Energy-Technet: results of a year's trials

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1. Introduction.

We previously described [P.Bussei and S.Merlino "*European workshop on Multimedia in Physics Teaching and Learning*" Europhysics News (2003) Vol. 34 No. 3] the key features of the project entitled "*Multimedia on Energy and Semiconductors for European Countries*" supported by the E.U. Commission within the Fifth Framework "*Raising Public Awareness of Science*" programme under its shorter title "*Energy-Technet*".

The objectives were concerned with designing and applying innovative pedagogical strategies as well as laboratory work, in order to improve the learning and teaching of science by students and teachers and to ensure effective communication of the scientific content of the two programmes. Specifically, our aim was to provide young students, their teachers and the general public in European countries with courses about '*Energy and its transformations*' and '*Semiconductors and their applications*', in the form of user-friendly multimedia packages, both on the Internet (http://informando.infm.it/Euprojects/) and on CD-Rom, for Windows® and Mac® platforms.

The project started from two existing Italian multimedia courses, produced by the Istituto Nazionale per la Fisica della Materia (INFM): "*Dal Silicio al Computer*" and "*L'energia e le sue trasformazioni*". Translated into English and Spanish and then re-edited, at the beginning of September 2002 they were sent out for the trialphase to schools in Europe and to selected non-European countries with the help of the partners involved in the project (http://informando.infm.it/Euprojects/).

The testing phase has been completed and as a result we have a considerable amount of data collected from Spain, the UK and Italy, as well as from some other countries where English is a first or much used language. Here we present a summary report of the results returned from the trials stage, as part of a dissemination process which we hope will help others in their work.

While, on the one hand, new multimedia technologies have shown their potential both for the teaching and popularisation of scientific and technological subjects, on the other hand the great variety of pedagogical practices makes it difficult to attempt any standardisation of the use of educational multimedia. There are no "miracle recipes" in this field. The dissemination of information about individual trials and their results does, however, allow local adaptation of such trials to be carried out elsewhere in similar pedagogical environments. Furthermore, a better knowledge of current practices should help in overcoming the reluctance of some teachers and parents to endorse the new educational technologies, as reported in some comments: "*[...] there seems to be so many of them [CD-Rom] around, that take so long to sort through that it is difficult to raise the profile of the good ones to the people who can get it known and used.[...]*"
"*[...]Teachers don't have the time to plough through the internet looking for these kind of things, but if someone shows the potential for the motivation amongst students, particularly the 'hard to reach' secondary students, then they jump at the chance to use them in lessons. [...]*".

2. Collected data.

Here we collect and discuss some of the results from the trial phase. We have chosen here to separate the comments from the two courses, although many of them apply equally to both multimedia. Furthermore, we have grouped the comments into the three main categories, as can be seen in the text which follows.

Energy and its transformations.

2A. Layout, technical issues and overall impressions.

Generally, the structure of this multimedia programme gained widespread approval, with few exceptions which were mainly about very technical aspects; almost all comments were positive: ("*[…] the design, layout and structure of the whole thing is fantastic![…]")*

First of all, the users appreciated the essential and appropriate graphic presentations, which did not distract the attention from the content, though there was the suggestion that the initial sequences should be rather more animated, in order not get the children's attention right at the start, ("*[…] colourful and entertaining opening animated sequences […]"*). The addition of more images in the notes and explanations was also recommended by some respondents, one of whom went further, in suggesting the reduction of the written text, wherever possible, in favour of greater interactivity ("*[…]but I would make animations together with voice-overs […]*" *the main part of the course* For young children, in particular, it is indeed better not to have to read a long text. There was clearly a demand for more animations, even short ones, plus a large number of interactive exercises and games; these were not, in fact, abundant in the course: "*[…] The animations and narrations are incredibly useful and much more engaging than reading the text. I found I listened to most of the bits but didn't really want to read all the words (particularly the silicon one)[…]*".

The media library, giving a quick access to animations chosen from a list, allows teachers to choose whichever animations support their lessons: *[…] I think there is a lot of very useful resources for teaching here, particularly in the media library and animations that teachers could use […], […] Nice, Animations are made very well. Especially I liked Multimedia library. […]*

As for the most technical aspects of the course, the users commented positively that, even though it was still at the prototype stage, the course presented:

"*[…] a relatively trouble free navigation functionalities: no need for teachers of intervention when CD was used as research tool by students […]*"

"*[…] a rapid access to photos, diagram and animations […]*"

"*[…] a well done integration of animation (amusing but informative) and text […]*"

"*[…]Only a minimum of knowledge of informatics is required, which allows teachers to concentrate in the science contents, not in the ICT. […]*"

The games were appreciated ("*[…] they (pupils) were invited to try the interactive game to see how they got on with recalling the knowledge gained. This they really enjoyed and many pairs spent time discussing alternative choices before committing the device to a hole. […]*". The interactive game in the first chapter was particularly liked; here, wrong answers did not receive a simple 'No' or 'Wrong!' reply: instead guidance and encouragement were given to reach a better answer.

Almost all the users commented about a possible ambiguity in some cases, where more than one correct answer should have been accepted, while the game only accepted one answer; this led to confusion. Furthermore: ("*[…] but in the games some of the pictures[of common domestic objects, for example] were difficult to interpret. I tried to understand what is depicted there but unfortunately I was unsuccessful. […]*");

People always like to see how successful they are being in these games and both teachers and pupils suggested adding a "score" panel, so that they could use the game as a self-evaluation tool. An annoying feature was pointed: the objects were in a fixed sequence, which forced the player, wanting at a certain point to review the preceding part of the course before proceeding, to repeat all the processes already executed.

To resolve such problems, we have reorganized many features. Presently the game shows two levels of difficulty, linked to certain scores. If a minimum score is not attained, the player is advised to review the contents of that level, before going to the next. The sequence of the features (accompanied by pop-ups facilitating the comprehension) within the appropriate level is now "random", in order to avoid the "repetition" situation. All the answers are now completely

argomented, to eliminate every ambiguity. The improved version of the game will feature in the new CD-ROM and web course.

Among other suggestions for improving the course were the following:

- The section of proposed "do-it-yourself" experiments for pupils, most of which could be done using simple household materials, was appreciated by users. However, the remark was made that perhaps *[…] movies that would demonstrate real experiment performed by real people would be more useful[…];*
- *[…] to make the pictures much bigger on the screen and to enlarge small parts to the full screen size so they can be commented on by the teacher […];*
- *a tool often requested was a section of tests, such as the multiple choice tests found in the 'From Silicon…' course ;*
- For the next multimedia the suggestion: *[…] At this level I think that the students may respond well to voice overs done by a similar age group. Each one could have a different student speaking.[…]*

The one really negative comment, from a single individual, was the definition of the course as *"an encyclopedia written in a simple language, which does not succeed in explaining and teaching the concepts of Physics that it was aimed to*".

2B. Local curricula issues.

The following was one of the most discussed issues,with respondents sometimes holding very different views. Originally the course was intended for pupils aged 9-13, because this age range fits in with the second cycle of the Italian compulsory school. The structure of school systems is quite different in other European and non European countries. Some found the course too difficult, others too easy for their own audiences.

"*[…] When analysing disk contents a doubt is raised about the audience this disk is meant for. In the notes it is said that the disk is for 9-13 years old children, but it seems that in the framework of the education system some of the topics of the disk and their parts are too complicated and ambiguously understandable.[…]*"

However, one respondent stated that the most significant animations were "too easy" for pupils more than ten years old. We concede that there may be some truth in this assertion as far as the first two sections, but disagree in relation to the final section ("A little physics") where some difficult concepts, such as energy conservation, heat and friction, work and forces are illustrated by animations that, in our experience, have been shown to be appropriate even for pupils of thirteen or more.

In any case, we designed the structure of the course to ensure that it could be used at more than one level, and by both pupils and teachers. We should have put more emphasis on this design feature in the accompanying notes.

Another problem, when it comes to the best ways of using the course material, is that due to the considerable differences in school curricula at national level. Rather ironically, the problem is not due to the lack of adaptability of a course designed for Italian schools to a different European reality; on the contrary, the use of multimedia proved easier in schools located in UK, in English speaking countries (as New Zealand, USA …) and in some East European countries, than in Italian ad Spanish schools.

This is because many concepts illustrated are not in the Italian "compulsory" curriculum, and the structures of the Italian and Spanish school systems do not favour the use of trasversal teaching tools, which needs a certain freedom in the organization of teaching on the part of the teachers.

In fact, while Italian and Spanish teachers appreciated the potential of the course,they gave their lack of time as the reason for not using the course in the classroom.

Many respondents criticized the nature and choice of the schoolroom characters used in the introductory animations (these involved dialogues between a teacher and pupils) Here, criticisms included the quality of the animations (sadly, we have to accept that with our budget we cannot

compete with today's high quality presentations in film and on TV) and uncertainty regarding their didactic value.

"*[…] The idea of a conversation between the scientist /teacher and students is nice, however the animation is a little basic, and the lips obviously don't move quite to the words. I still think it looks good but children are quite critical about animation standards as they are used to seeing all the million-dollar Disney productions. I'm not sure how much this would appeal to 11-13 year olds, but it may be more successful with 8-10 year olds if the content isn't too advanced.[…]* "

In particular, the image of the middle aged male teacher, dressed in a white coat, was considered a negative stereotype of the typical scientist, so definitely not a good choice if one is trying to attract young people into science, which every government in the world now seems to be promoting. Also, the exclusive use of a white, male teacher and of men's voices for animations, instead of a mix of male and female voices, etc., was criticized.

Another criticism was that the use of the materials would be limited outside Europe because the examples and illustrations chosen were Eurocentric. "*[…] The CDs are culturally biased, i.e. Eurocentric. If such CDs are to be used in South African (or more generally African) schools the pictures and examples would have to include more of the African culture […]*".

All these remarks made it clear to us that a thorough revision of the introductory animations is necessary, in the case we keep this part of the course, meant as an introduction to the concepts to be better analysed in the following chapters.

2C. Multidisciplinarity.

As a general feature, the users liked the course's multidisciplinarity, with historical notes and curiosities supporting the physics in the chapters; they also approved of the use of a mixture of photographs and reproductions of paintings.

"*[…] I found it very interesting and useful to be able to gain additional historical information about the concept introduced. Additional historical information certainly is one of the most interesting sections of the program.[…]*"

"*[…] I would like to mention good properties of some disk options, such as "Help" which assists in learning how to work with disk material and "Historical notes", which can be of course improved and changed till infinity. […]*"

An increase in the number of links among the different chapters and the glossaries was also recommended. We agree that in the prototype multimedia version the hypertext connections could be improved, so to strengthen the efficacy and multidisciplinarity of the course.

The users appreciated the large number of tables, particularly in the consolidation ("a closer look") sections, which allowed pupils to compare information and undertake active investigations.

It was criticized the lack of interactivity as for the exchange of information on line among the users.

It should be noted that in the trials phase, for practical reasons, only the CD ROM version of the course was used, making no use of the Web. But the Web site already exists. In fact, in the Web page of the project (http://informando.infm.it/EUprojects from which one gets access to the courses on line), a discussion forum is provided, where teachers and students can exchange opinions and questions about the course. In addition there is a facility called " INFM expert answers", where users may pose any kind of scientific question, and receive a reply from INFM scientists.

Finally, it was also proposed that we should develop the theme of Energy in a social and economic context, in connection with the ideas of sustainable development and environmental impact.

We are very pleased to say that this proposal is being carried forward in a new project which began during the trials phase of Energy/Technet . This new multimedia programme is called "The conquest of Energy" (http://informando.infm.it/energia2). It will be translated into four European languages (English, Spanish, French and German), disseminated and tested, thanks to financial support from the European Union, within the 6-th Framework, "Science and Society" Program. A

European portal dedicated to aspects of "Teaching and learning about Energy" will be a significant feature of this portal.

From Silicon to the Computer

2A. Layout, technical issues and overall impression.

This multimedia course, too, gained widespread approval: almost all comments received were positive; the few exceptions were mainly about very technical aspects.
("*[…] This tutorial explains one of the most difficult parts of physics. It is the reason why it could be very useful for teachers. […]*", "*[…] The programme uses good analogies to explain some quantum physics […]*").

The layout was regarded as "[…] *bright and attractive, and it does not saturate the reader with too much text on each page.[…]".* This also because of an intelligent use of number of links within the programme "*[…] clicking equation boxes and interesting historical notes does help to break up the text and allow the student to pick and choose […]*".
"*[…] This is a difficult area: what to leave out and what to include? The area is growing so fast that one could devote pages to the latest advances. Given this constraint, I thought that there was a sensible selection of topics and good continuity and coherence between the topics.[…]*"
"*[…] Theoretical material is presented professionally and understandable. Of course, one always may wish a deeper insight in some questions, but this strongly depends on the lecturer's goals and experience?.[…]*". This is, of course, true; we did not try to create an exhaustive course, but simply to give the fundamental tools to allow the student to understand the development of this fascinating discipline and, through that, to gain a better understanding of our society.

The section of tests, with some hundred pages of multiple choice questions, was praised "*[…] It allows students to test their acquired knowledge. The test is not very complicated, but it makes think about the answer and it is nice that comments and explanations are given in the case of right and wrong answers. It is also a good feature that you can choose the question freely and it is not obligatory to make the whole test from the beginning when it is essential to check the knowledge about the specific topic. […]*"

Following respondents' comments, we have designed a feature which shows the number of correct responses for questions with more than one acceptable answer. Unfortunately, we have not been able to set up a system to track and analyse the answers given by the student.

Among the criticisms:

- *"[…] The lack of a multimedia library, allowing a quick access to the animations, as in the Energy programme. […]".* In the new version of the course the "multimedia library" will be provided.
- *"[…]The use of the CGS system or of the atomic units instead of the widely accepted SI system […].* The main reason for that is that CGS system is still the most used among researchers; nevertheless, under the section "Unit of measurement" of the "Tools" button, within the multimedia, the user can find tables of conversion from one system of measurement into the other.
- "*[…] The boot up time is very long. Students in the US would find this irritating […]*".
- "*[…] The navigation may cause a little confusion at the beginning.[…]*". This may be true, because of the non conventional choice of the two levels of navigation, but we think that the instructions in the "Help" section could solve these problems.
- "*[…] The vocabulary used was very formal such as 'state of affairs' and not very chatty; however the voice was not unpleasant to listen to. I just felt the tone and accent used could alienate some listeners.[…]*" In fact, it was observed that "*[…] the voice of the narrator is very dry and a bit stuffy. I felt a little like I was listening to an old Open University programme, where the lecturers always speak in very proper Queen's English.[…]*" The choice of the linguistical level is one of the many difficulties to be dealt with, when

translating a Multimedia from one language into another. We definitely think the level of the language must be appropriate to the aim of the course.

Perhaps the use of "*[...] a mixture of male and female voices [...]*"could partially help, with the double advantage "*[...]it would help to attract young women into science and the dominant use of a male voice is somewhat unfriendly to them.[...]*"

2B. Local curricula issues.

"*[...] I think a lot of the content of this is very complex for school students, and it takes quite a lot of time to go through the necessary steps to learn enough to follow the higher levels. I feel it is better aimed at undergrads but then it is hard to know how to reach them at the right time. [...]*"

"*[...] I asked a number of students to view the package. They found it helpful but commented that they would need to use it in conjunction with tutor support in order to maximise its benefits. [...]*"

"*[...] The material is covered at a level in advance of what might be expected within A level Physics British school system and there might be a problem using this CD-ROM as the content overlaps Electronics/Physics/Chemistry.[...]*"

These comments illustrate very well the relevance of the problem encountered in matching the CD to current European or non European syllabi and using it as a didactical tool. Here we are encountering the same difficulties found in the use of the multimedia described earlier. Some correspondents suggested that it would be more effective for lecturers to be encouraged to use elements of it in their teaching, then give discs or a website address for students to follow it up. Probably it could be an ideal teaching tool on a university introductory course on solid state physics.

2C. Multidisciplinarity.

Due to the very technical subjects treated, in this multimedia course there is less content of an interdisciplinary nature than in "Energy and its transformations"; nevertheless people involved in the trials found the historical notes very useful. One observation was that "*[...] photographs of the key scientists and a more detailed biography [...]*" would be enjoyed. Unfortunately these modifications are not feasible at this stage of the project, but we are bearing this observation in mind for future multimedia Projects.

Someone reported that "*[...] some of the graphics seemed to have extra information [...]*" not reported in the text. This is, in fact, in the spirit of multimedia programmes where text and visual materials are integrated to give as much information as possible.

3. Conclusions.

The experimentation of the courses was carried out in several countries: Italy, Spain, UK, USA, South Africa, Slovakia, Czek Republic, Poland, Japan, New Zealand, Australia.

Comments, suggestions and criticisms were almost all (80%) positive, with helpful advice from both teachers and their students, about how best to improve the structure and the formulation of the courses.

The data collected about the trials of the CD versions are much more comprehensive and detailed for English speaking countries, while in Italy and Spain the state of affairs is more complicated: the general comments, both of Spanish and Italian teachers, are few and much less detailed than expected. In both countries there were problems in using the multimedia courses in the classrooms, either because the subjects were not in the official syllabi, or because of a lack of any tradition in the use of these didactical tools. It has to be noted that only 20% of people involved answered the questionnaire.

We suggest that the different reactions to the use of the courses in the classrooms, shown by Italian and Spanish teachers on one hand, and by teachers in the English speaking world in the other, are reflecting an important difference in the structure of the national school systems. In fact, we note that, contrary to what one might expect, the translated English version, trialled in many

English speaking countries, was more favourably received than the original language version, designed for Italian schools.

Many questions clearly have to be considered regarding the use and dissemination of multimedia programmes in schools.

1. **How can teachers be motivated to adopt MM?**
   In England and in other countries, teachers are obliged to adopt IT by the national curriculum, while in Italy IT is a compulsory part of the curriculum, but not in cross-curricular context: IT is seen just as another independent discipline. In other countries countries IT represents a free choice and its adoption is pioneered by enthusiastic teachers.
   The Spanish high school physics curriculum, furthermore, was reduced in recent years and is no longer compulsory.
   Two complementary approaches seem to be effective in training and supporting teachers:

- Providing teachers with high quality, refereed (evaluated) materials that can be used immediately: single MM products, integrated lesson plans and "instructional paths", student centred activities, etc.
- Providing teachers with general knowledge and skills that will enable them to evaluate existing materials and adapt them to their specific needs.

And this prompts two more questions:

2. **Are teachers aware of the benefits of MM?**
   Often teachers, although they accept new ideas and new teaching styles, have some problems translating them into everyday practice, especially if they work alone. They need:
   • *direct examples about other teachers' activity*, in order to identify with them, recognise their own problems, and consider how the proposed material can be implemented;
   • *an exchange among peers* willing to point out the problems arising in the implementation of a vertical curriculum, and to accept and share good practice common solutions
3. **Do teachers value the benefits of MM declared by "experts" ?**
   Evaluating the MM does not necessarily guarantee its optimal use in the teaching – learning process: it depends on many factors which need be taken into account when considering what to use, how to use it, and with whom.
   On the other hand, evaluation may be helpful as a starting point in the desirable separation of well thought-out and well produced MM from the "low quality" ones, which can, unfortunately, be found in large numbers on the web or offered by commercial companies.

Summing up, it seems that there are almost three key factors for MM diffusion and success:

1. Curricular reform (contents and examination)
2. Development of high quality resources
3. Providing compulsory training for all teachers

We now list what we judge to be the most important results deriving from the criticisms and suggestions, which must be taken into account during the design phase of a MM programme.

Technical aspects

- **Layout**: The graphical aspect must be simple but engaging; it must not distract the user/student from the contents.
  The MM must not saturate the reader with too much of text on the screen; links, glossaries, informative boxes, historical notes, curiosities in form of pop-up windows or similar, should help the user find variation and added interest in an otherwise too long reading sequence. Such features also allow the individual user to choose the information which is of most interest personally .
- **Navigation**: The access to the contents and other facilities has to be made as simple as possible. Also the access has to be very rapid; a long waiting disencourages the users, giving them a negative impression about the MM.

- **Informatics skills**: try to minimise what is required , no matter whether we are talking about a CD-Rom or some other kind of MM.
- **Utilities and help sections**: help sections are always welcome; they must be essential but exhaustive. The same is true for the tables (e.g. conversion factors, physical constants), table of contents, general index or media library. These facilities allow the user to make rapid searches.
- **Path configurator**: a sort of 'topic-shopping trolley' that allows the users (especially teachers) to pick up only the contents they need, in order to build their own MM lessons.
- **Test**: one ore more test sections (perhaps of increasing complexity) is desirable to allow students to check their level of understanding of the contents. Both right and wrong answers must be discussed and justified.
  It should be possible to choose what test to do (even better if tests are subdivided in sections).
  An improvement frequently recommended was the possibility of keeping a record of the students' answers.

Contents

- **Levels:** The material must be presented in an understandable but rigorous way, with coherence and continuity. The subdivision of the contents into two or more levels of knowledge may help the teacher when choosing them for use bearing in mind the personal needs and experience of the students.
- **Animations**: Where possible use animations rather than text. They do not have to be unnecessarily complicated; simple animations with a voice-over are quite enough. If the budget allowsconsider the use of voice-overs made by similar age group, especially for young pupils, and a mixture of male and female voices.
- **Images**: make the pictures as large as possible, so that when on screen they can be commented on by the teacher, especially when they involve information not explained in the text.
- **Games**: These allow the youngest students to review and consolidate acquired knowledge. Moreover, if they are accompanied by a scoring system they can become an occasion for self-evaluation and discussion.
- **Experiments**: These sections suggest (previously tested) activities for the students, and/or videos that demonstrate real experiments done by real people. Other possibilities could include java applets or virtual laboratories.

Multidisciplinarity

- **Links and glossaries**: they increase the effectiveness of the multimedia and the possibility of stimulating the curiosity of the students - even towards other disciplines.
- **Pictures, historical notes, etc**: the use of photographs and reproductions of works of art is always welcomed. Historical notes, scientific and historical curiosities and the biographical notes of scientists (even better if these are accompanied by a picture) broaden interest and demonstrate important links between the principal discipline treated in the MM, and the world of history, arts, economics and society.