made.

Another key factor for the success and sustainability of the project included the support of the professional associations who proved influential in recruiting teachers and highlighting findings across their networks. Finally, the activity itself – that of encouraging students to engage with content by virtue of presenting it to others – is grounded within a strong theoretical framework and one shared by the Deutsches Museum, the Explor@dome and others with Pencil: learning by teaching.

5.9. Bloomfield Science Museum Jerusalem, (Israel) – Health Matters

5.9.1. Summary description of pilot project

The Bloomfield Pencil pilot project consists of a teacher-training course about biomedical technologies that includes theoretical lessons and visits to laboratories, visits to related museum exhibitions and lectures by scientists, both from the university and from industry (TEVA Pharmaceuticals). During the course, teachers learn about the latest developments and breakthroughs in the field of biomedical technology, and how to teach the pupils through the use of Learning Objects (LO). LO's are resources (mainly digital) based on the idea of breaking educational content down into small units that can be reused in different learning contexts. Junior-high level teachers were chosen as the target group. According to the PPC this choice was also informed by the underlying aim of PENCIL: "If the course is ultimately to influence students to study science at university, the first step must surely be to encourage students to choose science options to graduate high school. If the course was to focus upon high school teachers, whose students have already chosen their graduation options, it was feared that the course might miss influencing the very students it should most be targeting."

At the end of the course the teachers were given the task of producing Learning Objects and "research" posters on the subjects they had been presented with throughout the course.

The project also included the development of a website based on the course results. The website includes three sections on the three topics chosen by the teachers to create their final learning objects and presents a variety of educational materials. The site is available both in Hebrew and in English.

In developing the programme, the project team started with the assumption that "when teaching scientific method, teachers tend to rely on an ideal rather than the real thing." They also acknowledged that pupils tend to have a stereotypical image of the scientist. Thus the course included visits to the laboratories as "an opportunity for the teachers to see for themselves the environment where research takes place" (BF04-13). The PPCs described the main objective of the project as "to give teachers (and therefore pupils) a deeper understanding about the nature of scientific research and improve the ways of teaching about it".

The Bloomfield museum also represented another valuable resource for this topic. The PPCs thought that tours of the museum exhibitions would provide an opportunity for teachers to access supporting information, which would help in the understanding of the technologies and research presented by the scientists. As the PPC explained: "So, for example, the Health Matters exhibition has a group of exhibits dealing with the development of drugs. This section was used to reinforce what the teachers saw at the computer simulations lab as well as the industry research laboratory. Other exhibitions were also used to demonstrate technology, for example, a large electromagnet exhibit presented in the electricity exhibition was used to simulate the alignment of atomic nuclei in the core of an MRI machine" (BF04-13)

Local context

The Israeli school system is structured as follows: primary (5 grades), secondary (4 grades) and high school (3 grades). The time prescribed for science (physics, biology and chemistry) at the junior-high level is 2-6 hours per week, with 3 hours being the most common. In grades 1-3, science is usually taught by the general class teacher. In grades 4-5 there is usually one science teacher for all the classes in the school, whereas in grades 6-12 there are specialist science teachers. Mathematics is taught by a different teacher and has its own scheduled timeframe. In contrast to science, maths is seen as an important topic in the Israeli school system, both in the curriculum and in the final examination, the latter being important for access to university. Peculiar to the Israeli educational system is that, due to the long military service, most students arrive at university four years after having finished school.

Primary school teachers are generally trained at teaching seminaries, Secondary school teachers gain either a B. Ed. or a B.Sc., and High School teachers generally attain a B.Sc. All teachers must take three years worth of in-service training at the start of their career, (about 300 hours worth of courses) and will have refresher courses every year. In the Israeli school system, teachers are encouraged to take professional development training through a variety of incentives including financial benefits. Teachers gather remuneration points that are used as a factor in determining the teacher's position on a sliding pay scale.

Other initiatives for linking school to real science already exist both in Israel (the Weissman Institute has laboratories open to school pupils on a regular basis) and in Jerusalem itself, the Hebrew University offers teaching laboratories that can be used by high school pupils under the guide of university students.

Finally, it is important to note understand that the Bloomfield Science Museum Jerusalem was founded by scientists from the nearby Hebrew University Jerusalem, and a strong connection is still retained. Prof. Peter Hillman, a brain researcher in the Neurobiological Department of the Life Sciences Institute of the Hebrew University, was the founder-director and "the moving spirit behind establishment of the Bloomfield Science". Researchers of the Hebrew universities are involved as advisors for the activities of the museum, their role being "central to the development of new exhibitions as well as in the educational direction of the museum" (BF04-3), whilst "the museum serves as a platform for the interaction of researchers of science with a variety of population groups" (BF04-3).

The museum has a strong relationship with teachers, who are involved in the exhibitions and other educational activities at each phase of their development. Some teachers are members of the educational committee of the museum, together with professors from the university, people from the Ministry of Education and other museum practitioners. In viewing the museum as a resource, teachers are encouraged to see it as "a library full of exhibits and phenomena, exhibitions and ideas that can be used to enrich their learning and their teaching" (BF04-2). Teachers of Kindergarten to 12th grade are offered in-service courses of different kinds in the museum: "The teachers are treated as adult learners and are presented with a wide range of experiences and methods for making scientific phenomena more tangible" (BF04-2).

5.9.2. Case study

I. Relationships between key players

The Pencil project at Bloomfield was the only Pencil project entirely devoted to training teachers. Bloomfield's main objective was to address the gap between real science and the way science is taught at school, and they felt that the best way to do that was by confronting the teachers with where science is done: the research laboratories; the people who do it: the scientists; and the way they do it and communicate it: via papers and research posters.

One of the PPCs described the idea behind the choice of the teachers as their target group as: "target the core, and the core will spread the information". Furthermore, they expressed the conviction that focusing on the teachers can have a deeper impact on the school system than simply teaching the pupils, "we see teachers as an influential community of non scientists" (BF02-1). The project team was also persuaded that "teachers have great influence on pupils' choices in high school courses" (BF02-1). Significantly, one of the PPCs also noted that one of the outcomes of Pencil should be to talk about "working with" the teachers rather than "working for" the teachers: "Working with teachers may be very difficult but we think it's a central point of our role as a museum. Even if this course hasn't reached the expected results we can learn so much from our mistakes" (BF03-1).

Bloomfield traditionally involves teachers at every stage of the development of their exhibitions and educational programmes, based upon the conviction that "this makes teachers more motivated" (BF00-0). Thus the project team worked together with the teachers from the first stage of the course. When the course was being designed, teachers were involved in a front-end evaluation aimed at identifying scientific content, in terms both of popularity and its links to the curriculum, and the right school level on which to focus. The course also met teachers' needs in terms of professional development. As one partner teacher noted: "I think they [such courses] are necessary to be up-to-date... the curricula are continuously evolving" (BF03-2).

The project team also cooperated with a variety of different players throughout the programme, including academic partners from the Department of Medical Chemistry, the Molecular Modelling and Drug Design and the Institute of Life Sciences, Department of Neurobiology and Interdisciplinary Center for Neural Computation at the Hebrew University of Jerusalem; local institutions such as the Chief Scientist's Office, The Ministry of Health, the Pedagogical Secretariat of the Ministry of Education, Culture and Sports, the Educational Institutions Administration of Ministry of Education, Culture and Sports, the Jerusalem Education Administration; and the TEVA Pharmaceutical Industries. The museum itself has an educational committee composed of teachers, museum management, academics, and ministry of education officials. The PPCs said the museum perceives itself as a "neutral body, a junction point which, for being friendly to everyone, can represent the best link among different bodies" (BF01).

In order to identify the needs of the education authorities and therefore obtain official recognition of the course a series of meetings were held with the Chief Inspector of Junior High School Science in the Jerusalem area, The Coordinator of Teacher Training Courses in Jerusalem and a selection of Teacher Leaders. Ensuring official recognition and the ability to grant remuneration points (used by The Ministry of Education to determine salaries) was necessary in order for the course to attract teachers. "The success of the PENCIL teacher training course in attracting teachers therefore depended at least in part upon its receiving official recognition" (BF04-10), the PPCS explained. Throughout the project, museum staff and partners met on a regular basis in order to monitor its development and check if expectations were being met. The course itself had both an internal coordinator and an external coordinator appointed by the Ministry of Education.

From the Inspectorate, the Pencil project team learned that the office was already committed to providing courses on the effective teaching of scientific literacy skills. The PPCs thus decided to include these skills in the programme of the course and later claimed that "the incorporation of literacy skills in the course was seen to be beneficial" (BF04-10).

Working relationships were built with the TEVA industries, whose expectation of the project was clearly to raise their public image, although they were "genuinely interested in having quality researchers for their laboratories" too (B00-6). During the visit to the TEVA research facility, the manager of the laboratory participated in a long discussion with the teachers both about specific research topics and the ethics of pharmaceutical testing on animals.

Relationships with scientists from both academia and the TEVA industries were considered "very important to the success of the course" (BF04-7). The scientists were involved in the planning phase of the project and the PPCs found "there was much to learn from the researchers", their advice being sought particularly in order to identify the most up-to-date topics and technologies to introduce in the training course. Presented with the project goal of bridging current research and classroom teaching, scientists also contributed with suggestions on how to manage the interaction with teachers.

In the end however the PPCs observed that it wasn't easy to form relationships between the teachers and the researchers. "This may be because the interactions were not balanced enough, with one researcher at a time interacting with a group of teachers. The relationships were cordial, informative but not particularly constructive" (BF04 p.18). On the contrary, relationships between both teachers and scientists with the museum were easier and deeper.

II. Use of educational (and other) research

Project staff based their ideas upon current research in education. Thus they referred to specific literature on inquiry-based and free-choice learning, such as "Reconsidering the character and role of inquiry in school science: Analysis of a Conference" (Grandy R, E and Duschl, R. A. 2005)

The evaluation planning also benefited from a review of educational research, such as the Personal Meaning Mapping approach originally introduced by J. H. Falk and colleagues (1998)

Access to both research advice and literature references on the use of focus groups in educational research was gained through the interaction with the University of Napoli team, both during the evaluation visits and on the specific support page created on the Resource centre website.

III. Models and practice of teaching and learning

The PPCs referred to their vision of science being an "international cooperation among individuals. [...]Science is research, not a fixed body of knowledge" (BF00-6b) and claimed that this vision was explicitly portrayed in the training course. This implied presenting the achievement of scientific findings as a process and the findings themselves as temporary and controversial. The PPCs explained that "the subject we chose is particularly suitable for showing that science is just an interpretation of nature: medicine is indeed the field in which more different theories apply; therapeutic choices are based on percentages of success in the past" (BF00-6b) The use of simulation and modelling approaches in health sciences was also stressed throughout the course.

The teaching methodologies used in the course included formal lectures by scientists, museum staff and a learning object expert: visits to academic and industrial laboratories of different nature (experimental, theoretical, computer based); and use of hands-on exhibits in the Health exhibition on display in the museum.

Teamwork and communication skills were also supported by the Pencil project when the teachers designed and produced their own digital learning objects and research posters.

Finally, the learning objects approach may be described as personal experience enabling different learning styles and the different paths to be followed. Indeed, the idea behind learning objects is that, ideally, every student can sit in front of a computer and browse through the interactive path their own way, while the teacher is able to identify difficulties encountered by each student. "LO's are about differences in learning styles, identifying where gaps are and filling those gaps. [...] We do not categorize learning, we just propose a number of strategies that we think might work" (BF00-6b).

Learning to design scientific posters was also another means of confronting the teachers with real science and the way it is produced, logically organized in a communication tool, and shared among individuals. As one of the teachers observed, “the way a poster presents science is important because science is indistinguishable from the procedure through which it is created” (BF02-1).

IV. Use of evaluation tools

The project evaluation strategy for both the training course and the teachers’ website included front-end evaluation, ongoing reflective evaluation and summative evaluation. Three main research questions guided the evaluation strategy:

1. Do meetings between teachers and researchers of science improve teachers’ perception of the scientific process?
2. What do teachers expect from their encounter with researchers?
3. What educational materials can be developed as a result of the meeting between researchers and teachers of science?

In order to build the course upon solid foundations, a front-end evaluation was undertaken while planning the teacher training course. In order to identify the foremost fields in current medical research, a review of scientific literature was carried out. The focus was on microbiological research and neurobiological research, as both were topics which the museum currently had, or was planning an exhibition. The PPCs also met research scientists in these fields and discussed what particular areas they were currently studying.

The final subject areas and target group for the course were then confirmed following a review of school curricular at elementary, junior-high and high school levels. This analysis found that the subjects of microbiology, neurology and technology were best matched with curriculum content in the higher grades. It was also found that at junior-high level “the curriculum is so oversized that its very breadth provides the teachers with flexibility, as they know they are not really expected to teach all of the curriculum, so they are actually more free to choose which aspects of the curriculum to teach.” (BF04-9). The final analysis led the PPCs choosing biomedical technologies as the topic of the course. In addition to connecting to both microbiology and neurology, it was thought that such a topic “may well interest the teachers and provide a good spring board for presenting diverse research project”.

The course itself was evaluated against its primary objective of changing teachers' perceptions and visions of science and scientific practice. Secondary objectives were also taken into measured and included teachers’ understanding of Learning Objects, and ability to create their own.

To conduct their evaluation, the project team used a variety of tools including focus groups, questionnaires, interviews and personal meaning maps[6]. Focus groups were used at different stages of the evaluation. At the front-end stage, five focus groups were carried out with teachers and museum representatives in order to select the “core themes” and the target public for the course. Focus groups were also used to “receive immediate feedback” in the middle and at the end of the course. To evaluate the website materials, three more focus groups were conducted, “one with the teachers that participated in the course, one for teachers that didn’t participate and one for teachers scientists, and policy makers”. (BF04-15)

[6] Personal meaning maps (cf ref) refer to a process whereby individuals write down the key words, and connections between such words to demonstrate their understanding of a topic. Following an intervention (course or activity), the individuals are asked to add further comments to their maps (but in a different colour pen) in order to demonstrate the ways in which their understanding has changed and developed. Researchers may then assess the comments (and the difference between them) with reference to depth, breadth or mastery or other factor.

Questionnaires were used in order to evaluate the different elements of the website. Teachers and experts were asked to code elements on a 4-point scale addressing attraction power, usability, structure and scientific accuracy. Personal meaning maps were used with participating teachers at the beginning of the course with a view to assessing their vision of the scientific process. This particular tool was particularly useful in this incidence because, as the PPC explained, it "enables participants to articulate and negotiate their perceptions and understandings of these words/phrases in their own words and from their own cognitive frame of reference" (BF04-17). The teachers were also asked to describe in 7-10 sentences a day in the life of a scientist dealing with biomedical research (Where does he/she work? Whom does he/she meet? What does he/she do?).

Some teachers were also interviewed on the phone in order to go deeper into the meaning of their sentences. Interviews were also used with educational policy makers in order to identify curricular needs and ways to integrate scientific skills in scientific teaching. Finally, the pilot project coordination team also kept a journal where they recorded their observations in real time throughout the development of the project. To them "this served as a form of self-assessment and may be used to recreate a picture of the course" (BF04-17).

The evaluation process produced a rich variety of insights and observations:

a. Impact of teachers meeting with scientists

Before the courses, all teachers used concepts that referred to scientific experimentation in their personal meaning maps: questions, experiments, observations, facts, and results. Approximately 50% of the teachers referred to social aspects of knowledge building, such as discussions with other scientists, teamwork and basing new knowledge on prior knowledge. Very few referred to the communication role of scientists (academic or popular). When asked to describe "a day in the life of a scientist" the teachers came up with similar pictures, such as: "The Scientist deals with biomedical research. Most of his work is carried out in the laboratory, in the development of medical instruments. He is involved in the development of new medicines. The scientist carries out the research according to the needs and the data that he gathers in the field". An alternative description was as follows: "A scientist working in biomedical research generally works in a laboratory connected to a hospital and to a university, with an aim to improve patient treatment, and to discover [things] about illnesses etc. The scientist meets with the team performing research with him, with the financial sponsors of the research, with the people who need the information deriving from his research, people dealing with statistics. The scientist works according to his hypothesis, prepares an experiment, orders equipment that he needs, helpers etc…".

In the meaning maps produced after the course some interesting changes emerged. 50% of the teachers referred to scientists writing and publishing scientific articles and meeting with colleagues from all over the world. Two teachers described the "dry" (theoretical) work of the laboratory as opposed to the "wet" (experimental) work. Indeed, the teachers were particularly surprised by the way that a computer-based laboratory of one professor looked more like an office than a lab.

b. Teachers expectations' of encounter with researcher

Many teachers expressed an interest in receiving up-to-date scientific information, which they did not necessarily have time to find using other sources. Many teachers' expectations matched those planned by the PPCs, that is, of meeting "the real thing – how ideas come to life, how scientists actually work in research as compared to how the scientific process is described in books" (BF04-22). Some teachers said they expected the encounter would represent an "enrichment, meeting with high quality people" (BF04-22). Half of the teachers mentioned the pupils when describing their expectations: they thought the scientist would have been able to present the students with a more lively picture of science. Interestingly, these teachers also associated a more "enjoyable" science with a "more" real one. They also expected the scientists to be able to inspire methods to teach science "in an experiential manner and not dryly like a formal lecture" (BF04-23).

After the course, however, the teachers seemed to be quite disenchanted about the practice of science and even after visiting the laboratories they lamented the lack of having seen the "real scientist, but sometimes just the student or postdoctoral researcher". The PPCs concluded that most teachers had quite a romantic view of science and scientific practice and, most disappointingly, that they would rather stick to this view than accepting the one they had been confronted with. Indeed, one teacher said that "We will keep teaching the ideal, the way it should be" (BF02-1)

c.Teaching materials

Both PPCs and participating teachers seemed to share the expectation that the programme would aid the development of materials or approaches that would enliven science teaching at school. Unfortunately, it appeared that teachers found it hard to link the topics they learned about, from the lectures and the visits to the laboratories, to the curriculum. This produced a gap between the newly learned technique of digital Learning Objects and teaching content, with many teachers preferring to use the tool to teach topics drawn from the curriculum with which they were already familiar, rather than the ones they had learned about throughout the course. In response to this, the PPCs observed that "asking the teachers to present challenging new material in a challenging new format was perhaps asking too much of them" and that "the chosen topic of biomedical technologies, while popular with the teachers is not necessarily the best choice for the curriculum" (BF04-24). In contrast, the posters seemed to be a more friendly tool for the teachers, who expressed an intention to use this approach with their students at schools. The coordinators are convinced that "the production of a poster is an effective method for bridging between the classroom and the research laboratory" (BF04-25).

In reviewing the evaluation findings, the PPCs noted their evaluation had revealed some weak points of the programme and raised additional questions. One of the original objectives of the evaluation plan – to look at changes in pupils' perceptions of real research - was dropped during the course of project because "we didn't feel we had really succeeded in changing the ones of the teachers that much" (BF03-1) and thus they doubted that it would be worth measuring any changes in student attitudes. The pilot project team was also convinced that the course was too ambitious: "It was a very long course, maybe too long, requiring a strong time commitment. Maybe the three components of the course would have been more successful separately" (BF02-1). It was also noted that most teachers "were expecting to learn the use of educational tools which they could then use in the classroom. They were not expecting to learn how to design and build those tools themselves" (BF03-1)

One of the main questions about the course was the target group. The PPCs said they had chosen junior-high schools because they thought it was important to introduce pupils to scientific topics at that stage of their education in order to motivate them to choose scientific subjects when they went to high school. However, in summarising the lessons learnt from the project the PPCs said "Now we are persuaded that the topics we chose for the training course can't have any impact on junior-high school pupils because they don't have the right impact on their teachers. Maybe it would be better to move the target to high school, so trying to motivate pupils to do scientific studies at university" (BF03-3).

The project website was evaluated against its objective of providing teachers "with raw material from which they can develop teaching materials best suited to their own teaching needs. Questionnaires were used to evaluate usability, navigation and content issues and were sent to teachers and a group of experts. These experts included the scientific advisor for the museum, a teacher-training expert, and an expert of educational websites for teachers and children. The content was considered to be 'attractive' and in general the website was 'clear', although no comments were collected regarding the relation to the curriculum. With regards to the usability, the materials were described as "very good, displaying multi-modalities of representations" (BF06-29). However, the website expert questioned the design of the site and her comments were taken into account in the subsequent design.

The group of teachers evaluating the site included four teachers who had attended the teacher-training course and two science teachers from Jerusalem schools. The teachers found some elements of the website more attractive than others. Particular appreciation was expressed for the pictures and films provided by the laboratories. The teachers' views were particularly interesting with respect to connections to the curriculum: some were considered to be very well linked, others much less so.

The website was also presented to a focus group which comprised members of the educational advisory committee of the museum. The site was well received by this group and considered useful for school. This view is in contrast with the summary views of the teachers who could not see themselves using the website as it did not correspond to the materials with which they teach.

V. Professional development of museum and science centre staff

The pilot project team at Bloomfield felt that Pencil presented them with a great opportunity for designing a kind of programme they wouldn't have been able to carry out otherwise. In particular, the project allowed them to go deeper into the processes of self-monitoring and reflection than they had been able before.

The kind of evaluation strategy they designed was also different from their usual practice, as it was addressed issues such as changes in perceptions of science and of science teaching methodologies. One of the PPCs explained that her ability to plan evaluation and an awareness of its role had increased due to the project,

The two evaluation visit from the Napoli University academic partners also represented a deepening of insight and an opportunity to go deeper into project assessment. As one PPC summarised: "we have carried out discussions we wouldn't have been able to carry out without the visits" (BF02-1).

VI. Emphasis on issues of gender equity and social justice

Due to its location in Jerusalem and the commitment of its founders and practitioners, the Bloomfield Science Museum has a long history of experience in mediating learning across different cultures. All museums labels are written in Hebrew, Arabic and English. The staff in the museum is mixed and the exhibitions are always designed with a view to the variety of needs and views.

The teachers participating in the training course were chosen from different areas of the town and included both Arab and Hebrew teachers, teaching in both Arabian and Jewish schools. The museum maintains good relationships with both ethnic groups and the PPCs reported that teachers of both groups feel welcomed in the museum.

Given the general objective of confronting teachers with real-world science, the PPCs were also committed to ensuring female scientists were among those selected to meet the teachers: "we wanted a woman to be one of the leading scientists to take lectures at the course. One of the labs we chose for the visits is run by a woman" (BF00). Project staff felt that prejudices exist in the way teachers perceive males and females with regard to science and that these prejudices have an influence on the way science is portrayed at school.

VII. Involvement in, and fostering of, wider network

The Bloomfield team played a very active role in supporting communication within the Pencil community. Besides the online chats through the Xplora portal, the team contributed with enthusiasm to Pencil meetings and discussions taking place through the mailing list.

A part of the Bloomfield project budget was allocated to translate educational materials produced by other PENCIL pilot projects into Hebrew. According to PPCs, there is lack of educational materials in Hebrew, which can be accessed on the Internet, and many teachers wouldn't be able to use the ones in English or other European languages. The translated materials will be published on the project website.

Through the contents published on the website the pilot project coordinators expect to have "more impact than the personal and professional enrichment of a select group of teachers" (BF04-5).

VIII. Sustainability of initiative

By teaching teachers rather than pupils directly, the project team meant to produce a cultural change in the teachers that would, in the end, have an impact both on the pupils in the classroom and on the teachers' colleagues. As the PPCs pointed out, the philosophy of the project is "meet the core, and the core will spread the info". Another primary means for disseminating project outcomes in terms both of materials and methodologies – the use of learning objects in school teaching – is represented by the website. The website presents both the scientific contents of the course and the learning objects. Based on their evaluation of the training course, the PPCs concluded that most teachers were happy with having been presented with this new teaching tool, and many of them said that they will be using the learning object technology in their future teaching.

The very nature of the learning objects means that they are transferable across different contexts and are usable by any teacher. This is due to their being modular, focused, and interactive. Also, like any other digital resource, learning objects can be labelled with metadata information and therefore made easily searchable by the teachers in terms subject matter, language, age suitability etc. Indeed, the use of learning objects has been fostered by other European projects, such as CELEBRATE.

5.9.3. Conclusion of The Bloomfield Science Museum Jerusalem case study

The Pencil pilot project at Bloomfield may be considered significant in three main ways. Firstly, the museum saw itself as the bridge between the practice of science (in laboratories) and the teaching of science (in schools). A more common metaphor speaks of the need to *build* a bridge between the two learning environments of schools and museums. But by establishing *itself* as the bridge between the environments of science practice and science teaching, the museum has clearly positioned itself as an ally of both schools and of research, rather than something separate which needs its own bridge to be reached.

By acting as a mediator, the museum was thus able to bring teachers and scientists together. In order to do this, Bloomfield clearly worked hard to identify and build relationships with the key players in the fields of research. Lastly, to support the process of mediation, the museum staff used their own pedagogical and technical expertise to help teachers create new curriculum (including digital) materials, and also developed their own website to support such a process.

Secondly, the Pencil project prompted the PPCs to engage in an extensive process of evaluation. The findings challenged the expectations of the coordinators, and helped them to think deeply about their project plans. As a result, the PPCs are very open about the mistakes they made and the lessons they learnt from the process. For example, the PPCs were clear in stating that the project may have better served an older age group as this would have been a better match for teacher expertise in content; they also noted that they may not have prepared teachers appropriately prior to their visits to the labs. Such openness is refreshing. Furthermore, it is highly valuable for informing the development of similar and related projects involving the teaching of particular content, or establishing connections between research and practice.

Thirdly, the Pencil project at Bloomfield has highlighted the value of Learning Objects and other digital tools as pedagogical materials, which may be used across Europe and beyond. The partner teachers also contributed to the development of Learning Objects and other curriculum materials on the topic of biomedical technologies, and these are now available online to be shared more broadly. In addition, by virtue of the particular political climate in which Bloomfield is situated, the museum staff have the responsibility of serving a very mixed community. By translating project materials into the key languages of the region (Hebrew and Arabic), and by translating the resources from other Pencil projects into Hebrew, Bloomfield has clearly demonstrated the role that museums can play in supporting science learning in spite of any local environmental constraints.

Whilst the results and impact of the Bloomfield Pencil project may be considered significant, several aspects could have been improved. Firstly, although teachers were invited to be part of the early focus groups to identify a particular topic of study, it would seem that they were the recipients of the initiative, rather than true partners. Secondly, the flow of information between research scientists and teachers appears to have been one-way, and thus the researchers may have missed out on the wisdom and expertise of experienced teachers with regards teaching of under-graduates, or even new recruits to the lab. It is thus recommended that these points be addressed by Bloomfield, or other institution planning a similar initiative, if the project is to be continued.

5.10. Ellinogermaniki Agogi, (Greece) – The virtual observatory

5.10.1. Summary description of pilot project

The Greek Pencil pilot project aimed to demonstrate the ways in which hi-tech equipments like robotic telescopes may be used as educational tools for schools all over Europe. Over the two-year period of the project, two contests were organized for students from all over Europe. A web portal was created to welcome participants and guide them through the contest by giving all the necessary materials and information, both scientific and practical. After having registered, participants were provided with a series of telescopic images of astrophysical objects (planets, stars, galaxies) and a set of possible observations to choose from with the help of the teachers. The subject matter and degree of complexity were divided according to different age groups. Participants submitted a "research project" in order to access a network of remotely controlled robotic telescopes and use scientific data from the telescope for their research. If the proposal was accepted by the committee, they obtained observation time on one of the telescopes. Classes could also "talk to the scientist" at the telescope via a videoconference, which allowed pupils to ask questions and "meet the scientist" in his/her research context. Once the proposal was approved, the participants conducted their research and then reported the findings to the scientific committee. The best researchers won a prize in the concluding award ceremony. The project involved many schools from almost all the countries in Europe, with over two hundred teams taking part.

Before and during the European Science Week 2005 several interactive sessions on popular science were organized based on science subjects and educational material related to the contest topics and on the results of the research projects developed by the contest participants. The programme included ten Contest Science Days during which contest participants had the chance to discuss and interact with experts about their projects, and six Public Science Days during which youngsters and the general public could get additional information on the latest achievements in astronomy and learn about the results of selected contest projects. An online course was organized for teachers of the participating schools and science centre educators in order to ensure the success of the activities.

The project website supported students and teachers during the whole process, providing them with educational materials, newsletters, scientific papers, and links. Communications tools were provided in order to encourage cooperation among the schools involved. Suggestions were asked to astronomers via an "ask to the expert" section on the web site. Effective training was offered to teachers, including teachers' workshops in which the project activities were presented, and a series of online seminars delivered via the Internet.

Local context

The Greek school system is structured in 6 grades (6-12 years old) of primary school and 4 grades of (compulsory) secondary school, followed by 3 grades of high school. In all of the grades one teacher is usually in charge for each discipline. In primary schools the time prescribed for maths is 4 hours per week and, in the last two grades only, two hours per week are prescribed for physics. In secondary schools 4 hours per week are prescribed for both maths and science (2 for physics, 1 for chemistry and 1 for technology). In high schools, the time prescribed for maths and science depends on the choice of subjects (theoretical, science or technology direction), ranging from 4 hours each per week to 7 and 11 respectively. In high school science teaching includes physics, chemistry, biology and many different elective subjects (for example astronomy or communication technology).

In Greece, future science teachers have a degree in maths, physics, chemistry, biology, or geology. There is no specialization year for science education, or compulsory courses in pedagogical methods for science, though teachers may take some voluntarily. Individuals with science degrees have to sit a specific national examination in order to be appointed as a science teacher in the secondary education. The candidate takes a test in two scientific disciplines and another test in science didactics.
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In 2002, an institution called Teachers Training Organization was established by the Greek Ministry of Education. This institution (whose governing board is appointed by the Minister of Education) organizes all the continuing (in-service) teachers training activities in public Regional Training Centres.

The structure of the school curricula is based on both goals and contents. Curricula comprise a full guide to the educational task, and consist of: clearly formulated goals for each subject within the framework; the contents to be taught, structured into units; and directions indicating the method and teaching aims for each subject. In primary schools, teachers must follow the curriculum in terms of both contents and its stratification into levels corresponding to the six grades. All the courses are compulsory for all pupils and are considered to be of equal value. In high schools the curriculum is more flexible in terms of pupils choice of direction and elective subjects. The curricula and timetables are drawn up and proposed to the Ministry of National Education and Religious Affairs by the Pedagogical Institute. Curricula are tested, evaluated and periodically revised according to developments in the subject area and in the realm of educational research.

Ellinogermaniki Agogi is a multi-grade Greek-German private school in Athens, and a member of EDEN (European Distance Education Network). It constitutes a kindergarten, primary school, high school and lyceum (senior high school). The school has four departments, for German, English, Science and Research & Development. The facilities include finely equipped labs for Physics, Chemistry, Biology, Artwork, Music and Computer studies. There is also a library, video room, gymnasium, swimming pool and outdoor sport facilities and courts. It also has a planetarium and a small science centre. All these enable the students as well as their parents to participate in various cultural, athletic and social activities. There are 250 teachers teaching in the diverse grades covered, with the R&D department counting 20 people alone. The main activities of this department are the development and evaluation of educational material (electronic and conventional) and the training of the teachers in the application of ICT. Among their other activities, the research group of Ellinogermaniki Agogi author official books for science and physics teaching for the last two grades of elementary school and the last two grades of high-school.

5.10.2. Case study

I. Relationships between key players

During the development phase of the project, the pilot project coordinators collaborated with representatives of the Ministry of Education, the Pedagogical Department of the University of Athens and the Democritus Institute for Scientific Research.

In contrast to all the other PENCIL pilot projects, the leading institution in this project is not a science centre or museum but a school. The PPC is the head of the Research and Development Department at the school. Project team members are both teachers and members of the department, and by virtue of their presence in school are afforded direct and constant dialogue both with other members of the department and with full-time teachers. Thus, they are able to see at first hand how their proposed activities are applied in the classroom.

A cooperative relationship was also established with researchers working with the telescopes, and these researchers were asked to be available for video conferencing with participating pupils.

II. Use of educational (or other) research

As members of the Research and Development Department of Ellinogermaniki Agogi the PPCs are both users of existing literature and promoters of explorative projects in the field of educational research. The Department has been involved in numerous research projects prior to Pencil, and have a particular interest in use of ICT and e-learning methodologies. The school also works in a close co-operation with education departments of universities in Greece, Germany, Austria, Portugal, Spain, Italy, UK and France

The pilot project activities and methodologies were based in particular on the team's experience of The Teaching Science with a Robotic Telescope (EUDOXOS) project (2003-2004), a collaboration with the Institute of Nuclear Physics at the National Centre for Science Research 'Demokritos'. This project produced the first prototype of a user interface that allowed school pupils to exploit the Andreas Michalitsianos Telescope of the "Eudoxos" National Observatory for Education and Research in Greece.

III. Models and practice of teaching and learning

The pedagogical approach followed by the school refers explicitly to life-long learning, connecting learning to aspects of everyday life, constructivism as a theory of learning, and to inquiry-based teaching.

The pilot project allowed participants in the contests to follow the process of designing a research project, submitting a proposal according to given requirements, having it examined by a scientific committee and, if their proposal is successful, accessing real experimental devices such as the robotic telescopes, in the very same way astronomers do. This enabled participants to get a feel for the nature of science and its mechanisms. As the PPC explained: "The goal is to induce the learner into a 'culture of practice' which makes the knowledge more meaningful and in context" (EA07-1).

The data used by the participating student was authentic, whether in the form or images or measurements. No mediation, interpretation, or simplification of the data was made between the source and the user. To support students to make sense of the data, the web-based platform offered advice and suggestions about kinds of analysis to perform, including the use of indirect measurements or statistical calculations.

The manner in which the research results were reported was a key aspect of the project. Communication was seen as part of the scientific process and as a means for learning.
The project also fostered an interdisciplinary approach to the subject areas explored in the activities. "We think that a primary characteristics of innovative science education in Europe should be its implementation across different disciplines" (EA04-2). With respect to this approach, project coordinators specifically referred to the UK based project Science 2010.

IV. Use of evaluation tools

The PPCs observed that the activities proposed in their projects has previously been tested and evaluated in the framework of a previous project, the Eudoxos project. They commented that their project already constituted an example of best practice and that no evaluation was needed. Thus their objective was "to disseminate this best practice through the PENCIL project" (EA04-1). As a result, the project team simply developed a series of questionnaires to perform a 'validation' of their activities. Questionnaires were developed for teachers and school directors.

The validation plan was aimed at confirming the design; quality-of-service and user-satisfaction; financial viability; and self-sustainability of the programme over the long term. Specifically, the so-called ‘balanced scorecard’ method adopted by the project team was used to provide “a set of measures that gives a fast but comprehensive view allowing a look at the ‘business’ from four important perspectives: a) How do users see us? (user perspective); b) What must we excel at? (internal perspective); c) How can we continue to improve and create value? (innovation and learning perspective), and d) How do we look to stake-holders? (financial perspective)” (EA06-8).

In addition, a joint evaluation of users and services offered across three dimensions (strategic importance, significance, and cost effectiveness/profitability) was used to help the team plan a constant renewal of the project.

The project services were classified in three main categories to be validated, namely Observations (real-time or scheduled), Educational resources (courses, lesson plans, seminars, etc.), and Image requests. Two types of questionnaires were developed in order to address the end-user as an individual and as an institution (taking into account both the institution’s objectives and the aggregation of individual end users’ satisfaction). Individuals were examined via online questionnaires, which were completed at the end of a session and through statistics based on the data registered in the log-files of the project servers, including data such as the user’s country-of-origin and pattern of usage. Users granted a license to use the services for extended periods of time (usually, one-month) were asked (as an obligation in order to get the “extended-time use”) to fill in two questionnaires, one for user satisfaction and one for pricing considerations. Institutions such as schools and other formal learning settings, science museums, parks, centres were also asked to complete hard-copy questionnaires on user satisfaction and pricing consideration.

The questionnaires were based on standard “service use satisfaction” survey methods in the case of individual users, and on a customization of the VALNET method in the case of educational institutions. The VALNET validation framework is a method that aims at providing qualitative and quantitative evidence of the positive impact of the innovation, product or service. It analyzes the innovation content of the services along five dimensions, namely Pedagogical, Organisational/institutional, Technological, Economical, Cultural/linguistic.

For detailed results of the validation plan, see the internal report produced by Ellinogermaniki Agogi.

V. Professional development of museum or science centre staff

Since the pilot project represented the further development and testing of a previous initiative, there was limited new professional development on the part of the project staff. However, with respect to issues of evaluation, the PPCs mentioned that the interaction with the evaluation team from the University of Napoli had prompted “a bigger awareness of the necessity of an internal evaluation of the project activities” (EA04-3).

VI. Emphasis on issues of gender equity and social justice

Being web-based, the project activities are naturally accessible for all students – boys and girls – able to use a computer connected to the Internet. The evaluation team from the University of Napoli proposed examining different behaviours of boys and girls during the activity and changes in numbers of girls taking astronomy classes as a result of the activities. However, this proposal was not taken up by the project team.

VII. Involvement in, and fostering of, wider network

Being completely web-based, the programme allowed pupils, students and the general public from all over Europe to participate. One of the explicit aims of the project was to "build on the youngsters involved in a series of science projects in order to create a Virtual Community of young prospective researchers. They should become the promoters of the best practices and contribute to the final validation of products and criteria" (EA02-2). All participants to the project were included in a mailing list and received a regular electronic newsletter that kept them updated with activities in all science projects and new items appearing on the project's portal.

An existing network of remotely controlled robotic telescopes was exploited by the project. Participants were given access to the network through the project's portal itself. The network includes the Liverpool telescopes at the Canary Islands (2 m diameter), the Skinakas telescope in Crete (1.5 m diameter) and the SGAO telescope in Israel (40 cm diameter).

As the activities carried out throughout the project were repetitions of activities implemented through the previous Eudoxos project, the PPCs said they hoped that their involvement in Pencil would help them disseminate their activities to a wider community of teachers across Europe (EA04-2). To foster dissemination, the project team made a series of initiatives including announcements on the Xplora portal, a live broadcasting of the solar eclipse of March 29 2006, promoted both through the Xplora and the Ecsite websites, a demonstration of their activities at the 2006 Xplora Science Teachers Conference at Cern, a presentation of the project at the 2006 EDEN (European distance and e-learning network) Annual Conference, at the European Open Science Forum 2006 and at the International Astronomical Summer School 2006. Unfortunately, the PPCs found that the dissemination efforts via Xplora and Ecsite were not highly successful.

In terms of networking with Pencil colleagues working across Europe, it appears that the difference between the Ellinogermaniki Agogi project and the other, more exploratory projects limited potential communication and sharing of ideas.

VIII. Sustainability of initiative

The PPCs expressed an intention of keeping their platform online and updated and to organize more contests in the subsequent years. They also plan to extend the network of telescopes for the participants to use and are actually building a 40 cm telescope in-house. Around two hundred participants took part in their contests and thus a much larger network of telescopes would be needed if the number of participants were to grow as hoped.

Finally, the PPCs mentioned that their validation strategy will allow them to give their project "proper positioning in both media and the market [which] is very important for the long-term sustainability of the venture" (EA06-7).

5.10.3. Conclusion of Ellinogermaniki Agogi case study

In contrast to the other thirteen pilot projects in Pencil, the Ellinogermaniki Agogi project was developed by a group of members of the Research and Development Department of a school. Thus, informal educational activities were produced in a school by former teachers. The project also differs in the sense that its prime objectives were to validate an existing format, and to promote the initiative to new audiences.

From a review of the project it is clear that an extensive process of summative evaluation was conducted in which pragmatic and marketing issues were addressed alongside educational concerns. However, it is unfortunate that the project did not attempt to study any processes of learning on the part of students engaged in the competition activities. In this way, an important opportunity was missed with respect to gaining greater insights into the learning of astronomy.

This criticism notwithstanding, the management of the on-line summative questionnaires may be of interest to other institutions planning to assess on-line resources.

The Ellinogermaniki Agogi project did not seek to establish close partnerships with teachers. Indeed the content and format of the project had already been developed. However, the project does provide a useful model for teaching the nature of science. The requirements of the competition, for example, provided a clear message with regards the process of science i.e., the need for clear objectives; the need for evidence-based interpretations; the role of communication etc.

In summary, whilst the Ellinogermaniki Agogi project does not offer any particular insights to the ways in which museums and science centres may build partnerships with schools, the project does offer an interesting resource for supporting science learning in schools.

5.11. Technopolis (Belgium) – Interactive Forensic Science: Who did it?

5.11.1. Summary description of Technopolis case study

The Belgian pilot project, modelled on an interactive game format, explored the nature and practice of forensic science. This topic was chosen for its popularity (as demonstrated by the wide success of TV series such as CSI), and its links to the social context, in the sense that sense that forensic science is an important part of police work and is frequently mentioned in the media. By using an exciting story about crime scene investigations, the game activities designed by the project aim to demonstrate the relevance of the scientific content upon which they are based, and thus enhance pupils' motivation towards studying science and technology.

The pilot project programme consisted of three different parts:

- a kit/workshop to be used in schools
- the MysteriX® science truck
- the online games.

The content featured in the activities included aspects of chemistry (DNA, substance identification, etc.), biology (the nature of hair, pollen, fingerprints etc.), and technology (the use of equipment etc.). The target group was pupils aged between 10-14 years. 10 primary schools and 11 secondary schools across Flanders were involved in the pilot project.

The school workshop was led by a Technopolis edutainer[7] and lasted 90 minutes. In the introduction a story was told about a burglary , which had been committed in school: the money for a school trip had been stolen from the director's office. Next, a series of possible suspects was presented and the crime scene investigations begun. The investigations consisted of five games/experiments involving fingerprinting: decoding a secret message: analyzing mud; constructing an identikit; and analyzing textures. In the final part of the workshop, pupils built an alarm to be placed under the director's doormat to prevent a future burglary. The toolkit for this workshop included all the materials to perform the experiments, a log to fill in the results, an educational file for the teacher (including follow-up suggestions) and materials to work with afterwards in the classroom.

MysteriX is a science truck containing 9 hands-on exhibits, each inspired by a story of an epidemic caused by a virus released into the air by terrorists. The truck travels around Flanders, visiting towns for one week at a time in order to allow students from local schools to visit. Apart from forensic science, topics covered also include geography, language, and music. Three new exhibits have been developed for the Pencil project, wherein pupils are engaged in decoding a foreign alphabet, assessing blood group types, and classifying clues.

The interactive website also developed as part of Pencil and entitled 'The mystery of the vanished blue canary bird', consists of 7 online games simulating crime scene investigations in a house in which a bird has disappeared. The "experiments" to be performed are: identifying footprints; comparing fingerprints; completing a DNA test; recognizing materials/clothes; analyzing voice recordings, blood typing; and analyzing pollen.

Local context

The Flemish school system comprises non-compulsory pre-primary education for 2 to 6 year olds and compulsory education for 6 to 18 year olds. Schools are grouped in three different educational

[7] This is the name that education staff are given in Technopolis to stress their double function as educators and entertainers

networks: public schools, Catholic schools and province/municipality managed schools. The catholic school population covers about 70% of the total.

With regards to teaching methods or educational projects, each school board defines its mission autonomously. National control is thus excluded as long as the projects do not contradict the democratic principles upon which the Belgian state is based. An important principle in Flemish educational administration is the use of attainment targets and developmental objectives. Attainment targets are minimum objectives with regard to knowledge, insight, skills and attitudes. Developmental objectives are the minimum achievements that the educational government regards as desirable for a specific age group of pupils.

In pre-primary school the curriculum is based on the developmental objectives. Science-related areas of learning include environmental studies (subjects: nature, man, society, technology, time and space) and mathematics for pre-school education (subjects: numbers, measuring and space). In primary school the curriculum is based on attainment targets and curriculum subjects. Science-related subjects include environmental studies, and mathematics for primary education (numbers, measuring, geometry, strategies and problem solving skills and attitudes). Secondary education is divided in three stages. The first stage has two different courses of study, A and B. The core curriculum is based on attainment targets and developmental objectives. Five cross-curricular attainment targets have been formulated as well: learning how to learn, social skills, education for citizenship, health education and environmental education. In the first year, A science-related curriculum subjects comprise mathematics, biology and technological education. Optional subjects include scientific work, technological education and nautical techniques. In the second year, A pupils learn mathematics, physics, biology, and technological education. Basic optional subjects include: agricultural and biological techniques, construction and woodworking, Greek-Latin, printing technology, industrial sciences, naval training, mechanics-electricity, modern sciences and technical training. For the first year in B, an almost identical timetable applies. The differences are as follows: in the core curriculum the subject natural sciences are included instead of the subject biology; and only mathematics is included in the optional subjects. The second year of B covers pre-vocational education, with the core curriculum including mathematics and natural sciences. The second and third stages are divided in different courses of study, including General Secondary Education, Technical Secondary Education, Art Secondary Education and Vocational Secondary Education.

5.11.2. Case study

I. Relationships between key players

Teachers and pupils were involved in the testing phase of the pilot project and as a result, changes were implemented to ensure coherence with the attainment targets of the national curriculum. As one member of the PENCIL staff at Technopolis stated “Thanks to the involvement of teachers in the formative evaluation stage, we paid more attention than usual to the support materials, while the pupils’ involvement allowed us to have a final product which is more attractive to them”.

The partner teachers were mainly recruited among a group with whom Technoplis already worked before and whose willingness to participate was already known.

The evaluators from the university of Napoli had a chance to meet one of the edutainers in charge for the school workshops, who showed them the school kit and explained in detail how the sessions were carried out. From the discussion, it was clear that teachers were not directly involved in leading the sessions apart from helping the edutainer to keep the pupils’ quiet and attentive. “With pupils in that age (10-12 years old) it is very difficult to carry out an activity with more than one leader”, the edutainer explained. Furthermore, it appeared that many of the teachers were happy for (and often expected) the Technopolis staff to lead the sessions, as this perhaps provided the teachers with a break from their usual responsibilities.

II. Use of educational (and other) research

The educational activities of the pilot project were developed in collaboration with the National Institute for Criminalistics and Criminology, the Centre for Human Heredity of the University Hospital of Leuven, and the Faculty of Pharmaceutical Sciences of the University of Ghent.

III. Models and practice of teaching and learning

The main objective of the Technopolis Pencil pilot project was to enhance pupils' motivation towards studying science and technology. This objective was pursued using a hands-on/minds-on approach to stimulate excitement, curiosity and enjoyment on the part of the pupils and thus enable learning-by-making and learning-by-playing. As one of member of the PENCIL staff at Technopolis explained, "all the educational tools in the pilot project were designed in such a way that teamwork, observation skills and deduction skills are necessary in order to 'solve' each exhibit or game. The key-points are the use of hands-on activities and the desire to make the pupils (and our general visitors) be excited and have fun". This point was reinforced by a further comment made by the PPC during the first visit to Technopolis on the part of the University of Napoli: "Of course, when we do something in Technopolis, it should always be fun, it should always be interactive, because, as you know, 'I hear and I forget, I see and I remember, I do and I understand'. So, what we do is about doing and about understanding, it's about learning through interaction but also through play, it's a combination of amusement and entertainment and learning".

The evaluators from the University of Napoli had an opportunity to examine, and play with the online aspect of the project before it was launched. They noted the appealing appearance of the games, but felt that there was a lack of scientific content, in that many of the 'crimes\ were solved by following a standard pattern. However, one member of the PENCIL staff at Technopolis explained that the games were designed for pupils aged 10 and thus their aim was to simply stimulate pupil's curiosity towards finding explanations.

The evaluators from Napoli also met with the edutainer (a former teacher in kindergartens and primary schools) who developed the final version of the school kits. The experiments in the kit were felt to be more complex than the online games but still lacking in scientific content. Furthermore, the evaluators felt that the educational file for teachers was organized according to very general topics which did not specifically connect with the scheme of the workshop. However, it should be noted that the general comments received from teachers during from the formative evaluation process suggest that they were happy with the scientific content.

IV. Use of evaluation tools

After the initial concept and design phases, all the educational activities in the pilot project were developed in cooperation with Pencil teachers. Their feedback was gathered by means of validation questionnaires and face-to-face discussions, and sample test sessions held at Technopolis. As already discussed, an extensive formative evaluation study was carried out with both teachers and pupils. This evaluation study resulted in some adaptations of the three educational programmes, whilst the prototype testing resulted in extending the duration of the workshop to give the pupils enough time to complete the assignments.

Test sessions were also organized to evaluate the new exhibits in the MysteriX truck. The scripts explaining how pupils needed to perform the experiments were substantially transformed because the assignments were not always correctly understood. A certain number of technical flaws were discovered and corrected, primarily enabling the edutainer coaching the sessions to have more overall control.

In terms of the online games, teachers played a role in the design phase of the activity, as the underlying story and contents were discussed with them prior to the development. This survey was conducted via email. Test sessions were then organized in Technopolis, in which pupils behaviour was observed. When the activities were completed and in operation, feedback from teachers continued to be gathered through evaluation forms. The feedback obtained in this second phase was mainly positive about both structure and contents of the activities. After a suggestion made by the evaluators from the University of Napoli during the first evaluation visit, evaluation forms were also given to pupils.

In summary, the evaluators from the University of Napoli found the formative evaluation programme to be extensive, but the summative evaluation programme to be lacking in focus. They also noted that observations of the students engaging in the activities would have been valuable for determining the impact of the programme on pupils' learning. Furthermore, given that one of the main objectives of the pilot project was to enhance pupils' motivation towards studying science and technology, the evaluators recommended organizing focus groups with pupils instead of questionnaires, as the latter are limited in the ability to assess changes in attitude. Finally it was suggested that Masters level students from local universities could be involved in leading such studies. Unfortunately, such studies were not be completed by Technopolis due to a lack of time and money.

V. Professional development of museum or science centre staff

The PPC noted that Pencil had led to several insights with respect to ways of working. For example, the project had pushed staff to clarify objective and determine a clear structure for the activity. Secondly, the project had provided Technopolis staff with an opportunity to meet peers from other institutions and share experiences. Finally, the experience of working with the university teams had led to more developed understanding of evaluation.

VI. Emphasis on issues of gender equity and social justice

The Pencil project at Technopolis did not specifically address issues of gender and enquiry. However, the participating teachers were asked if they noticed any gender differences with respect to the impact of the educational programme, but none were noticed.

VII. Involvement in, and fostering of, wider network

The Pencil team at Technopolis welcomed the opportunity to meet with staff from other Pencil projects and wished that they had had more time to read relevant materials. They also commented on the nature of the Pencil programme whereby the emphasis on evaluation had forced the team to reflect on their practices: "This kind of project forces us to look at ourselves form outside the box and question what we are doing, because we see it through the eyes of others."

5.11.3. Conclusion of Technopolis case study

The Pencil pilot project at Technopolis embraced a key objective of Pencil in developing an evaluation programme to assess and improve their educational programmes for schools. The actual project built upon existing resources but attempted to test the suitability of these in a more comprehensive manner. Whilst a full evaluation programme, which also assessed pupil attitudes and measured the expressed objective of the initiative – that of enhancing motivation towards aspects of science and technology – was not completed, it is clear that the Technopolis staff appreciated the value of such measures and will hopefully introduce this approach in their future work. To this end, it is recommended that they work in partnership with academic institutions that may be able to advise on appropriate methods and provide skilled staff to conduct them.

In building on an existing programme, the Technopolis Pencil project was able to demonstrate the role that science centres and museums can play in communicating science to a broader public. By developing on-line materials, and providing a travelling science exhibition in the form of the MysteriX truck, Technopolis was able to reach a much larger audience than would have been reached if the resources were located at the science centre alone. Secondly, by developing resources on the theme of forensic science, the Technopolis Pencil project was able to build on popular interest in this subject (already heightened by television programmes such as CSI) and thus introduce children to the basic processes and practices of science – experimentation; the role of evidence; the use of technological equipment – in a fun and hands-on way.

5.12. Città della Scienza , (Italy) – So…Science! Social dimensions of science, gender and diversity

5.12.1. Summary description of pilot project

The Pencil pilot project at the Città della Scienza aimed to explore ways of promoting the social dimension of science. Project staff invited teachers and their students from local schools to engage in discussions with Città educators, to join in workshops, and to try out new ways of teaching with a view to developing effective methodologies for communicating science and highlighting its social implications and contingencies. The Pencil team also hoped to assess the ways in which male students and female students would respond and react to the resources available in the science centre.

The Pencil project at the Città thus involved 11 schools, 22 classes and 50 teachers. The team also brought in academics from local universities and teacher training institutions to provide lectures and training on science teaching. The participating students attended a variety of workshops led by Città della Scienza facilitators and, on occasion such activities were extended back into the school curriculum.

When reviewing the impact of the Città Pencil project, it is important to note that schools in the Napoli area generally work in a very different way to the approach advocated by the science centre. Whilst kindergarten schools support hands-on learning and encourage students to experiment with phenomena, by secondary school, most teaching formats are lecture based and offer little scope for inquiry on the part of students. In contrast, Città della Scienza promotes inquiry learning whereby students engage with science phenomena, conduct their own investigations and follow their own lines of curiosity to find out more.

In addition, due to the pressures of tight timetables, many secondary level teachers are unable to visit the science centre in advance of their visit, or adequately prepare their students for the experience. (Indeed many visits are not even booked by the individuals taking the group.) In this way, the close communication developed between teachers and Città staff represents a significant departure from normal practice.

5.12.2. Case study

I. Relationship between key players

Whilst teachers were not instrumental in the design of the Città Pencil project, a number of meetings were set up early in the project in order to get teachers 'on board'. These meetings also served as an introduction for teachers about the proposed new ways of working. In addition to general meetings, teachers also attended special presentations (90 minutes in length) led by professors in pedagogy from local universities, and had special meetings with the Pencil pilot project facilitators in order to discuss topic areas and didactic pathways. Such a process is not typical for most schools visiting the Città.

In addition to working with Città staff, the Pencil project created an opportunity for teachers to work together. When asked how the Pencil project will differ from other connections and visits to Città, one primary school teacher said: "a widened community…moments of exchange, of comparison with different educational realities". One secondary school teacher also commented that that the Pencil project would help him learn how other teachers do things, how they simplify things and what methods they use. Other secondary school teachers added that they would also learn new insights and techniques from primary school teachers including the use of simplified language, and the translation of text and theory in to practical activities.

However, in advance of the activities, some secondary teachers expressed a concern that the [informal learning] approach used by the facilitators would be too different or 'disturbing' for their students and that they did not want the facilitators to encourage behaviour that would not be appropriate back at school. In contrast, Kindergarten teachers welcomed the input of the facilitators, particularly with respect to their expertise on scientific content.

In summary, from comments in interviews and in other informal conversations, it appears that it was sometimes difficult for Città pilot project staff to establish a partnership with teachers. The teachers were defensive and competitive about their own degree of expertise, commenting that they could have done the same activity had they had the resources.

With respect to the involvement of internal players, the Pencil PPC acknowledged that the profile and impact of the project in Città was not as large or as visible as it could have been. Furthermore, the facilitators were often taken away from their Pencil responsibilities in order to work on other institutional concerns. It would appear that the internal relationships, which potentially could have provided support to the Pencil initiative, were missing.

The relative lack of internal support, notwithstanding, the Pencil team was fortunate to have strong contacts with academic staff at local universities and used these contacts to develop rigorous teacher training programmes.

II. Use of educational (and other) research

The Pencil PPC was particularly proactive in bringing research findings to bear on the Pencil initiative. He invited local professors of pedagogy to lead sessions in some of the early meetings with teachers in order to introduce aspects of educational theory, in particular constructivist perspectives of learning. Professors of epistemology and philosophy of science were also invited to talk to teachers.

In terms of his own understanding of educational research, the PPC read articles recommended by the academic evaluators and spent considerable time reflecting upon the nature of learning.

III. Models and practice of teaching and learning

In discussions about the nature of teaching and learning in the context of a science centre versus a school, staff from the Città della Scienza identified a clear division. The PPC referred to informal learning as studying topics in which the individual is personally interested. A further emphasis is on the manipulation of objects, and the exploration of different phenomena. In contrast the PPC and his colleagues felt that teachers have to concentrate on the delivery of content and that this means that their approach is less student-centred. The perception of teachers on the part of the Città staff was that they simply entered a classroom and began lecturing, rather than firstly stopping to engage the students.

However, following the Pencil activity, the facilitators commented that they understood more about the pressures involved in helping students to concentrate and cover a body of material. In this way, they had come to understand the constraints under which teachers operate. Unfortunately, the Città staff felt that many secondary level teachers had not changed in response to the activities, and thus were not always able to see and engage in learning opportunities presented by the informal activities (i.e. the chance to stray from the content topic and explore a phenomenon in greater detail), and in addition saw such approaches to be disruptive to the normal order.

With regards to the scientific content of the activity, again the PPC noted a difference in the view of the participating schools. The kindergarten teachers, who tended to be more relaxed, object-focused and student-centred, welcomed the approach of the Città staff and valued their content knowledge. However, the secondary level teachers commented that they had a good understanding of the scientific content, and that they could have done the same activities themselves, had they had the resources.

Finally, with reference to the process of evaluation that accompanied the Pencil programme, several teachers were particularly interested in exploring these procedures further. Such teachers were keen to learn more about how to evaluate student conceptions in order to know how to 'intervene' and thus teach effectively. Thus the notion of evaluating student understanding seemed to be a shared interest of both informal and formal educators, and as such may be useful point for both types of educators to develop a shared model of teaching and learning of science.

IV. Use of evaluation tools

A range of pre and post activities assessment tools were used to assess the impact of the Città programme. For the kindergarten students these included children's drawings and group interviews; questionnaires and concept maps were used for pupils at primary and secondary level; and interviews were conducted with teachers. Videos of all the activities in situ were also made.

Initially, the teachers were very suspicious of the evaluation questions. They wanted to prepare the children for the questions the day before questionnaire was administered. They were also nervous about being videoed. It seems that both techniques were perceived by teachers to be tests of their performance rather than tools for exploring the ways in which students learn and could be helped to learn further. The evaluation team from King's College London proposed inviting teachers to conduct the evaluation process themselves. In this way, they would be part of the process rather than scared by it. Furthermore, teachers are probably best placed to detect any changes or developments on the part of their pupils, as they are most used to pupils' behaviours and abilities.

In developing the questionnaire, the PPC admitted that he had difficulty phrasing the questions. Rather than measure content knowledge, he wanted to see if the students knew how to use analogies, examples, and how to do different sorts of experiments. Thus he designed questions that examined student's understanding of scientific processes in other part of everyday life.

With respect to the impact of the activities of the professors of education, limited evaluation was made, however the PPC offered the valid explanation of having limited resources and time to conduct such a study. Indeed he then made the observation that an alternative project could simply focus on conducting a thorough evaluation rather than developing any activities. He joked that such a plan would be more efficient as "my effort would be concentrated on these aspects and not on the organisation of buses, and the transport of school groups and so on." On this point, it is fair to note that evaluation can take time, but if conducted well, the results usually make it worthwhile.

Finally, however, it is interesting to note that several teachers were particularly enthused by the Pencil programme because they wanted to learn more about how to evaluate their own work and the learning of their students. For example, one teacher commented that she wanted a methodological way to evaluate children to be fair/accurate (to separate the process from emotional connection of teaching) (page 17 of DM 2000003). In response to such comments, and from feedback from the King's team, the PPC has since considered developing a further project with a small group of teachers to explore this aspect in depth.

V. Professional development of museum or science centre staff

In leading the programmes for the Pencil project, the facilitators gained a deeper understanding of how to modify their teaching approach to assist learners in different situations. They also leant to appreciate the high levels of stress and the physical demands under which teachers operate in teaching 7 hours each day.

The Pencil project also afforded opportunities for the professional development of the partner teachers with respect to the presentations given by academics in the field of pedagogy, and the chance to meet and discuss practice with colleagues. Some teachers also requested that the Città develop further training sessions on informal learning approaches, and use of Città resources.

VI. Emphasis on issues of gender equity and social justice

An explicit focus of the Pencil project at Città della Scienza was to identify any differential impact on male and female students as a result of the programme. The results of this study are discussed in greater depth in the Città internal evaluation report and in Deliverable D30. In summary, however, the following findings were made: the activities appealed to girls, and thus encouraged their involvement, however, the boys tended to take over the practical activities and may, as a result, have gained a greater understanding of the science concepts involved. A suggested reason for the difference in behaviour proposed by the PPC, Città facilitators and partner teachers is that society encourages boys to engage in science and technology – and, for example to play with meccano, or chemistry sets – whilst girls are encouraged to listen, and not to assert themselves.

VII. Involvement in, and fostering of, wider network

The PPC noted that he had limited time to engage with other projects in the wider Pencil network, although he did visit the Deutsches Museum to learn more about their processes of evaluation. However, he did welcome the notion of a wider network as this would provide opportunities to learn about other practices, and to deepen his own understanding of learning in informal contexts.

VIII. Sustainability of initiative

The experience of the Pencil project for both Città della Scienza staff, and partner teachers was on the whole highly positive and had led to a new understanding on the part of teachers as to the ways in which a science centre may support school-based learning,

The particular interest of two or three teachers in the process and practice of evaluation has led the PPC to consider the possibility of developing a study group of teachers and perhaps a further project specifically focusing on methodology and evaluation techniques. The PPC sees this as an 'added value' of Pencil. Such an initiative could constitute a sustainable result of the Pencil project.

The King's evaluators, meanwhile, noted that if the PPC were to engage in more facilitator training, he could also involve school teachers and then they could then train other school teachers. This would prove effective as it is recognised that teachers tend to listen more to their peers than to external presenters. Again this could constitute a sustainable result of the Pencil project.

5.12.3. Conclusion of Città della Scienza case study

The Città della Scienza Pencil pilot project offers a valuable model for institutions seeking to build relationships with a large number of schools. In addition to organising a well-developed programme constituting teachers' meetings, teachers' lectures on topics of pedagogy led by respected academics, and an extensive programme of activities and workshops for students, the Pencil project served to act as a forum for local teachers to get to know one another and to share ideas.

Whilst inevitable problems were encountered in promoting an inquiry model of learning to teachers who had had little opportunity engage in such methods previously, the final results demonstrate that the teachers came to appreciate the contribution that such methods could make. Furthermore, the science centre facilitators had grown to better understand the constraints and pressures under which teachers operate on a daily basis. This mutual understanding provides a solid basis for future collaborative ventures.

The Città Pencil project also demonstrates the use of a range of evaluation processes, including the evaluation of the impact on young children (by assessing drawings) and the use of pre and post concept maps (also known as personal meaning maps). Whilst the PPC noted that evaluation processes were time-consuming, it is significant to note that their use also prompted partner teachers to reflect further on the use and application of evaluation techniques. In this sense, the Città project provided a useful model of practice to its partner teachers.

5.13. Cité de l’espace (France) – Future technologies for science learning

5.13.1. Summary description of pilot project

The Cité de l’espace Pencil pilot project sought to explore the role of new technologies in supporting the science learning of primary-aged students. The project comprised several components including the involvement of young children in the testing of new exhibition prototypes, the testing of new technology based teaching methods, and the development of resources to support learning in the exhibition space and back in the classroom.

The Pencil project at Cité de l’espace served to support existing plans for a special exhibition space designed for young children. This venture was initiated in part in response to recent policy documents from the city of Toulouse calling for more informal learning resources for young people.

In terms of background context for this project, it is important to note that in France (as in many other countries) an understanding of science is held in high esteem: if an individual is good at science, he or she is deemed to be clever. In turn, this results in the perception that science must be difficult, which has led to some students feeling that they can’t possibly do science or engage in it, no matter how the material is presented. The Pencil project at Cité de l’espace set out to change this perception.

5.13.2. Case study

I. Relationship between key players

The Pencil project at Cité de l’espace was predicated upon the development of strong partnerships with schools: the involvement of students in the evaluation of the new exhibits required a close relationship with teachers in order for the student feedback to be effectively captured. To this end, the project benefited from an existing system whereby science centre educators worked part-time in la Cité and part-time in schools. These educators were then able to help in the recruitment of partner schools, as teachers are more likely to trust and value recommendations of ‘one of their own’ (as such educators were perceived), rather than an external player.

Most of the partner teachers welcomed the opportunity that the Pencil project presented in terms of establishing greater connections to the science centre, as without the support of the project, visits would be too costly. Finally, the partnership was cemented when teachers saw the extent to which the opinions of their students were respected, and saw how much the students enjoyed and learnt from the experience. Other than in expressing feedback, however, partner teachers were not directly involved in developing any of the written materials to support the proposed exhibition, or in the design of the proposed accompanying workshop activities.

Whilst the PPC was the only member of the education department working on the project (and occasionally felt isolated), he did work closely with the exhibition managers and designers, and considered the arrangement to be useful in emphasising the importance of the educational message of new exhibits. The PPC also commented that he hoped such cross-departmental arrangements – and particularly the involvement of stakeholders in the evaluation – would be continued in the future.

In terms of external partners, the PPC established a relationship with education researchers from local universities to assist him in the design of workshops. Students from the universities were also involved in the evaluation of the workshops by commenting on the programmes as part of their course. Finally, the human-technology interaction group at the university of Bordeaux was able to advise the PPC on the use of technology (proposed for the workshops), and ways in which to connect technology with science learning opportunities.

II. Use of educational (and other) research

In addition to benefiting from the theoretical frameworks regarding the use of technology offered by the University of Bordeaux (discussed above), and the workshop assessment devised by the science education researchers, the PPC explored contemporary research findings relating to the analysis of student experience following a visit to a science museum, and also read papers on evaluation circulated by King's College London.

However, the PPC also commented that he did not have time to read enough papers to keep up-to-date with research in informal learning. Furthermore, whilst he enjoyed some of the discussions which occurred in the Pencil chat rooms relating to such papers, he felt that there was limited opportunity to discuss the papers with colleagues (internally and more broadly in Pencil) in a relaxed manner.

III. Models and practice of teaching and learning

In developing a series of interactive exhibits, the model of teaching and learning advocated by the Cite is one of hands-on engagement. In supporting the conceptual learning to accompany the physical hands-on approach, the Pencil PPC understood the need to provide a context or introduction to what would otherwise be the quite abstract principles of astronomy. To this end, he developed a cartoon character to be used as a mechanism for leading students through the exhibits, and as the central character for printed resources to be distributed to schools as pre-visit preparatory reference, and post-visit follow up material. The character, a robot named Marcus thus "tells other children what he has done and what he had understood" (page 7 DM 10161), in the hope that this, in turn, will help the children develop confidence that they may understand the material too.

The material presented in both the exhibits and the taught workshops relates to everyday experiences (for example the phases of the moon, explanations for day and night and the seasons), but is, nonetheless, fairly complex. It was therefore considered necessary for one Explainer to be allocated to each exhibit in order to support student learning. Furthermore, given the complexity of the topic, the learning objective was confined to the coverage of content rather than any exploration of the development of such ideas and the socio-historical nature of science. Nonetheless, effort was made to consider the ways in which scientific phenomena were explained by different cultures in the past.

IV. Use of evaluation tools

To evaluate the differential impact of the workshop activities, researchers from the University of Bordeaux used pre- and post-tests to compare knowledge gain following the implementation of the use of technology (e.g. the use of interactive whiteboards) in the workshops. A second population of students, who completed the same workshop without the use of the technology acted as the control.

In considering the selection of evaluation tools to assess the impact of visits to the exhibition in conjunction with a visit to the planetarium and participation in a workshop, the PPC asked for advice from King's College London. The King's team suggested that the PPC organise the programme of activities in different ways for different populations of students as follows:

	Activity 1	Activity 2	Activity 3
Group 1:	exhibition + planetarium	evaluation	workshop

Group 2: workshop	evaluation	exhibition + planetarium.
Group 3: exhibition + planetarium	workshop	evaluation
Group 4: evaluation	workshop	exhibition + planetarium

In this way, all four groups of students experience the same programme (none miss out on a particular activity), but the evaluation results for group 1 test the impact of the exhibition and planetarium; for group 2, the impact of the workshop is tested; and in group 3 the combination of activities is tested. Group 4 acts as the control.

A further proposal included an attempt to find two very similar schools, and offer different experiences to each, and then look for any changes on the part of the students (the similarity between contexts providing a basis for comparison). Other suggestions to capture the impact upon individual students included the use of small focus groups, or videoing their interaction at activities and then replaying the tape and inviting the students to talk about what they were doing. Finally, the evaluators suggested asking students to write a diary of their experiences or to complete a personal meaning map in order to ascertain the personal impact upon the student. If the map was then revisited following a further six months, the long-term impact of the initiative could then be examined.

Some of these suggestions were taken up by the PPC; the full evaluation findings are presented in the Cité de l'espace's internal report.

V. Professional development of museum or science centre staff

In terms of professional development, the PPC stated that he had benefited personally from his involvement in the project and had developed a greater understanding of learning. He also noted that he had gained new skills and information from colleagues across the wider Pencil network. Furthermore, he commented that his involvement in the Pencil network had enhanced his profile in the science centre.

Colleagues from across the Cité (and amongst exhibition design contractors) also acknowledged the value of conducting formative evaluation as advocated by the Pencil project and are keen to repeat the process in future products.

VI. Emphasis on issues of gender equity and social justice

The pilot project at the Cité de l'espace did not explicitly address issues of gender and social justice. However, during the interview process the PPC and the King's evaluators discussed further ways of enhancing girls' interests in astronomy (beyond the introduction of the new exhibits tested in the project). The evaluators from King's College London suggested that girl's interest in astronomy could be piqued by presenting it as a story about beginnings and endings and by highlighting the significance of astronomy in human history (rather than simply presenting astronomy as an abstract body of knowledge).

VII. Involvement in, fostering of, the wider network

The PPC welcomed the opportunities that the Pencil network presented, and enjoyed communicating with colleagues from across Europe. However, he would have also welcomed greater sharing of information relating to evaluation and theories of learning and teaching. He admitted that discussions about the latter were ongoing in the Pencil chatroom, but that it was difficult to participate unless fluent in English. He also commented that he would welcome further opportunities to share experiences on the best ways to establish working relationships with schools.

VIII. Sustainability of the initiative

The Pencil project at the Cité de l'espace provided new insights with respect to the involvement of target audiences in the development of new exhibits. The results of the Pencil project clearly demonstrated that money could be saved by prototyping the exhibits first, and exploring their pedagogical and communicative potential with members of the audience before building the permanent exhibition. The assessment of the taught workshops also provided the Cité will some useful guidance on how best to present astronomical content. In this way, aspects of the initiative will certainly be continued into the future.

5.13.3. Conclusion of the Cité de l'espace case study

The Pencil pilot project at the Cité de l'espace experimented with a new way of working: involving the target audience – on this occasion, primary aged children – in the evaluation of prototype exhibits. Whilst such processes may be employed elsewhere, the practice constitutes an innovative activity in the context of this science centre. In addition to building strong relationships with local schools, the Pencil project also developed new ways of working inside the science centre. This has led to educational messages, and the voice of the learner, becoming more integrated into exhibit design.

The project also benefited from the involvement of external partners, in this case researchers from local universities. These specialists were able to advise on the design on the technology-based workshops, whilst undergraduate students in the area of science education helped to evaluate the workshops.

In terms of areas for improvement, the project could have benefited from a more rigorous evaluation protocol (as advised by the project evaluators), and one that examined impacts other than knowledge gain. For example, any changes in motivation towards science as a result of being part of the exhibit evaluation project, or engaging in the technology-enhanced workshops were not assessed.

Finally, it is important to note that the premise on the Pencil project was based will be continued into future projects within Cité de l'espace. In this way, the science centre will hopefully act on the lessons learnt in the Pencil project and develop further ways on involving audiences, and integrating new learning technologies into the development of new programmes and exhibits.

5.14. Universeum – Teknikens Hus, (Sweden) Learning for a sustainable society

5.14.1. Summary description of pilot project

The Pencil pilot project at the Universeum – Teknikens Hus was based on establishing an extended period of cooperation between teachers in order to develop a cross-curricular educational path on the theme of sustainable society. The project involved five primary schools in Göteborg and five primary schools in Luleå (about 400 students aged from 10 to 15 years old, 20 teachers).

The classroom activities were planned and revised in periodic meetings between teachers and science centre staff, with the aim of coordinating several thematic visits to the two science centres. According to the resources that the science centres were able to offer, the chosen themes (sometimes overlapping one with another) were: forest, recycling, water, energy, space, food and communication. The school activities consisted of general cross-curricular programmes involving almost all school subjects, and specifically designed educational paths based on a role play approach which involved pupils "building" their own sustainable houses, or lab activities designed to allow pupils to discover more about recycling or water pollution.

The thematic visits to the science centres were designed as specific inquiry-based learning units, which were complementary to the ongoing curriculum at school. According to the different concepts on which the two science centres are based, visits to Universeum were more focused on the exploration of ecosystems and to issues linked to their preservation, while visits to Teknikens Hus were more focused on a sustainable use of technology.

The main objective of the project was to stimulate pupils' interest in, and awareness of, the topic of sustainable society. Through the formal/informal educational programmes and workshops with scientists, the pilot project tried to help pupils understand how human everyday behaviours can affect the earth's ecosystem and how we may preserve it using scientific and technological developments in an appropriate way.

Local context

The Swedish school system is specifically charged with contributing to the enhancement of pupils' knowledge and awareness of sustainable development including its social, economical and ecological implications. Teaching sustainable development therefore should involve democratic processes; critical attitude; interdisciplinary cooperation; and a diversity of pedagogical methods. (see the Swedish Agency for School Improvement website[8]).

In Sweden, compulsory education is organized in 9 grades (6/7 to 15/16 years old pupils). Primary school (Grundskola) institutions usually cover all these grades. In primary schools, time prescribed for science and technology across the whole 9 grades is about 800 hours, and time prescribed for maths is about 900 hours (for comparison, about 1500 hours are prescribed for Swedish language). Most of the teachers in primary school system are generalists. In grades 7 – 9, more teachers have a scientific background, but at the lower levels many teachers lack knowledge in science and technology, even though all are expected to teach science.

[8] http://www.skolutveckling.se/in_english/)

5.14.2. Case study

I. Relationships between key players

The Pencil pilot project at Universeum and Teknikens Hus (hereafter referred to as U and TH) was based on the notion of establishing long-term relationships with a set of partner schools. U and TH recruited the teachers from amongst a group of teachers with whom they had already collaborated successfully. The final group were selected in order "to have a variety of different social backgrounds represented in the target group" (U project coordinator) but "all the contacted teachers agreed to participate and they were enthusiastic about being part of Pencil" (TH project coordinator).

During the planning phase, teachers worked closely with U and TH to develop a common educational programme. Some of the school programmes were developed in conjunction with a broader collaboration involving local institutions such as the Swedish Agency for School Improvement and the Municipal Consumer Guidance Office of the City of Göteborg (Konsument Göteborg).

In order to support the teachers – each with different needs and backgrounds – in their delivery of the programmes back at school, the two science centres developed teacher training sessions in sustainable living. Such courses were developed in collaboration with the University of Göteborg (which was also involved as external evaluator) and the Institute for Sustainable Development.

The relationship with teachers was maintained during the course of the activities with regular meetings designed to check, and if necessary refocus, the coordination of formal and informal activities. Both the PPCs were really happy with the meetings, and explained that: "the meetings helped us to better understand teachers needs: they want the science centre to do things they cannot do at school and they want us to help them with the preparation and follow-up work at school" (U project coordinator). In addition, the TH PPC said that "having a chance to talk to the teachers more than usual helped us to refine our objectives from very open ones (like: have pupils more interested in science and technology) to more specific ones". Usually, science centre staff prepare activities without close consultation with teachers, and thus the Pencil project was a new departure for the PPCs.

With regards the teacher workshops with scientists at Universeum, the PPC commented: "they were happy to meet scientists. Teachers want the science centre to act as a mediator between scientists and schools. The mediation is important because they are less afraid of the science centre than of the university. People feel much more comfortable in a science centre than in a university because the science centre is a neutral place. A science centre can filter the interaction by talking to the scientist in advance and helping him or her to understand how to communicate to teachers."

II. Use of educational (and other) research

In the development of the pilot project, Universeum staff worked closely with researchers from the University of Göteborg, whilst staff from Teknikens Hus worked with researchers from the Institute for Sustainable Development. These researchers participated in periodic meetings with teachers, collaborated in the development of the teacher training and provided teachers with lesson plans and resources from the literature about how to teach sustainable development.

III. Models and practice of teaching and learning

The U and TH Pencil pilot project involved the development of activities to be conducted by teachers in their own classes. Thus different teaching/learning models were followed by different teachers according to their own choices and needs. The common approach shared by all the teachers was to treat sustainable development as a cross-curricular subject and then to use different tools and approaches to stimulate children's interest about the various points of view from which the subject could be addressed.

Role play was used as a teaching tool in several instances, including, for example, the "Housing in the future" project carried out by one school in Göteborg. The teacher responsible for science, mathematics and technology teacher commented:

> "When we started to design this project we built a storyline to introduce different topics and different approaches into the school arena. The next step in our storyline was to define characters for our students to play. We decided to have characters because acting a character means you will ask questions you wouldn't have asked otherwise: you are someone else and you can behave like someone else! The characters then gathered in groups to build their own houses. The students built puppets of their characters and scale models of their houses. In building the houses we tried to make the students able to answer questions such as:
> - how could we reduce the use of warm water?
> - how could we reduce the heat loss using, let's say, different kinds of windows?
> - what kind of alternative tools could we use to get energy without using fossil fuels?
>
> "You must remember they are kids of about 14 years old and they are used to consuming as much as energy as they want without taking care. It's really strange for them to think about saving energy".

In considering ways in which students could be encouraged to think about the importance of looking after the planet, the U and TH staff and partner researchers decided to present the topic by looking at the Earth from space (in this, they explicitly acknowledged that most children would be familiar with science fiction movies and the notion of assessing planets as viable places to live). Thus they also included content from the space technology of the science centre. The second visit to the Universeum was then focused on how human behaviours could affect the planet Earth. The session included discussions about ecological footprints and sustainable development and the correlation between things that happen in the Swedish ecosystem and in the equatorial rainforests.

At a second school, a social sciences teacher explored the use of non-scientific subjects to enhance pupils' awareness about sustainable development. The teacher commented:

> "I tried to connect environmental studies about Africa with social, economical and historical issues and, in particular, I tried to point out that environmental problems can't be solved without economical and social efforts. We studied African history during the imperial time to give the pupils a historical background for some of the present-day problems in Africa. […] We also tried to connect environmental problems with the economical and social problems that are war-related. […] Before that, we have also studied Natural Geography, and in particular, rain forests, desert areas and the polar areas. This has given the pupils a background knowledge about different environments before studying Africa, so that they could compare, for example, the various natural African environments with our environments here in Northern Europe. Before this African week, we went to Universeum twice. We visited the rain forests part of the exhibition and there we read a lot about the desert areas in the world too".

In connecting visits to the science centres with topics studies at school, several teachers commented in both interviews and in the questionnaires that their students seemed calmer and that they didn't rush through the exhibits, as they knew that it was possible to return and ask more questions later. In this sense, the science centres have become truly accepted by students and teachers as a complementary experience for their school learning.

IV. Use of evaluation tools
To conduct their internal evaluation, U and TH collaborated with an external evaluator (the University of Göteborg). According to the initial plan, the evaluation of the pilot project was to involve teacher questionnaires and in-depth interviews only. The evaluators from the University of Napoli suggested that according to the educational objective of the pilot project it would have been better to involve pupils in the evaluation directly. Following these suggestions the Pencil team (without the help of the external evaluator) developed a questionnaire for pupils, but this was administered only at a late stage of the project.

Both the PPCs mentioned they were not that entirely happy with the work done by the external evaluators: the lack of pre- and post-testing of students reduced the value of the evaluation results for designing projects. From such comments, it is clear that the PPCs were thinking deeply about the possibilities of evaluation and ways of involving students and teachers – an attitude that bodes well for future projects.

V. Professional development of museum or science centre staff
The greatest impact of the Pencil project on both the PPCs has been on the way they manage their relationships with schools, which has already been discussed in section II. Another important aspect of the work completed during Pencil is that both the PPCs were encouraged to document the process of development of the pilot project actions. This helped:

- to produce self-awareness about the choices they made during the project
- to facilitate the exchange of ideas between the two museums ("two museums for one pilot project means half of the money, but also means two different contexts to experiment and learn", the project coordinator at U commented)
- to clarify for themselves the model of science they want to portray

VI. Emphasis on issues of gender equity and social justice
Whilst teachers were asked in questionnaires whether boys and girls were affected differently by the projects actions, (and responded in the negative), there were few other actions that explored the issue of gender in the U and TH Pencil project. However, both PPCs commented that they would like to plan some evaluation of gender differences in future projects.

In contrast, issues of social equity were strongly emphasized by the Pencil pilot projects. For example, a cross selection of schools were recruited to take part in the project, and different activities were designed to take into account different needs of pupils.

VII. Involvement in, fostering of, wider network
With respect to the wider Pencil group, the PPCs welcomed the large consortium meetings that offered the opportunity to meet colleagues face-to-face and exchange ideas. However, they would have welcomed more feedback, advice and information sharing on aspects of evaluation. The PPCs had also thought deeply about the Xplora resource and listed several suggestions such as case studies about educational projects developed in science centres describing evaluation methodologies, results and findings. They also proposed news on exhibitions and shows in Europe.

VIII. Sustainability of initiative
The model underlying the U and TH Pencil pilot project involved enabling teachers to use the science centres according to their own needs. This meant that teachers were welcome to use either science centre as much as they needed, and small groups of students were also able to visits both institutions for free during the pilot project period. Clearly, the financial implications of such an arrangement means that project is not sustainable (without further funding). And yet, as stated in

the final section of the internal evaluation report: “If you want good results you must find solutions so the schools can visit the science centre without considering the cost”.

5.14.3. Conclusion of Universeum and Teknikens-Hus case study

The Pencil pilot project led by the Universeum and Teknikens Hus may be considered successful in several ways. Firstly, they acknowledged the importance of establishing strong and close relationships with schools, and individual teachers, in order to support the teaching of students. Such relationships were fostered over a close collaboration lasting two years.

Secondly, such relationships led to the development of new teaching materials (also supported by local academic partners), which cut across curriculum topics thus embedding issues of sustainable development more deeply than if they had been isolated in one subject area alone.

Thirdly, in welcoming teachers and schools to work closely with the two science centres, and enabling as many free visits as were required, the Pencil project promoted a strong model of learning whereby informal environments are seen and appreciated as adjunct resources to schools, and the learning opportunities they provide are acknowledged to be complementary to the school experience. This model is in contrast to the majority of school-museum experiences, wherein school groups only visit a museum or science centre once a year, and then mostly as a ‘treat’ at the end of term.

Unfortunately, the pilot project did not conduct a detailed evaluation of the impact such a programme had upon the students of participating schools. Thus only anecdotal evidence on the part of teachers – such as the perception that students were calmer and more focused in their visits – provides any justification for such staff-intensive programme on the part of the science centres. However, the feedback from teachers clearly indicates that the project was valued and useful. Moreover, both pilot project coordinators recognised the deficits in the evaluation protocol, and as a consequence had come to understand the value of evaluation in providing insights for future projects and guiding modifications to existing programmes.

In summary, the Universeum and Teknikens Hus pilot project offers innovative ideas and guidance to other science centres hoping to engage teachers and students in issues of contemporary science and society. Unfortunately, the project fails to offer any answers in how best to support strong relationships with schools with limited funds. However, this second point highlights the need for continued funding of museums and science centres, for, as the Universeum and Teknikens Hus Pencil project has demonstrated, their programmes, staff and exhibitions constitute a valuable and complementary resource for schools.

6. Conclusions

6.1. Summary of main findings

The 14 Pencil pilot projects represent the breadth of contemporary practice in museum and science centre partnerships with schools across Europe and in Israel. In building such partnerships, the projects have explored new ways of working, developed innovative approaches and have, as a result, enhanced the teaching and learning of science and mathematics in their own local contexts. Many of the lessons learned during the projects' lifetimes are relevant to science and mathematics education in schools.

The 14 projects are documented as case studies, wherein the processes and outcomes of project activities are described across eight parameters or dimensions of analysis. The case study conclusions identify key factors responsible for the success of the projects and also areas for improvement. These factors are summarised below.

6.1.1. Factors for success

The key factors promoting the success of Pencil pilot projects can be clustered into three sets: building on, or adding to, institutional capital; supporting partnerships; and, theoretical framework.

1. Building on, or adding to, institutional capital
Whilst not sufficient to guarantee the success of a project, certain forms of institutional support are necessary for building a strong project framework. For example, the support of management (within the museum/science centre, or school/local authority) can help to facilitate the active participation of individuals, thus also promoting their commitment. Building on the established expertise of an institution, meanwhile, provides advantages in terms of capitalising on an existing infrastructure, gaining access to resources, and utilising tried and tested communicative approach.

Also included in this cluster are those factors that help to embed effective project practices thus ensuring longevity. For example, projects that support the professional development of staff may help to ensure that the practices tested and refined by the projects are sustained in subsequent years.

Table 1: Institutional factors for success

Factors for success	Exemplar pilot projects
Project builds on established expertise of the informal institution or school	**IMSS Experimentarium**
Project builds on the high profile/reputation of the informal institution as viewed through the eyes of teachers	**NEMO Heureka**
Project is supported by high levels of internal support	**Technopolis Explor@dome**

Project builds on an existing programme which is already supported by an institutional infrastructure	Explor@dome Heureka
Project develops a working practice which could be readily transferred to other topics – ensuring audiences/interests in future years	Technopolis Cité de l'espace
Project provides professional development to informal institution staff and/or teachers	CiênciaViva
Project enjoys the support of external organisations such as professional teaching associations, or local teaching administrations	NMA CiênciaViva Explor@dome

2. Supporting partnerships
The second set of factors refers to issues relating to the ways in which the museums/science centre partnership with schools is developed and fostered. These factors include the importance of involving teachers in the development of projects, and working to ensure that the skills and expertise of both sides of the partnership are respected to ensure that strong relationships are established and sustained.

In addition to working with teachers, engaging students in the design of the project, or targeting students directly (rather than providing resources for teachers to use) can serve to enhance student motivation and thus help to ensure that the project achieves a positive effect.

Finally, projects that seek to support particular aspects of the curriculum are more likely to be successful than projects that offer resources surplus to or unconnected to curriculum requirements.

Table 2: Partnership factors for success

Factors for success	Exemplar case study
Teachers involved in the development of the project from the outset	Citta della Sciennza Bloomfield
Project involves building a strong relationship with schools	Universeum – Teknikens Hus Deutsches Museum Experimentarium
Students involved in the design of the project	NMA Experimentarium Deutsches Museum
Project offers museum/science centre staff an opportunity to understand the practices of teachers (including the constraints under which they work)	CiênciaViva

Project supports curriculum	**Ellinogermaniki Agogi** **NEMO** **Heureka**

3. Theoretical framework

The third set of factors highlights the necessity of a strong theoretical and practical framework to ensure the success of a project. The project framework needs to be supported by both an understanding and application of current theories of teaching and learning, and the use of evaluation processes to provide a mechanism for reflection. As such, factors for success include active engagement with theory, and working in partnership with academics. This cluster also notes the significance of sharing good practice with other institutions in order to enhance the impact of project initiatives.

Table 3: Theoretical framework factors for success

Factors for success	Exemplar case studies
Project is based on a sound understanding of theories of learning and teaching of science and technology	**Experimentarium** **NEMO** **Deutsches**
Project benefits from working closely with academic partners	**Cité de l'espace** **Citta della Scienza**
Project uses an evaluation protocol that examines the needs, outcomes and the processes of learning and teaching using both qualitative and quantitative methods	**Bloomfield** **Deutsches Museum**
Project involves an outreach component thus spreading the reach of the initiative still further	**Bloomfield** **IMSS** **Heureka** **Ellinogermaniki Agogi**
Project staff mediate the communication between practicing scientists and science teachers	**Bloomfield** **Universeum-Teknikens Hus**
Project develops cross curriculum links thus supporting students to make connections and construct meaning	**Universeum-Teknikens Hus**

6.1.2. Areas for improvement

Whilst all the Pencil projects exemplify aspects of good practice, the case studies also highlight a number of areas requiring further attention. Over and above a failure to fulfil the factors for success described above, three main areas for improvement may be identified: conducting evaluation; Working with teachers; and, attention to issues of gender and other aspects of social equity.

1. Conducting evaluation

Several projects suffered from an evaluation protocol which addressed only one aspect of a their activity, by for example concentrating on the evaluation of student attainment in test scores rather than examining student scores in conjunction with student engagement in the course of the project. A further example would be using quantitative measures only, instead of employing a mix of both quantitative and qualitative measures to triangulate findings.

2. Working with teachers

Although most projects were built on a strong partnership between the museum/science centre and school, there were occasions where teachers were not included as equal partners in the design and development of programmes. Instead, teachers were simply involved in the delivery of activities, or the review of materials. On such occasions, the projects missed out on the professional expertise of teachers in terms of pedagogical practice, knowledge of the curriculum and knowledge of student ability and interest. Furthermore, such imbalances in a partnership can lead to the invalid perception that museum/science centre staff are in some way 'better' at teaching science than are teachers. A more balanced partnership can serve to inform teachers about the potential applications of informal teaching methodologies, whilst providing museum and science centre staff with a more detailed understanding of curriculum requirements and techniques for ensuring progression, and also provide insights into the issues and considerations under which teachers work.

3. Attention to issues of gender and other aspects of social equity

Whilst few of the projects explicitly sought to address aspects of gender or social equity, it is worrying to note that such issues were not considered in general terms in the design of projects. As publicly-funded institutions, museums and science centres have a responsibility to serve all members of their local community and as such they need to explore ways of enhancing the access to their resources from populations that do not tend to visit. The Pencil project offered an exciting opportunity to work with new schools and new audiences, and to explore programmatic approaches to support the science learning of boys, girls, non-native speakers, and individuals from social or cultural backgrounds unused to Western educational practices. If future projects are to be developed and be successful in terms of supporting the needs of new audiences, they must consider ways of addressing issues of inequity.

6.2. Final words

In addition to the identification of factors for success and areas for improvement, outlined above, the review of the Pencil pilot project case studies has also led to the development of a set of *Criteria of Innovation*, documented in D28, and *Recommendations for Practice*, documented in D31. All three reports are designed to inform policy and practice, and to offer advice, recommendations and guidelines for future initiatives in which museums and science centres work in partnership with schools.

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8. Annex A: Interview protocol for first round of visits

1. NEEDS – To what extent do stakeholder needs affect project design and implementation?

1a. Whose needs were taken into account in designing the project? (See also 5a)
1b. How, and by whom, were these stakeholders identified? (See also 5a)
1c. How were needs identified for each stakeholder?
1d. How did stakeholder needs affect the project design?
1e. How are stakeholder needs updated?

2. RESEARCH/EXPERTISE – To what extent is the project taking account of existing good practice and experience?

2a. Who is responsible for identifying existing expertise and research evidence to support the project?
2b. How do you normally work with teachers/schools?
2c. How was existing expertise identified?
2d. How was relevant research identified?
2e. What expertise and research was identified?
2f. How did expertise and research evidence inform the project design?
2g. What gaps in expertise and the research were identified?

Note that external evaluators can help projects to identify existing expertise and research evidence

3. SCIENTIFIC CONTENT – What is the science content and what model of science is portrayed?

3a. What is the scientific content of the project?
3b. How was the scientific content chosen?
3c. What model of science is portrayed?
3d. Is the model of science portrayed explicitly or implicitly?

4. DECISIONS/COLLABORATION – How do partners make and implement decisions?

4a. What is the management structure for the project?
4b. Who is responsible for making decisions in the project? (See also 5d)
4c. How are decisions made? (See also 5c, 5d)
4d. How are decisions recorded?
4e. Who is responsible for seeing that decisions are enacted?
4f. Who is responsible for ensuring that decisions are taken equitably (age, gender, ethnicity, etc.)?
4g. How actively is information sought and shared between the project partners? (See also 6f)
4h. How are collaborations nurtured and fostered?

5. EVALUATION – What is the project aiming to do and how does it monitor and evaluate its work?
Is this point about the local specific impact? Rather than as part of the wider Pencil programme?

5a. Who was responsible for developing the evaluation strategy?
5b. How was the evaluation strategy developed? (See also 3c)
5c. What aspects of the project were chosen for evaluation? (See also 3c)
5d. What indicators were chosen to be evaluated?
5e. What data will be collected? What will be done with the data?
5f. Who was chosen to perform the evaluation?

5g. How will the results of the evaluation feed into the project implementation?
5h. Who has access to the evaluation findings?

6. EQUITY – To what extent does the project promote social justice and equity?

6a. Were stakeholders identified on an equitable basis?
6b. Who is responsible for equity issues in the project?
6c. What is the project's conceptualisation of equity and social justice?
6d. How does the project ensure equitable access to decision-making and participation? (See also 3b, 6c)
6e. How does the project ensure its resources are used equitably with respect to its particular target audiences?

7. PEDAGOGY – What teaching approaches does the project choose and how does it identify effectiveness?

7a. What is the model of learning underpinning the project?
7b. Who is responsible for choosing the teaching approaches used in the project?
7c. What is the role of the school teacher in the project?
7d. How and why were teaching and engagement strategies chosen? (See also 5d)
7e. How are the purposes of the teaching approach conveyed to the project participants? (See also 1d)
7f. How is the effectiveness of teaching strategies monitored?
7g. How is effective teaching identified and shared within the project and beyond? (See also 3g)

8. NETWORKING – How does the project receive and add value to the Pencil network and to the wider education community?

8a. How did ideas from elsewhere affect the project design and implementation? (See also 2e and 3)
8b. Who is responsible for networking with project partners and the wider community?
8c. What strategies are used for sharing ideas and information beyond the project team?
8d. How is information to be shared with others and within the team identified?
8e. Who receives information about the project?

9. Annex B: Interview protocol for second round of visits

1. ADDING VALUE – To what extent does the Pencil network add value to the individual pilot projects?

1a. Would the projects have happened anyway?

2. CONNECTING WITH THE BROADER COMMUNITY – How and what does Pencil communicate within ECSITE and beyond?

2a. How does Pencil identify what can and should be communicated?
2b. What strategies does Pencil use to communicate with the wider community?
2c. How do individual projects communicate with wider community i.e. see themselves as active players in the purpose of Pencil, not just sitting comfortably under the Pencil umbrella

3. DECISION MAKING – How does Pencil make decisions?

3a. What decisions does Pencil make and who makes them?
3b. Who is Pencil? Should one person from every project act as a representative to create a Pencil 'board' for example?

4. BARRIERS TO EFFECTIVENESS – What barriers to effectiveness are identified and how are they addressed?

How is effectiveness defined (to Pencil or to individual projects)
4a. What barriers are identified?
4b. How are the barriers addressed and by whom?

5. MODELS AND THEORIES

5a. What models of learning are implicit and explicit in the project design and implementation?
5b. How does the project utilise theoretical models and conceptualisations?
5c. How are models shared / promoted
5d. How does Pencil make use of external sources of expertise (with regards to models and theories)?