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Acknowledgements

The report we are presenting here is one of a series of reports communicating the outputs of the Permanent EuropeaN resource Centre for Informal Learning (Pencil), an EU-funded three-year project linking 14 museums and science centres with local schools in 12 countries. Two universities, King's College London, UK and University Federico II, Naples, Italy, were contracted to provide academic support and evaluate the projects carried out by the 14 informal institutions. Ecsite (The European Network of Science Centres and Museums) acted as the coordinator for the whole project. Designed as a sustainable action, Pencil is an attempt to improve the quality of science and mathematics teaching and learning at the intersection between formal and informal contexts.

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1 Executive Summary

The aim of this report is to present a series of findings emerging from the experiences gathered by Pencil's fourteen pilot projects in carrying out educational programmes at the intersection between formal and informal learning environments and methodologies. For each finding we propose a recommendation by which future projects may build upon lessons learned throughout Pencil.

The contents of this report are based on a study of Pencil's fourteen pilot projects carried out by University of Naples and King's College London. The data sources include interviews conducted during two evaluation visits to each pilot project, online chats, discussion groups and pilot project internal evaluation reports. Findings and recommendations fall into eight categories covering aspects of interest in the pilot project, including relationships between key players involved in the projects, models and practice of teaching and learning adopted, use of evaluation tools and emphasis on issues of gender equity and social justice. The categories are defined to greater extent in D10, Assessment of Pilot Projects.

2 Background

Science centres and museums represent a significant educational resource, and one which is becoming increasingly recognised across Europe. They design educational programmes addressing different subjects of science and technology. They also offer educational programmes to pupils of all grades and sometimes cooperate with their formal partners in developing these programmes. The Pencil pilot projects were designed to explore the different aspects, opportunities and barriers of this cooperation in an action-research framework. This report presents a set of findings emerging from the pilot projects' experience, and as such may represent a knowledge base for future programmes to build upon. It also offers a set of recommendations based on lessons learned throughout the project about what proved to be good practice.

The role of Pencil university partners – University of Naples and King's College London – has been to document and collate the factors and issues which the pilot projects have reported to be important in determining the success, or otherwise, of their projects. These factors and issues have been divided into eight areas or parameters, defined in full in D10.

All findings are complemented with specific examples and quotes from individual pilot projects and with a brief discussion including references to the academic literature where appropriate. Recommendations for future projects, based on the experiences of all 14 Pencil pilot projects, are then offered.

3 Methodology, aims and structure of this report

3.1 Methodology

The findings presented in this report emerged from an analysis of Pencil's fourteen pilot project and are based on interviews conducted during two evaluation visits to each pilot project, online chats, discussion groups and internal evaluation reports compiled by individual pilot projects. The nature of the interviews is described in detail in D10, with which this report shares the same data. After a preliminary study of the data, eight areas of main interest were identified, which again are presented in D10. We then analysed our data, comparing across the different pilot projects and looking for key findings in each of the eight areas. Using our experience in the field of science education and existing research literature, we discuss each of the findings and propose recommendations for future practice.

3.2 Aims

This report addresses the following aims:

- To present a set of key findings on how science centres and schools can best collaborate, emerging from the lessons learned through Pencil's fourteen pilot projects
- To discuss these findings on the basis of our experience in the field of science education and knowledge of the existing research literature
- Based on the discussion of the findings, to provide a set of recommendations for science educators to build upon in designing effective programmes at the intersection of formal and informal contexts, and for policy makers to inform their decision making

3.3 Structure of the report

The following sections present findings for each of the eight areas of interest. Each finding is followed by the related recommendation. The final section presents our conclusions based on findings and recommendations.

4 Findings from the Pilot Projects and related recommendations

4.1 Relationships between key players

4.1.i Roles of each party

FINDING

Nearly all the pilot projects noted that the role of the education staff was to work with teachers, not in place of them. As the PPC from IMSS reported "We don't want to teach anything… but we want to work in a group".

However, since teachers generally expect museums and science centre staff to be experts in their own venues (in terms of content, and in teaching/learning approaches), it appears that many teachers actively defer to staff from the informal institutions in terms of planning and developing activities. In some cases, this may lead to staff from the informal institutions feeling that their skills in science teaching are more developed than those of the visiting teachers. Furthermore, they may view their interactions with students as separate from, rather than complementary to those of teachers.

Teachers, however, have expertise in planning curricula, managing the progression of learning opportunities over the course of a school year, and managing the discipline of a class of students. Some teachers also have considerable content knowledge. But teachers also know that the museum/science centre staff has more time to develop activities which specifically address content in their institution, and thus may feel that it makes sense to defer to the direction of museum or science centre staff.

The coordinator of the pilot project at Ciência Viva recognised the problem that this clash of expectations and perceptions may cause. Thus for part of the Pencil project, explainers from Ciência Viva shadowed teachers in school in order to learn more about the practice of teachers, including the constraints and opportunities under which they operate. In so

doing, the Ciência Viva Explainers formed strong relationships with the schools, gained new respect for the practice of teachers, and reinterpreted their role as one of complementing the teaching that goes on in schools.

RECOMMENDATION

In developing activities and programmes between schools and informal science institutions, it is important that both sides of the partnership acknowledge and respect the expertise of the other.

4.1.ii Previous experience of teachers

FINDING

The success of a museum or science centre relationship with schools depends, for a major part, on the commitment of the partner teacher. For example, IMSS worked with teachers whom they knew to be enthusiastic; The Experimentarium contacted teachers with whom they already had had a rapport.

Whilst the motivation of teachers may be compromised by competing agendas back at school, the enthusiasm and commitment of individuals is more likely if they understand and appreciate the benefit of the proposed project. To this end, La Cité de l'Espace used education staff who worked part-time in the science centre and part-time in schools as advocates for their project. By hearing about the value of the project from their peers (rather than perceived 'outsiders') teachers were keen to be involved.

RECOMMENDATION

Teachers who have benefited from a previous programme, or are in some way knowledgeable about the potential of a project act as strong advocates for new projects and can help to 'validate' the educational worth of the proposed project to others.

4.1.iii Cross-disciplinary appeal

FINDING

The content of museum or science centre activities often appeals beyond the domain of science. For example, IMSS found that teachers of literature were also interested in the project; the Deutsches Museum contacted teachers of physics, ethics, and languages for participation in their project; and The Universeum-Teknikens Hus project targeted humanities teachers to highlight the cross disciplinary nature of their theme of sustainable development.

RECOMMENDATION

By targeting teachers from subject areas in addition to those from science, the project theme is more likely to be addressed and embedded across the curriculum. Furthermore, by helping teachers to present the topic through different subjects, such a project will help students make greater connections with the subject matter, aiding learning.

4.2 Use of educational, and other, research

4.2.i Accessibility of research material

FINDING

The value of educational and evaluation research was noted by most of the pilot project coordinators, and most welcomed the references provided by the University of Naples and King's College London. However, the time taken to read such materials was cited as a constraint, as was the academic tone in which such materials were written,

A preferred source of advice was that afforded by colleagues (either within the institution or known through the Pencil or ECSITE network), or academics working closely with the museum or science centre.

RECOMMENDATION

To help informal educators and teachers learn about new approaches in both formal and informal contexts, and at the intersection between the two, short practice-based articles, and summaries of research findings relating contemporary theory to practice are needed. (It should be noted here that the University of Naples has constructed, and will further develop an on-line Resource Centre in the form of short summaries of research articles and books designed to support the work of Pencil and subsequent museum/science centre–school partnerships). Opportunities to discuss such ideas through chat rooms, or in regular discussion groups are also recommended.

Secondly, the value of keeping up to date with theory should be noted by the managers of staff. Without opportunities to learn from other projects and research findings, staff are unable to effect the educational mission statements of their institutions, and projects risk wasting time and resources in continually reinventing the wheel.

4.3 Models and practice of teaching and learning

4.3.i The experiential approach

FINDING

Several Pencil pilot projects were based on the premise that students should have the opportunity to engage directly with scientific material and phenomena. For example, the IMSS project was designed to provide students with the chance to experiment and test the accepted theories and understandings at the time of Galileo. In this sense, many of the projects followed a discovery learning approach.

Thus the aim of the IMSS activity was to: "replicate the initial discovery process" and "try, as it were, to nudge them without actually giving them the final answers, to find out for themselves", and "encourage experimentation, questioning authority, give license to free thinking".

The experiential / discovery models of learning advocated by IMSS are a popular approach in the informal sector. However, museums and science centres should note findings by Klahr and Nigam (2004) that such techniques require careful facilitation. Klahr and Nigam argue that 'children in discovery situations are more likely than those receiving direct instruction to encounter inconsistent or misleading feedback, to make encoding errors and causal misattributions and to experience inadequate practice and elaboration. These impediments to learning may overwhelm benefits commonly attributed to discovery learning such as ownership and authenticity'

Whilst many of the pilot projects involved student engagement with hands-on exhibits and experiments not usually possible in the school context, they also nonetheless acknowledged that they are not proposing to replace school-based methodologies, rather they hope to support and extend school based learning: "this experience, for instance, is not something that replaces anything at school, but it's something that should be integrated with school. It is important that it is done outside school however, as that

reminds students that learning can take place anywhere" (interview with Pilot Project Coordinator).

RECOMMENDATION

The experiential, discovery approach, in the new context of a museum or science centre can provide students with opportunities to explore/act in new ways. However, such activities need to be supported by specially trained staff, and integrated with school-based learning to ensure that students are able to make connections between experiences and thus construct clear understandings of scientific phenomena.

4.3.ii Related issues

FINDING

In addition to content objectives, many of the pilot projects also sought to present issues related to the nature of science: the practices of science (experimentation etc) and the socio-historical bases of science. Museums of science offer students the opportunity to see the how the products and theories arising from scientific endeavour have changed over time, whilst many informal science institutions mediate public access to scientists and highlight the ways in which science is conducted and scientific knowledge accrued.

RECOMMENDATION

Whilst it is essential the science centres and museums provide experience that complement school-learning, they should use their resources (collections, exhibitions, staff, and access to the scientific community) to illustrate the ontology (what we know), the epistemology (how we know what we know), and process (the construction of explanations based on evidence) of science.

4.3.iii Encouraging motivation

FINDING

Some of the Pencil pilot project explicitly sought to promote students' motivation towards, and interest in, science. For example, the Experimentarium Pencil project was based, in part, on the premise that young people welcome the opportunity to develop communication and presentation skills. By training young people to communicate science, therefore, the project appealed to students' initial interest in communication, but in so doing led to an enhanced interest in science. Furthermore, when the young science communicators presented science demonstrations to fellow students, as a peer-teacher, the interest and motivation of other students was piqued, as evidenced by comments such as "I want to be like them".

The Pencil pilot projects at NEMO and Ciência Viva also sought to enhance student motivation in science by offering students the chance to research and construct exhibits for display either in their own school 'science centre', or in the real institution.

The Bloomfield museum, meanwhile, sought to enhance teachers' confidence in teaching the nature of science by organising a series of opportunities for teachers to meet and work with practising scientists. In this way, the teachers learnt at first hand about contemporary research, the practical techniques and processes involved, and gained a greater knowledge about the cutting edge topics which they could use to motivate their students back in the classroom.

Finally, several projects (for example, the Deutsches Museum, the National Marine Aquarium and Universeum-Teknikens Hus) highlighted the social relevance of science by presenting the value of research for understanding the world around us, and for offering solutions to contemporary problems.

RECOMMENDATION

Promoting students' [and teachers'] motivation towards science by highlighting aspects of scientific practice – such as communication (including exhibit design), and the social

benefits of scientific research – can serve to support students understanding of both content and science process.

4.4 Use of evaluation tools

4.4.i The usefulness of evaluation

FINDING

Prior to the Pencil projects, many coordinators had relatively limited views about the nature of evaluation. It was largely considered synonymous with testing of practical issues, appreciation of the activities and knowledge gain.

Some projects had a more reflexive view of evaluation. For example, IMSS commented that they did not wish to evaluate what people have learnt, instead they said that they would consider it interesting to know if the activity 'gave something' to the people who participated.

Other pilot projects looked at changes in people's perceptions of and attitude towards science. On several occasions, Pencil evaluators reminded pilot project coordinators that the emphasis in evaluation should be on 'value', and that evaluating meant to value the work (both the process and outcomes). Indeed, evaluating the impact of a project should be part of the process of developing new approaches. It gives practitioners a deeper understanding of their work and a means of improving effectiveness. It also reinforces the role of informal institutions in the social arena by providing more reliable evidence of a programme's impact.

Many pilot projects recognized the importance of being able to present evaluation results when appealing to potential benefactors and policy makers, and found that arguments about the effectiveness of a project were stronger when based on rigorous evaluation results.

RECOMMENDATION

Evaluation should be considered as a legacy: "this is what we did, this is how it impacted on us, the teachers, the students. And this is where we'd like to go/do/learn in the future'.

4.4.ii Choice of evaluation method

FINDING

The fourteen Pencil Pilot Projects represented a great diversity of actions and objectives. Some of them focussed on pupils' motivation, some of them on perceptions and views, some of them on attitudes. And the subject matters they dealt with were pretty diverse as well, covering mathematics, environmental issues, chemistry, astronomy, technology, medicine. Pupils involved ranged from kindergarten to secondary school, and in some cases teachers themselves were the target group. Different evaluation strategies were needed in order to study the impact of each different programme with regard to its objectives.

The following methods of evaluation were found to be useful by Pencil pilot projects:

- *Direct observations*
- *Logbooks*
- *Questionnaires*
- *Open-ended and closed interviews*
- *Focus groups*
- *Concept and personal meaning maps*
- *Online survey*s

In addition, the following techniques are recommended:

- *Stimulated recall (Stevens and Hall, 1997), wherein students observe a video of their activities and comment on what they were doing/thinking at the time, and reflect on what they think now.*
- *Inviting others to document the experience (in this way, the impact is seen through an objective observer's eyes)*
- *Analyses of audio- and/or video-recordings, which enable to access information that might have eluded observation (or the related field notes) and is not filtered through participants' memories or perceptions*

A multi-method evaluation strategy provides enhanced reliability of evaluation findings, in that it allows for cross comparison among independent sources of data.

RECOMMENDATION

A clear set of objectives is necessary in order to identify appropriate questions by which to evaluate the project. The effectiveness of the evaluation process then depends on the consistency between questions to be addressed and the choice of the evaluation strategy, including the selection of tools, the timing of data collection and methods of analysis. To help them conduct effective evaluation, practitioners should consider involving external experts to design and carry out the evaluation or to provide training and advice. Educational research literature and online resources should also be taken into account as a source of reference.

4.5 Professional development of museum and science centre staff as a result of project

FINDING

Many pilot projects commented that as a result of being involved in Pencil, they were faced with the important issues of evaluation and communication that they had not addressed before. The exploratory nature of each Pencil projects, together with the presence of a large number of partners including teachers and experts from academia, made it necessary for pilot project staff to engage with new and more complex evaluation and reporting procedures. An important role in this regard was played by local and external academic partners who provided advice and support on research based methodologies. Many pilot projects noted that they hope to be able to make good use of the lessons learned in their future practice. For example, coordinators at Bloomfield observed: "My ability in planning evaluation and my awareness of its role has been raised. The interaction with visiting researchers [...] helped me to evaluate other programmes as well."

However, while the large portion of the available resources of the project were allocated for the design, implementation and maintenance of programmes, limited time was set aside for reflection and discussions about evaluation on the part of museum and science centre staff.

RECOMMENDATION

The allocation of resources to staff to enable reflection and evaluation on results of projects should be reconsidered by science centres and museums. It is likely that such a change (essentially a form of professional development) will be cost effective, in that evaluation and reflection provide insights and understandings that go beyond the particular programme and represent a knowledge base upon which future projects can be built.

4.6 Emphasis on issues of gender equity and social justice

4.6.i Social justice

FINDING

Although in general the Pencil pilot projects did not explicitly address issues of social justice, many of them were committed to working with schools from a socially deprived areas, whilst others specifically targeted teachers from the vocational schools who rarely tend to visit informal education institutions. However, no specific evaluation strategy was employed in order to assess the impact of the project on issues of social equity, and project staff did not report any findings (anecdotal or otherwise) from their own observations of project activities. When pressed further by the university researchers to reflect on the ways in which their projects had addressed issues of social and gender equity, several of the PPCs spoke about the design of informal environments and the 'free-choice' methodologies used therein as naturally supporting social inclusion by providing opportunities for a range of learning styles, and by encouraging enquiry and emotional engagement.

RECOMMENDATION

Given the levels of public support/funding that museums and science centres receive, it is important that they serve all members of society equally. Traditionally, the visitors of informal science institutions have tended to be from the more highly educated and wealthy sectors of society. To change this visitor demographic, museums and science centres need to actively recruit new audiences.

4.6.ii Gender

FINDING

In working at the intersection between formal and informal learning environments, the Pencil pilot projects explored a variety of educational approaches designed to challenge

girls' resistance and lack of self-confidence towards science and technology subjects. Some projects, such as, for example Experimentarium, focused on aspects of communication to attract female participants. Others, such as Explor@dome, and Heureka, emphasized the connections between science and everyday life. Both these strategies have been identified in the research literature as being successful in increasing female interest and engagement in science activities.

Few projects, however, examined issues of gender when evaluating the project's impacts on its target audience. This deficit is surprising since it is well known that there is a gender bias with regards to engagement in science: women are largely underrepresented in science careers; whilst graduate students in science and technology are for approximately two thirds men. By offering opportunities to serve and foster different learning styles and bridge the gap between real science and the wider public, informal learning institutions such as science centres and museums can play an important role in addressing the gender issue.

The projects that did explore issues gender, including Città della Scienza and NEMO, found notable preconceptions of the part of girl students that 'science was not for them', or that 'I am no good at science' – views which constituted substantial barriers in their involvement in the activity. In the case of NEMO, such perceptions on the part of girls were very much reduced following participation in the activity.

RECOMMENDATION

It is important to consider issues of gender difference in the perception, motivation, and learning styles of students when designing and implementing educational programmes. Furthermore, by taking gender into account when conducting evaluation, educators can gain a deeper understanding of existing issues and thus design new programmes that actively enable *both* boys and girls to engage with science and technology.

4.7 Involvement in, and fostering, of wider network

FINDING

All of the pilot project coordinators commented that the wider Pencil network offered the potential for sharing ideas and insights across institutions and local contexts. However, many also commented that the results of formative evaluation – such as visitor interest, or practical issues relating to the staging of the programme – should also be circulated to inform project design.

RECOMMENDATION

A broader sharing of front-end evaluation strategies and results, such as the design and response to questionnaires or the structuring of discussion groups, would greatly enhance the value of a network. Furthermore, such openness would help to raise the profile and use of evaluation across the museum/science centre field.

4.8 Sustainability of the initiative

4.8.i Long-term nature of changes in practice

FINDING

From an analysis of the pilot projects, it is clear that changes in practice (even when for the better) cannot be effected or expected in large institutions overnight. As one PPC remarked: "This big museum is like a supertanker: changes that have to take place take place very slowly".

RECOMMENDATION

In order to help cement new ways of working into the existing practices of large organisations, initiatives need to be repeated, and refined, over the course of an extended time period. In this way, the innovative practices and perspectives become embedded.

4.8.ii Working to the strengths of the institution

FINDING

The Pencil pilot projects which emphasised their particular strength areas of expertise, and highlighted the ways in which they offered resources and experiences distinct from those in school, were more likely to be perceived by their partner schools as valuable and worth repeating or sustaining. For example, the 'peer teacher' project led by the Experimentarium proved very popular not only with the individuals involved, but also amongst the workshop audience of the peer teacher. In this way, a supply of new students keen to take part in the project was ensured, and prospective benefactors could see that their support would enable far-reaching results.

RECOMMENDATION

To ensure the sustainability of projects, it is important that institutions emphasise the 'value-added' of their project. This contributes to the perception of the institution as a

provider of alternative materials, approaches, methodologies, and helps to paint a positive picture of the institution as a site of innovation.

4.8.iii Implementing successful methods elsewhere

FINDING

Innovative aspects from the pilot projects which proved successful are now being applied to other areas of practice within the larger institution. For example, formative evaluation of exhibits involving the testing of prototypes with the target age children will now be standard at Cité de l'espace.

RECOMMENDATION

In evaluating the effectiveness of their innovative practice, and identifying factors of success, science centres and museums may learn valuable lessons which they can apply to benefit future practice.

4.8.iv Funding

FINDING

Many project coordinators reported that the programmes they were able to carry out in the framework of Pencil could not have been afforded in the usual practice at their institution. This enhanced scope for innovative work referred to the opportunity to engage in self reflection as well as evaluation.

The extent to which the schools were involved was also sometimes seen as not sustainable beyond Pencil.

RECOMMENDATION

Science centres are expensive machines (as are some of the educational approaches they develop), wherein all resources must be fully exploited and cost-effectiveness is a discriminative criterion. In order for the formal educational system to benefit from the

advantages offered by the interaction with informal learning institutions such as science centres and museums, appropriate funding needs to be allocated.

5 Conclusion

The fourteen Pencil pilot projects were developed in different national and local contexts and covered a broad variety of approaches, methodologies, subject matters. However, by comparing across the different experiences in the different contexts, general findings emerge that reflect the Pencil experience as a whole. Together with individual case studies for the fourteen pilot projects presented in D10 and the criteria of innovation and quality presented in D28, these findings represent the legacy of the project in terms of lessons learned to build upon in future projects.

The academic partners for Pencil used a knowledge of existing practice, and the research literature in the field of science education, in both formal and informal settings, to discuss findings from the pilot projects and propose a series of recommendations. We hope these recommendations will prove useful for science education practitioners and policy makers to inform their decisions in future practice.

Our findings fall into eight categories that were identified as the ones of greatest interest in Pencil after a preliminary analysis of the data. The areas covered include the way pilot projects developed relationships with different players such as local administrators, private benefactors, school directors and teachers; the way educational research findings were taken into account; the models of science teaching/learning applied through the projects; the way pilot projects evaluated their actions; the professional development of museum and science centre staff as a result of project; the role of gender and social issues; the value of being involved in a wider network; and the sustainability of initiatives.

The findings from the Pencil pilot projects show that cooperation with schools, while being a common practice for science centres and museums in Europe, still presents many challenges and opportunities for development. From the side of informal institutions in particular, a change of perspective from “working for teachers” to “working with teachers” seems to be desirable, in that working as peers enhances engagement and allows for both

partners to benefit from each other's expertise. Both teachers and informal practitioners involved in Pencil recognised the potential enrichment to their practice from this kind of cooperation.

By being involved in Pencil, all the partners have been confronted with a wide array of expertise, practice, and experience. Communication and exchange of ideas were also seen to be an added value of the project by most partners. Furthermore, in having to report their results to partners and to the broader community of science educators, Pencil pilot projects were required to evaluate the impact of their programmes at a deeper level than internal needs usually imply. While demanding it terms of time and resources, such evaluation provides science centres and museums with an enhanced understanding of their own practice and supports them in strengthening their role when interacting with the formal educational system, and with policy makers and potential benefactors.

It is important to notice, though, that many factors that proved successful in the Pencil experience may not be sustainable beyond the project. Indeed, Pencil funding allowed for pilot projects to explore practices they cannot usually afford. Adequate funding is needed in order for informal institutions to fully exploit their potential as learning environments which can complement school based learning and teaching across Europe.

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