Education and Culture
Leonardo da Vinci

PARTNER: **Institute of Education, University of London**

EDITOR: **Harvey Mellar (with contributions from project partners)** DATE: **2007-11-27**

REVIEWER: **Vegard Engstrøm** DATE: **2007-12-11**

SUPERCOMET 2 Evaluation Report VERSION: **A**

CONTENTS

ANNEXES

The Evaluation Report contains five annexes containing the following documents related to the evaluation process:

Annex 1 - Evaluation Strategy

- SC2_Evaluation_plan_20070108_HGM

Annex 2 - Evaluation Strategy adopted by Research Unit in Physics Education of Udine University, Italy

- SC2_testing_report_IT_Monitoring_20071012_FC

Annex 3 - Pro Forma for the National Testing Report

- SC2_national_evaluation_report_20070507_HGM

Annex 4 - Evaluation Instruments

- SC2_trialling_instruments_all_20070423_HGM

Annex 5 - National Testing Reports

- Austria & Germany_AT&DE
  1. SC2_testing_report_AT&DE_20071108_RG
  2. SC2_testing_report_AT&DE_questionaire_pupils_1_RG
  3. SC2_testing_report_AT&DE_questionaire_pupils_2_RG
- Belgium_BE
  4. SC2_testing_report_BE_20071017_WP
- Bulgaria_BG
  5. SC2_testing_report_BG_20071010_NN
  6. SC2_testing_report_BG_questionnaire_pupils_20071010_NN
  7. SC2_testing_report_BG_questionnaire_pupils_boys_20071010_NN
  8. SC2_testing_report_BG_questionnaire_teacher_20071010_NN
- Czech Republic_CZ
  9. SC2_testing_report_CZ_20071024_EM
- Spain_ES
  10. SC2_testing_report_ES_20071023_JMZ
  11. SC2_testing_report_ES_Spanish_20071023_JMZ
- UK_GB
  12. SC2_testing_report_GB_20071009_GI
- Italy_IT
  13. SC2_testing_report_IT_20071012_RV

14. SC2_testing_report_IT_BraidaTrial_20071012_MB
15. SC2_testing_report_IT_Monitoring_20071012_FC
16. SC2_testing_report_IT_PaperSchools_20071012_RV
17. SC2_testing_report_IT_Path-Fieldppt_20071012_FB
18. SC2_testing_report_IT_WorkSheetA_20071012_MB
19. SC2_testing_report_IT_WorksheetB_20071012_MB
20. SC2_testing_report_IT_WorksheetC_20071012_FB

- Latvia_LV
  21. SC2_testing_report_LV_20071015_AP
- Netherlands_NL
  22. SC2_testing_report_NL_20071026_PU
- Norway_NO
  23. SC2_testing_report_NO_20071012_HR
  24. SC2_testing_report_NO_questionnaire_pupils_20071002_HR
  25. SC2_testing_report_NO_questionnaire_teachers_20071002_HR
- Poland_PL
  26. SC2_testing_report_PL_20071031_GW
- Portugal_PT
  27. SC2_testing_report_PT_20071105_VT
- Romania_RO
  28. SC2_testing_report_RO_20071108_CH

0 Executive Summary

This report presents an evaluation of the SUPERCOMET materials based upon a synthesis of 12 National Testing Reports written by the project partners. These reports relate to the state of the materials as they were in January 2007. This evaluation report first describes the overall evaluation strategy and then presents evidence related to the Teacher Seminar and Guide and then the classroom materials (the Computer Application and the Hands-On Kits). Specific feedback is provided, and the report concludes with a set of general recommendations and a discussion of the overall added value of the project.

Trials were carried out in 13 countries in both schools and teacher training programmes (usually in universities). Over 500 teachers and trainee teachers and over 2500 learners were involved in the trials. The nature of the data gathered from the various trials is very variable, and this report has tried to balance these various sources of evidence in order to give as realistic a picture as is possible.

The majority of the National Reports expressed strong agreement with the proposition that the SUPERCOMET materials as a whole (i.e. the Teacher Guide and Seminar, the Computer Application, Low-Tech and High-Tech Hands-On Kits) constituted a valuable and useful addition to the available physics education resources. Many of the reports were confident about having seen improved learning as a result of using the materials in the classroom, and students were reported as reacting very positively to the materials.

The learners' views expressed in questionnaires were positive, though they suggested that whilst the materials were interesting and attractive they failed to meet the highest aspirations that the project was setting for the materials.

The teachers' views expressed in questionnaires were quite consistent across the various reports. The Hands-On Kits were very well received and generally rated as very useful and very attractive. The Computer Application was well received and generally rated as useful and attractive.

Recommendations:

The Teacher Seminar and Guide materials are very useful, but need further development both in terms of deepening of the explanation of superconductivity, and in terms of greater explicitness about the pedagogic messages.

The Computer Application, and in particular the animations, are a valuable tool. However the presentation, organisation and navigation of the materials need further improvement (some of these changes have already been carried out in the final version of the materials). The materials also need to incorporate greater student interaction, and there is a need to focus more clearly on pedagogy.

There is great enthusiasm for the Hands-On Kits, and there can be little doubt that these will be important and successful, and so further development along these lines is to be supported.

On-line work using freely available communication software should be explored more thoroughly.

1 Introduction

This report presents an evaluation of the SUPERCOMET materials based upon a synthesis of 12 National Testing Reports written by the project partners. The national reports differed greatly in the amount of detail they provided as a result of the different ways in which they had managed to integrate the SUPERCOMET 2 work with their other ongoing work.

It is important to note that the National Testing Reports relate to the state of the materials as they were in January 2007, and a number of the points raised in this evaluation report have been addressed in the latest version of the materials.

There are big differences between the National Testing Reports, which seem to reflect both the different positionings of the authors of the reports on the one hand as well as the differing realities on the ground in each country. It is impossible to separate out what might be national issues from what might be purely personal differences between research and development groups. However the positive side of this variation is that a number of different questions were considered by different partners, adding to the overall richness of the evaluation.

The report will first describe the overall evaluation strategy and then present evidence related to the Teacher Seminar and Guide and then the classroom materials (the Computer Application and the Hands-On Kits[1]). Specific feedback will be summarised, and the report concludes with a set of general recommendations as to the way forward and a short discussion of the overall added value of the project.

This report does not discuss any findings with respect to gender as these issues will be the subject of a separate report.

2 Evaluation strategy

The aims of the evaluation were:

A) To determine whether the SUPERCOMET materials (Teacher Guide and Seminar, Computer Application, Hands-On Kits) are a valuable and useful addition to the physics education resources available (for example by contributing to students' learning or interest).

B) To determine which aspects of the materials need to be changed or added to.

C) To determine the relative value of various parts of the materials, Each part of the materials (i.e. Teacher Guide, Teacher Seminar, each of the modules of the Computer Application, Low-Tech Hands-On Kit, High-Tech Hands-On Kit) to be assessed according to the following criteria:

- possibilities of use – to what extent can these parts of the materials be effectively deployed within the specific national context?

[1] The Hands-On Kits described in this report were draft lists of contents and experiments, mostly based on experiments from the Universities of Antwerp, Udine and Torun and developed as part of other projects. Work will continue in the project MOSEM to produce prototype Hands-on Kits which will be trialled as part of that project.

- curricular value – to what extent are these parts of the materials of value within, and offer content relevant to, the curriculum being taught in that school/country?
- academic achievement – to what extent do these parts of the materials contribute to the achievement of learning goals within that context?

D) To determine how best to use the materials within the specific pedagogic context of a particular country.

E) To provide case studies of actual use in each country.

A detailed outline of the project evaluation strategy is given in Annex 1. Some partners used their own evaluation methodologies (usually calling on previous work on evaluation of physics teaching materials) which they applied to the evaluation of the use of the materials in their own country (Annex 2 describes the approach adopted by the Italian partners).

Each partner drew up a National Testing Report in the format shown in Annex 3. All partners were provided with a set of test instruments, interview schedules etc which were based on instruments being used by partners within the project. No-one was required to use these shared tests, but these tests were available to call on as required. These instruments are shown in Annex 4. The National Testing Reports as prepared by the partners are given in Annex 5.

	Trainee teachers	Teachers	Students	Schools	Teacher training programmes
Austria & Germany	5	8	70	3	1
Belgium	0	50	587	8	2
Bulgaria	4	11	150	5	2
Czech Republic	4	17	550	6	2
Italy	51	14	348	12	5
Latvia	15	84	320	12	7
Netherlands	0	2	44	1	0
Norway	0	1	24	1	0
Poland	110	26	320	14	2
Romania	18	24	130	4	4
Spain	0	38	11	1	1
United Kingdom	40	8	0	0	2
TOTAL	247	283	2554	67	28

Table 1

The table above gives an estimate of the numbers of teachers and students that were involved in the study. .

The nature of the data gathered from trials with these participants is very variable, sometimes we have completed questionnaires or test results, or detailed classroom observations, but often we have a somewhat impressionistic summary based on the partners' experience of working with the trials. This report has tried to balance these various sources of evidence in order to give as realistic a picture as is possible.

3 Teacher Seminar and Guide

3.1 Trials

Not all partners actually delivered the Teacher Seminar; the Netherlands for example adopted a personal training approach rather than using the Teacher Seminar. However, most partners did deliver the Teacher Seminar, though they took a variety of approaches to doing so, the time devoted to the Seminar varying from four hours to two days with additional follow up support. The audiences were sometimes physics teachers, commonly a range of science teachers, and also some IT teachers were involved. Most reports said that the teachers were reasonably experienced in using ICT (though not always in using ICT for teaching), and where this was not the case then the situation was actually improving quite quickly. These seminars were in general well received.

The Teacher Seminar was commonly used to demonstrate the computer application, and in many countries to demonstrate the hands -on kits. Pedagogical discussion was often limited to an open discussion of curriculum possibilities.

Partners who devoted more time to the Teacher Seminar often spent the additional time teaching about superconductivity, the underlying theoretical concepts and its applications. The experiments with high temperature superconductors were a novelty for the teachers and much appreciated. Some countries (such as Latvia) who had difficulties in accessing liquid nitrogen expressed regret at not being able to carry out these parts of the demonstrations.

Some partners spent additional time on expanding on pedagogical issues. For example, because of the range of curricula in Spain the Teacher Seminar there introduced a curriculum mapping exercise, encouraging teachers to consider the 'softer' targets, such as "show awareness of the limitations inherent in scientific activity" as well as more knowledge-based objectives such as "state the factors which affect the size of the induced voltage."

In the Romanian study there was an attempt to support the face to face sessions with on-line support though the Physible platform, e-mail, and phone calls. However, whilst Physible accounts were created for 31 teachers, only six submitted messages to the message board, in each case just a single line.

3.2 Case studies

In order to provide a fuller picture of the way in which the seminars were carried out and their results, three case studies are presented here. (These case studies are taken directly from the National Reports, edited for consistency and clarity.)

3.2.1 Italy

The goal of seminars was to show teachers a new way of teaching physics and to integrate the use of SUPERCOMET in such a way as to transmit motivation and enthusiasm to their students. The aims of the seminar were that at the end of the seminar, trainee teachers would:

- be familiar with the Computer Application and Teacher Guide

- have a sound understanding of superconductivity and its history, sufficient for them to feel confident to use superconductivity in their teaching
- be able to safely perform a number of superconductivity-related demonstrations (such as levitating magnets above a superconducting disk)
- be able to integrate superconductivity into their teaching, and the curriculum they have to deliver
- be able to design learning activities using ICT and SUPERCOMET materials
- start to establish a community of teachers using SUPERCOMET in – and maybe out – of their classrooms.

- Session 1 - Five hours

Introduction about the SUPERCOMET 2 project
The Computer Application and the Teacher Guide
ICT and Physics education
The history of superconductivity
What is superconductivity?
Superconducting materials
The BCS theory
How to introduce superconductivity in the didactic practice
Introduction to the experiments and the videos
Discussion with teachers and task assignment (produce didactical paths)

- Session 2 - Five hours

Illustration of the experiments
Execution of the experiments (in series)

1. the falling magnet
2. the jumping ring
3. the cold light (l.e.d. in liquid nitrogen)
4. magnet levitation
5. magnet suspension

Discussion with teachers and task assignment (produce experimental forms)

Then the teachers met every two months (five hours each time) to discuss methods of work, problems, approaches, proposals for new paths for different types of schools and ages of students.

3.2.2 Poland

The seminars were carried out in Saturday/ Sunday classes and were organised in six hour modules Teachers were given printed copies of the translated materials. The first module was about the magnetism in general, and the second on the superconductivity. Electrical conduction was not covered as this is well covered by the textbooks already available on the Polish market.

In teaching magnetism the tutors introduced the magnetic field concepts, the magnetic field created by the electrical current and electromagnetic induction. The presentation had three stages:

1. Describing contents (usually known by teachers, but now no longer in all curricula)
2. Showing the experiments, mainly those given in the Teacher Guide book and the Computer Application
3. Showing simulations

The teachers appreciated all three elements.

All experiments with high temperature superconductors and with liquid nitrogen were a novelty for teachers.

In one group of 32 teachers who attended the seminar, the teachers all had degrees in physics or mathematics, and a good knowledge of ICT (though not of the use of ICT in the classroom) but only 15% has used experiments on electricity and magnetism in their teaching before. The majority of the teachers felt that after the seminar they were now able to carry out the experiments themselves. However, very few schools are equipped to make experiments even in magnetism, and nothing is available to carry out experiments in superconductivity.

3.2.3 United Kingdom

There were two groups:

a) The Teacher Guide and Computer Application were presented via a seminar to forty post-graduate trainee teachers. Of the forty six had a physics background, 16 a chemistry background and 18 a biology background. This trainee teacher cohort were taken through the Teacher Guide, with examples demonstrated via an interactive whiteboard, before having the Teacher Seminar presented. This was done over a day from 9:00 am to 4:30 pm

b) The seminar was presented to eight in-service science teachers where seven of the eight had a physics background. This in-service teacher cohort devoted the whole day to the Teacher Seminar and the teachers were given the Teacher Guide to take away and work through.

Option (a) proved to be too much for one day and the trainee teachers observed the demonstrations rather than getting a hands-on approach. However they did participate in the seminar via the interactive whiteboard activities

Option (b) allowed time for participants to have a hands-on and minds-on session, working through magnetic breaking, magnetic levitation, flux pinning, cooling l.e.d.s and transition temperature activities. The pedagogic knowledge base of the in-service teachers was much higher than that of the trainee teachers allowing the presenter to focus more on the subject knowledge.

Questionnaires where used to get immediate feedback with follow up feedback, via e-mail, requested. Once again the two cohorts can be considered separately.

a. Trainee teachers, immediate feedback

	Teacher Guide					Seminar				
1. strongly agree; 5. strongly disagree	1	2	3	4	5	1	2	3	4	5
Improved my subject knowledge	38			2		38	2			
Improved my pedagogical knowledge	21	15	4			3	25	8	2	
Provided material I am likely to use in school	40					2	4	29		5
Provided material to enable me to continue my own learning	22	19	9					32	4	4

Table 2

A number of comments regarding the visual way in which electricity and magnetism topics could be addressed were made, with a number (22) saying that their own understanding of basic electricity had been improved by the material on the Computer Application.

Only those with a physics background really thought that they would use the practical activities from the seminar in their teaching. However almost all thought that some activities, e.g. magnetic braking would be used if they taught GCSE[2] science or physics.

b. In-service teachers, immediate feedback

	Teacher Guide					Seminar				
1. strongly agree; 5. strongly disagree	1	2	3	4	5	1	2	3	4	5
Improved my subject knowledge						8				
Improved my pedagogical knowledge							6	2		
Provided material I am likely to use in school						7	1			
Provided material to enable me to continue my own learning								8		

Table 3

All teachers commented on the fact that they had not addressed superconductivity in their degree (or it had been long forgotten) and welcomed the fact that subject knowledge based INSET could be made available.

All commented that they would be likely to use materials from the seminar when teaching A-level[3], providing access to liquid nitrogen proved possible.

[2] An examination taken in the UK at age 16.
[3] An examination taken in the UK at age 18.

c. Trainee teachers, follow up feedback

During the 11 week school based practice 16 of the forty reported having used the materials in the classroom, with a further 11 commenting that they would have had they taught appropriate classes. Three reported resistance from their placement school along the lines of "we don't do it that way here".

Two trainees reported that they had revisited the material to improve their own subject knowledge.

d. In-service teachers, follow up feedback

During the following term, of the eight teachers, all had used the material from the Computer Application in their teaching, three had installed it on their school Intranet and two had borrowed equipment from Loughborough University to measure transition temperature with A-level students.

The main conclusion arising from these two are:

- A full day is needed for both the Teacher Guide and Teacher Seminar
- Presenters need to focus the day(s) on the relative pedagogic and subject knowledge of the cohort
- Some schools need to be convinced that there are other ways of doing things
- Those teaching A-level physics need easier access to materials and liquid nitrogen

3.3 *Feedback and suggested changes*

Opinions were divided over the value of the Teacher Guide and Teacher Seminar.

3.3.1 Positive

Many argued that all parts of the guide were useful, and that it could be used for both pre-service and in-service teacher education. It was even argued that the Teacher Guide and Teacher Seminar could provide a way to professionalize the teaching work of physics teachers. One report argued that the structure of the guide itself was a help to planning approaches to teaching and classroom activities, and in particular for developing new innovative approaches to teaching. On a more mundane level some simply claimed that the additional information provided in the Teacher Guide and Teacher Seminar made the teachers more confident and saved them work they would otherwise have to do themselves.

3.3.2 Negative

On the negative side, one report noted that though the Teacher Guide was given out to teachers it was not used, and three reports argued that the Teacher Guide and Teacher Seminar were unnecessary for qualified teachers of physics. It was argued that these teachers knew how to use ICT, and that use of the SUPERCOMET Computer Application was very intuitive. Information of more general, didactical, pedagogical kind was not considered useful by these respondents because teachers felt that they do alright without it, and they should be left free to use the materials as they saw fit.

3.3.3 Specific issues

Superconductivity: For many the basic background information on superconductivity was the most valuable aspect of the Teacher Guide and Seminar, though some noted that though this was interesting they were not in a position to repeat the experiments in schools. Several reports argued that this aspect needed to be further strengthened, both with more teaching ideas and also with a more in-depth account of superconductivity, including a more quantitative approach to explanation, and an exploration of the relationship to quantum mechanics. The practical support in how to safely set up classroom demonstrations in this area was welcome.

However, for some the idea of teaching superconductivity was just wishful thinking, and they saw the most important part of the materials as lying in teaching magnetism or electricity.

Teaching methods: Many welcomed the exposition of new teaching methods and active learning, and one report argued that this could help to reduce ‘authoritarian teaching’. However, another report argued that in the context of that country the teaching methods given in the guide were acceptable to teachers simply because they did not deviate much from the current methods they were using.

Experiments: There was a clear agreement that the experiments needed to be demonstrated in a seminar context, and that these could not be adequately explained in a book, or via the internet. The Teacher Seminar was seen by some as being primarily about the presentation of the Hands-On Kits, and these were seen as the most motivating and exciting part of the materials.

3.3.4 Suggested changes

The reports made the following specific recommendations for changes to the Teacher Seminar and Guide.

- The guide needs to be as short and to the point as possible, and to be as flexible as possible. Extended guides are not read.
- There needs to be more emphasis on what teachers do not know but need know to teach superconductivity well and interestingly.
- The technical aspects need to be less specific so that they are relevant to a range of different contexts.
- The teacher seminar should stress the fact that local experiments can and should be integrated in the use of the computer application.
- Incorporate examples of activities and lessons, examples of student worksheets and problem solving exercises.
- Incorporate evaluation tools looking at the content of the modules, but also at attitudes and skills.

4 Classroom materials (Computer Application and Hands-On Kits)

4.1 Trials

Teachers adopted a variety of approaches to using the Computer Application. Typically a module was used for between one and two hours, though sometimes single modules were used across longer sequences of teaching, up to 5 or 6 hours, and sometimes were used for as little as 30 minutes. One report commented that many pupils had difficulty working for longer than 30 minutes with the Computer Application, and stressed the importance of variety in classroom activities - so sessions might contain a presentation, some interaction with the Computer Application, laboratory experiments and then a class discussion to clarify ideas.

The materials might have different roles depending on the age of the student, in one report these materials were described as the main support for experimentation for 14-15 years old, while with 16-18 years old students they were seen as the starting point to build conceptual understanding, through integration with text books and additional experiments.

We describe below some of the common scenarios found in the reports of classroom use:

Teacher led: The Computer Application was often used with a projector by the teacher to display materials to the whole class. The lesson was typically help in the normal physics classroom. This approach may be adopted by choice or as a result of having restricted access to technology. The presentation was commonly combined with work from text books, using the video projector as a complement to the theoretical explanation. When combined with physical experiments the interactive animations might be used either after the experiments in order to deepen the explanation of the Physics phenomenon or they might be used as an introduction, with the experiments carried out after the presentation.

This teacher led approach was often used to demonstrate virtual experiments in order to support the explanation of abstract concepts, the animations being used to visualize and analyze experiments. Students might be asked to hypothesise what would happen when parameters were changed in an animation, and then the result of the animation compared with their hypothesis.

Independent study: Often students worked independently with the Computer Application, learning by discovery. Such sessions were commonly held in a computer classroom rather than the normal classroom. Pupils might work individually, or in pairs, or in small groups and would work independently of the teacher using guiding questions or problems prepared by their teachers. Often the teacher was present and could help when problems arose, or students might consult their classmates. In one report a teacher describes how he would interrupt the independent work after half an hour or so and talk and explain specific details with the intention of thus maintaining the students' attention.

Independent study might be organised in different ways, it might be broken up into small sections and repeated frequently (this might go along with the use of the materials as a revision tool), or the materials might be integrated with on going project work stretching over a long period. Sometimes the Computer Application was integrated with a 'station' approach, and the computer might be just one amongst several experimental stations in the classroom.

Those partners who had asked students found some 80%-100% of them had access to computers at home. Sometimes students had better access to technology at home than at school and in one report there was evidence of a large number of students downloading the Computer Application from the internet to their home computers. Other reports also said that students wanted to have access to the Computer Application at home for self study. On the other hand one report which described the results of asking students how they preferred to use the Computer Application found that 56% liked working autonomous in groups, 44% liked presentations by the teacher (44%), and no-one wanted to work with the application as homework!

Group work: Some reports describe organised group work going beyond simply allowing students to work in groups. One class looking at the module on electric conduction was divided into six groups of three, and each group had to study a part of the module. After 15 minutes, each group presented and explained its part to rest, using the projector, and everyone had to take notes on the crucial information. (For a another example of group work see the Case Study for Belgium below - section 4.2.1)

On-line: There was just one account of providing on-line support for working with the materials on-line which came from Italy. This was an online collaboration between three teachers (experts in using ICT) from three different schools. All the students had a computer and network connection at home. A Yahoo! closed virtual group was created, and 24 final year students were enrolled in the group and were divided into three working groups. Students received a copy of the Computer Application, and on-line they had access to:

- a database,
- a workplace where it was possible to insert link directories
- a workplace where it was possible to save and share digital photographs
- an agenda where it was possible to insert events, and
- a place where it was possible to chat.

All the students followed preliminary lessons in class, which aimed to provide them the basic skills for working online. The students were asked to follow the modules one by one. Online they were asked a sequence of questions to verify the level of the subgroup and to stimulate greater attention to certain conceptual 'knots'. The responses provided by the students were analyzed, corrected and fed back to the group. One group of students carried out experiments and their laboratory work was documented with video and photographs, and this was shared and discussed online with the other students.

4.2 Case studies

4.2.1 Belgium

This class took place in a classroom with 11 computers connected to the internet, and so enough for students to work with in small groups. After an introduction on electrostatics, the students had to study Module 3 Electric conduction in groups of two or three. They had to take notes individually and discuss difficulties among themselves. At the end of their notes, they had to come up with five questions touching the heart of the content of the module. This was their ‘summary’.

Different groups were finished at different times. The groups who finished first then had to test Ohm’s law with an experiment: they had to get the materials needed, built the set up based on the diagram in the Computer Application, and start measuring for different resistors. After doing this they had to put the data in an Excel file and find the formula of the curve fitting the plotted points, and see that the coefficient of the straight line was actually equal to the resistance of the resistor. The groups finishing last also had to do this, but they were helped by the groups who had worked more quickly, and the slower groups had to finish analysing data in Excel at home.

4.2.2 Italy

Approach: Our approach involves an exploration of phenomena and consists of a gradual study of the magnetic behaviour of different systems. The objective is to produce an explanation for the phenomena observed and thus formulate hypotheses, transform these into equations, propose interpretative models and, finally, compare these with the results of the experiments using the Computer Application. In this way the students learn to express their own ideas and knowledge, to analyze and compare these with those of their peers, to test the validity or non-validity of their own suggestions and to introduce a ‘model’ that is both qualitative and quantitative.

Strategies: The didactic strategy utilized is the PEC cycle (prevision, experiment and comparison). The ‘Prevision’ phase induces the student to express his or her own ideas, their own interpretative references (ideas using common sense and scientific concepts) and in doing this, to confront the link between expression in spoken language and descriptions in abstract language. The phase ‘Experiment or model’ helps the student to confront the problem of confusion between a physical reality and a model that may describe it. In the ‘Comparison’ phase an important role is played by the student’s reasoning strategies, both in critical analysis of cases where the prevision and the results of the experiment or the model do not agree and therefore it is necessary to decide what must vary in the following PEC cycle, and also in cases where the two do agree and it is necessary to generalize the interpretative model. The PEC method, as well as highlighting possible cognitive conflicts and thus allowing the students to resolve these, also allows them to acquire the knowledge that different points of view exist, correct for various disciplines, and thus the capacity to opt for this method results in a more efficient resolution of the problem.

Often the student relies upon an automatism to resolve problems and exercises and is not trained to reflect which path is the most advantageous in order to frame the problem. When the student finds him or herself before a phenomenon, he or she analyzes it utilizing different models, both scientific or not, and often does not perceive incoherencies and contradictions; this requires the act of revision, reorganization and a re-conceptualization of his or her knowledge. This strategy is fundamental for the process of building and integration of different interpretative models applied by students for the interpretation of a phenomenon.

Tools: Lessons were organised involving a series of class activities with the SUPERCOMET materials: a series of experiments, some of which will be carried out by students; while the section requiring the use of liquid nitrogen will be demonstrated and carried out by the teacher for safety reasons. All of the experiment information was supplied on worksheets.

Conceptual knots: Superconductivity is currently an area that is rarely dealt with in higher secondary school, either because only studies in the area are relatively recent or because it is still an unresolved mystery. Research into the teaching of physics has not yet investigated the learning difficulties linked to this area, and so the literature provides little reference material. The following potential conceptual 'knots' were extrapolated from an article in the "Operation Physics American Institute of Physics", which deals with the misconceptions of children in various fields of science:

- The particles in a solid do not move
- Substances and their properties correspond to determined types of particles; however the formation of a substance with determined properties is not seen as a result of the reorganization of the particles.

4.3 Use

4.3.1 Usefulness

The Computer Application was generally very well received. The most upbeat assessment of the materials shared by a number of reports was that materials are easy to use, attractive, interactive, clear, easy to read and understand, explain the topics well and stimulate imagination and provoke thinking. The principle specific advantages of the Computer Application over conventional teaching methods were said to be that:

- It helps learners visualize phenomena.
- It explains theoretical contents clearly.
- It helps maintain interest by bringing in a new way of teaching.
- The animations help learners to understand the presented phenomena.
- The use of the materials as a virtual labs provides pupils with access to a number of experiments that would otherwise be impossible for them to experience in a normal classroom, for reasons of safety, or because the effects are too fast, slow or small.
- It encourage the perception of models as tools for explanation.

The animations were seen as particular useful in firstly reducing the teachers' workload in drawing diagrams and graphs on the blackboard and secondly. enabling the presentation of dynamic aspects of situations which could not be demonstrated on a blackboard, Most reports stressed the use of the Computer Application needs to be complemented by the use of experiments.

4.3.2 Possibilities of use

Many of the reports said that computers were readily accessible within the schools (and at home), and that teachers were adequately trained in their use, and so that there were no problems in using the materials. Schools in some countries made significant use of large educational software packages and the Computer Application was seen to fit easily into the structures that existed to support those packages.

Others, however, reported computers as too few, too slow, with no access to the internet, and a lack of multimedia projectors. Even where technology existed there could still be problems in installing the Computer Application because of computer security issues.

Other reports spoke of the organisational problems of accessing technology (because it meant booking a computer room and leaving the physics classroom for the computer room) making it difficult to integrate the Computer Application into ordinary teaching.

It would be tempting to equate these issues with national circumstances, but this may not be accurate. Partners in different countries were often working with students in rather different kinds of contexts, and this had implications for access to technology. It is also possible that different group had different levels of expectation and this influenced their judgments as to how satisfactory a situation might be.

4.3.3 Curriculum fit

Most countries reported that the introductory modules (magnetism, electromagnetic induction and electric conduction,) directly connected to their curriculum. There were sometimes some minor issues, but broadly speaking there was a good fit. The theme of superconductivity was rarely explicitly part of the physics curriculum however (though it might feature as a possible option) and teachers had more difficulty justifying the teaching of this content.

However, nearly all reports spoke of a lack of time, which suggests that the match to the curriculum may not have been as close as was being claimed. One report suggest an alternative view of this lack of time – namely that studying in this way takes more time than conventional learning (though we saw in 4.3.1. and will see again in 4.5.1 that others believed that the use of the Computer Application saved teachers' and students' time).

4.3.4 Specific modules

Magnetism: Because of changes in the curriculum, and the actual limitations of the textbooks available in Poland this module was very useful in that national context. Others thought this module was good as a short survey of the field and for deepening students' understanding. The simulations of Oersted's and Ampere's experiments were specifically noticed as of value by one report.

Electromagnetic induction: Several reports commented on the value of the animations in this module, though others also stressed that the phenomena of this module can not be understood without carrying out physical experiments.

Electric conduction: Animations and models were felt to help students to better understand and learn electric conduction, though again there was a need to introduce these phenomena using real experiments. Two groups found this module of little use, one group seemingly because it was an area already well covered in the materials they had to hand, and another group because it seemed to be outside their curriculum.

Superconductivity: Many saw the modules on superconductivity as the core to the materials, students were said to be very interested in technological aspects. However some of these reports felt that the module did not go far enough, that important information was missing or not adequately explained. Those who saw the module *Introduction to Superconductivity* as important did not necessarily see the module *History of Superconductivity* as important and a number of reports expressed reservations about this, one argued that though this module might be partially useful for projects students preferred to use Wikipedia for this kind of information.

For some this material was simply outside the curriculum and so only of limited relevance. The material would only be of use to 'inspired' teachers, and the non-physicist teaching physics (often the majority of teachers) would be very reluctant.

4.3.5 Hands-On Kits

Overall there was very strong support for the use of the Hand-On Kits. It was seen as necessary to have these to complement the Computer Application. They were seen as giving more and better understanding and maintaining students' attention better. The High Tech Hands-On Kit was useful to demonstrate evidence of superconductivity phenomena, and the experiments generated high interest and excitement. Some argued that there was a need for more quantitative experiments with superconductivity.

This positive appraisal of the Hands-On Kits was not quite universal. Some saw the Low-Tech Hands-On Kit as of pretty low importance and basically unnecessary (either because there was little scope for experimental work in their teaching, or because these areas were already well covered). Others (not usually the same people) found the High-Tech Hands-On Kit problematic. There were difficulties in accessing the necessary equipment and liquid nitrogen, and the likely need to have to borrow from a University (though in Latvia these were not available in the Universities either). Since some found little room for superconductivity in their teaching they also naturally found little reason to want to use the High-Tech Hands-On Kit.

4.4 Motivation

In general there was plenty of evidence that found working with the SUPERCOMET materials motivating, particular when both the Computer Application and the Hands-On Kits were used together. They liked working with the animations, and don't like reading text or solving problems. One report commented that the teachers in some case had to stop the students playing with the experiments, as they spent too much time playing, leaving no time to explore the explanations of the phenomena.

Magnetism: Students were interested in different kinds of magnets and they usage.

Electric conduction: Many reported students were interested in this module, though some found the some of the animations used to explain simple facts were too long-winded. A couple found low levels of interest in this module.

Electromagnetic induction: Many students found this module interesting, and they were curious about different electromagnetic phenomena. A couple or reports rather this module as not quite as interesting as the others, and there was some indication that the students were not sufficiently motivated to follow up the experiments on induction as indicated in module.

Superconductivity: Students were very interested in the Introduction module, and appreciated getting up-to-date information about modern technology. Some reports said that students were also interested in the History module, but others suggested it was less popular, and the one report that asked teachers o rate the modules this came out as by far the least popular module

Hands-On Kits: These were very motivating. The majority of reports indicated high student interest and excitement.

4.5 Learning

4.5.1 Perception

Many of the reports were confident about having seen improved learning. Students were reported as reacting positively to the materials and this generates a good atmosphere for learning. In combination with real experiments and other tools (Web, books) this contributes to the achievement of learning goals and improved learning, deeper understanding, particularly for those topics that rely on visualisation. Some argued that the use of the Computer Application both saved time in the process of teaching and that more students succeeded in learning and in understanding the contents. One report said that pre and post tests for their students showed good gains for every student. One report argued that the Computer Application works best for revision/reinforcement purposes, halfway through and at the end of the subject.

However, one report commented on the need for students to learn how to learn using technologies, because they were new to this way of learning. To begin with the students treat the materials rather superficially, motivated by the Computer Applications and its animations. The realisation that it should be used as a real ‘interactive’ textbook takes some time. In general, they skip the reading at first, and as a result they do not know what the animations stand for. After 2-3 lessons they realize that text and animations go together in a united effort to explain things. After this phase, the learning gains rise to a satisfying level.

4.5.2 Tests

A number of partners set out to measure learning gains. None of these studies was done with any great rigour and so caution must be exercised in interpreting these results, but they are at least suggestive about other studies that should be carried out to examine the measurable impact of the SUPERCOMET materials.

A. A study of students working with the module on electric conduction, show an average score of 13 0 in the initial questionnaire rising to 36.4 points at the end.

B. A study of the learning of superconductivity showed that the students had gained a basic knowledge of superconductivity. Well remembered were applications in particular, the least knowledge was evident in explanations of the properties of superconductors.

C. The Polish partners carried out comparison trials with traditional and multimedia forms of teaching.

1. Magnetism

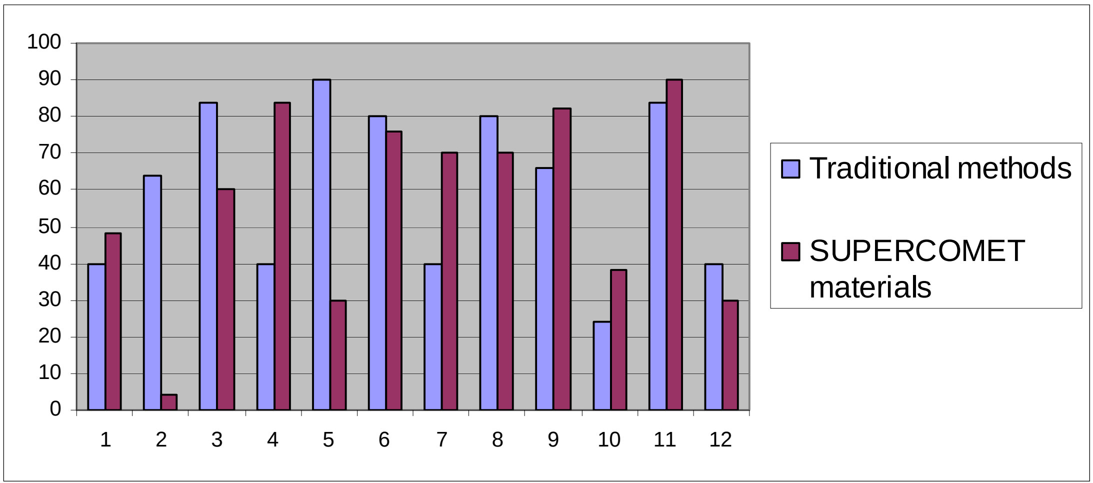

Figure 1

Figure 1 shows the scores on individual question in a test in a comparison between traditional teaching and teaching using SUPERCOMET materials. Those taught by the traditional method had more time to play with different materials and magnets. Those taught with the SUPERCOMET materials were shown the materials, and given them to look at and were given explanations from the Computer Application.

The scores of the class using the SUPERCOMET materials were as good as the traditional class or slightly better on most questions, but on some questions e.g. No. 3. "What do we use to improve the performance of electromagnets?" and No. 5 "Is aluminium magnetic?" the traditional approach outperformed the SUPERCOMET class.

2. Electromagnetic induction module

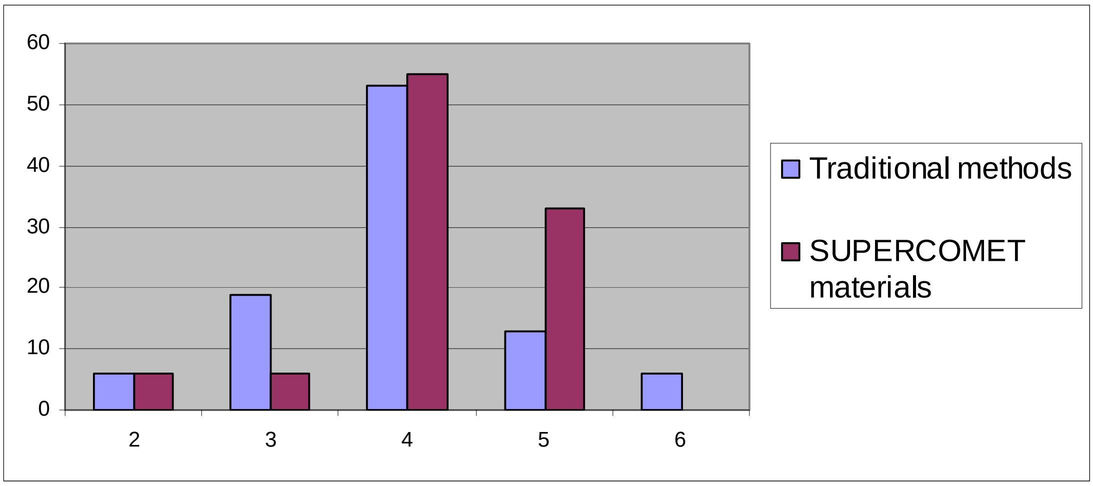

Figure 2

Figure 2 shows the number of students achieving specific scores in another study in which there was a comparison between traditional teaching and teaching using SUPERCOMET materials (scores out of 6 are shown along the X-axis).

In this case the use of SUPERCOMET materials has resulted in overall better scores; there are more scores of 5 and fewer scores of 3.

3. Electrical conduction module

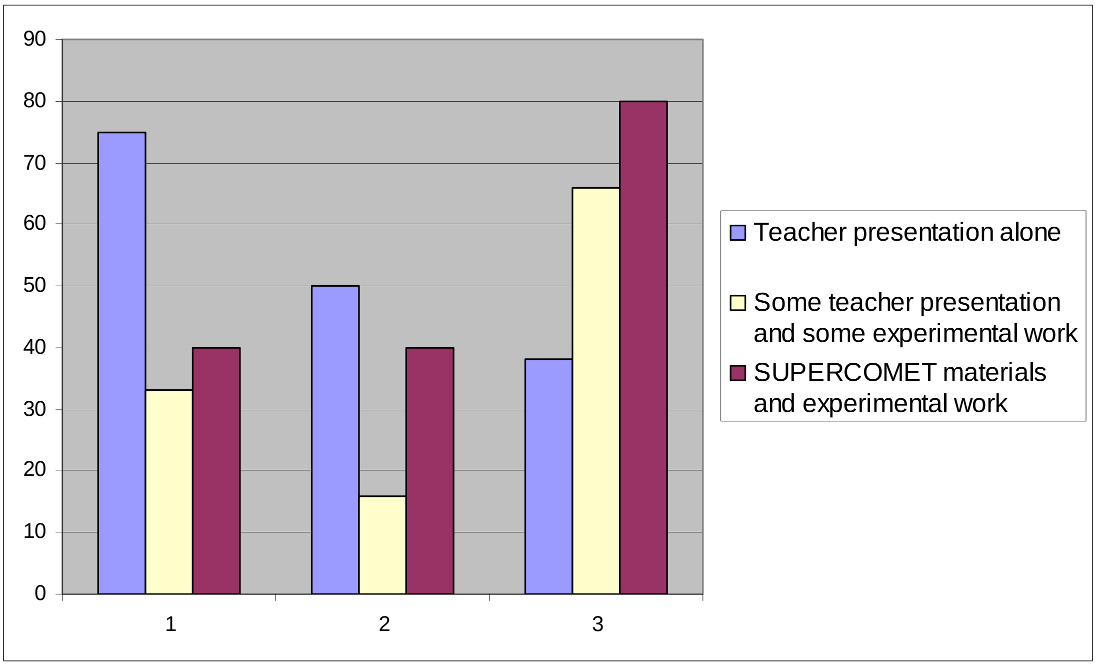

Figure 3

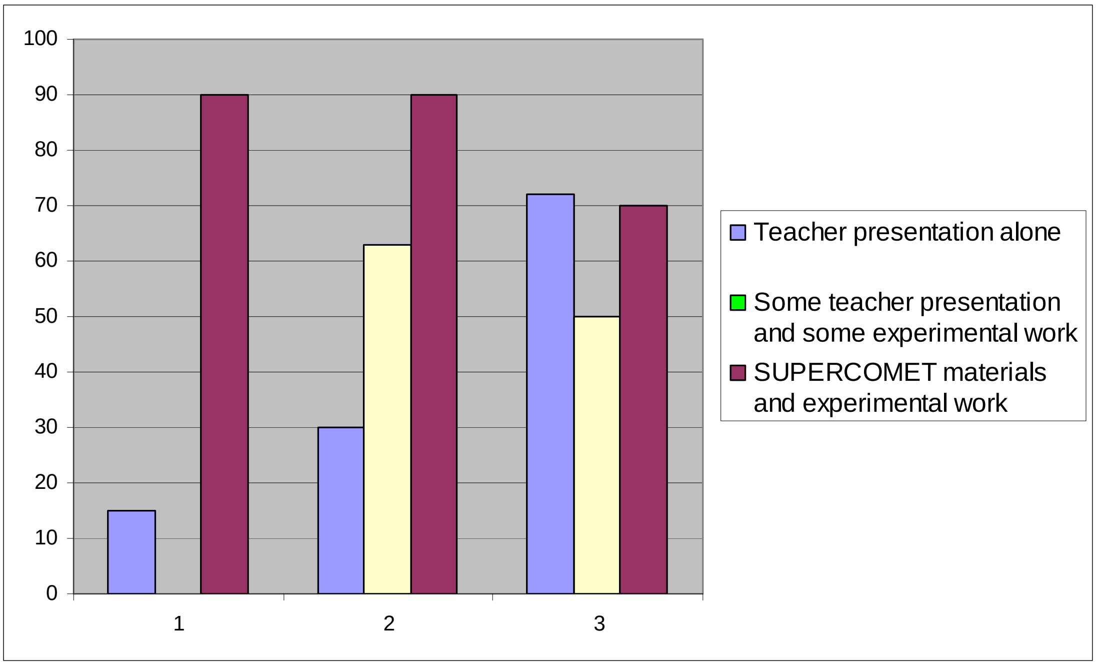

Figure 4

In another study a comparison between three conditions for two different sets of students was carried out. The results are shown in Figures 3 and 4.

The results in Figure 3 show that for these sets of students the teacher presentation alone was actually quite effective, whereas the results in Figure 4 show that for these sets of students the SUPERCOMET materials do rather well.

4.5.3 Differential Impact

Many reports saw the materials as suitable for all students, but offering some advantages for low ability students in that they supported motivation and made learning more concrete and interactive. Lower ability students were seen as being slower and moiré reluctant to adopt autonomous learning, but that the learning would be more permanent, and the use of a computer meant that the materials were continuously available.

On the other hand the text was thought to be more suitable for higher ability pupils and the *Introduction to Superconductivity* module was seen as more suitable for higher ability students.

4.6 Teachers' views

In a number of National Reports teachers' views had been obtained using either the shared teacher questionnaire or other similar questionnaires. The message from these questionnaires is quite consistent across the reports. The Hands-On Kits were very well received and generally rated very useful and very attractive. The Computer Application was well received, but to a lesser degree, generally rated just as useful and attractive. Open ended questions provided responses which indicated that the topics were felt to be well explained, and that the interactive animations were much appreciated, though other responses suggested some need for improvement in the materials, and in particular said that the Computer Application was sometimes somewhat long winded.

4.7 Students' views

In those countries that asked about their student's access to technology, they were found to have pretty good access to technology and were reasonably experienced and competent in its use. Student's views on the SUPERCOMET materials were solicited via questionnaires, three of the reports – Austrian and Germany, Norway and Bulgaria - used exactly the same questionnaire and a number of other reports used very similar questionnaires. The questionnaires gave similar responses across countries, though there was a small degree of consistent variation with the Austrian and German respondents being least positive, the Norwegians in the middle and the Bulgarians the most positive. The reports of the other questionnaires are broadly consistent with these three.

Roughly speaking, the learners agreed reasonably strongly with these statements:

- I find the subject of physics interesting
- The SUPERCOMET materials are easy to use
- The SUPERCOMET materials are interesting
- The page design in the SUPERCOMET materials is good
- The images in the SUPERCOMET materials are clear and understandable
- The images in the SUPERCOMET materials explain the topic well
- The quantity of images appearing in the SUPERCOMET materials is about right
- The movement in the animations in the SUPERCOMET materials and the speed of the screen changes are good
- The animations in the SUPERCOMET materials helped me to understand

They agreed weakly or were fairly neutral about the following statements:

- I find the subject of superconductivity interesting
- The SUPERCOMET materials are attractive
- The text in the SUPERCOMET materials is easy to read and understand
- The SUPERCOMET materials helped me to learn
- The experiments performed in the superconductivity course were interesting

They tended to disagree with these statements:

- The quantity of text appearing in the SUPERCOMET materials is about right
- The SUPERCOMET materials stimulate my imagination
- The SUPERCOMET materials offer meaningful experiences
- I found surprising things in the SUPERCOMET materials
- The SUPERCOMET materials changed my attitude about some things
- The SUPERCOMET materials promoted class discussions.

This indicates quite strong support for the materials, but suggests that they were failing to meet the highest aspirations that the project was setting for the materials.

Interestingly superconductivity seems not to have been of specific interest to students, it tended to be rated as less interesting than physics itself.

The Austrian and German partners carried out some correlational analyses on their survey results which yielded interesting insights:

- Interest in superconductivity - compared with interest in physics the distribution of responses showed more positive, but also more negative ratings. The correlation with interest with physics was 0.27, which was lower than the correlation of physics interest with other questions and it would therefore seem that the subject of superconductivity polarized the students, and that their interest relatively independent of their initial interest in physics.
- Interest in the Hands-On Kits - the outcome was clearly positive. The correlation with the physics interest at 0.39 was higher than with the interest in superconductivity.
- Interest in the Computer Application - the average score was below the mean as well as clearly below the interest in physics. The correlation with interest in physics interest was 0.42 – indicating that for interested students the program was better suited than for less interested. The differences between schools were minor, the problems therefore rested rather in the program itself than in the mode of application.

4.8 Suggested changes

The reports made the following specific recommendations about changes that should be made to the Computer Application and Hands-On Kits.

4.8.1 Computer Application - general

Presentation: Less text, more figures and pictures, more animations, more films (in particular films of the Low-Tech experiments). Some slides could be divided in order to have less text on each. All relevant keyword should be highlighted. One or more pages could be added with concept maps with links to slides. More exercises and questions needed.

Structure: The Computer Application should be less linear and more hypertextual in structure. Overall navigation could be improved, probably with a tab area (like the one used in Acrobat documents)

Personalisation: Add a personal work-guide. It should be more adaptable, allowing changes to be made. It needs a way to store results like answers, short calculations, and quiz choices.

Explanation: Many reports call for more and better explanations. There was a feeling that the text needed more work. One suggestion was that at the beginning of each module there should be practical examples (technical or everyday life) which would provide additional motivation for learning the topic.

Pedagogy: One report argued that the Computer Application provided illustrations to expand the possibilities in teaching and learning, more was needed to integrate this into effective and goal-directed learning.

Animations: One report argued that the animations as they stood often recreated actual experiments, whereas a better role for animations is to integrate thinking about a phenomenon, and to focus on explaining thinking with scientific models.

Technical: A number of technical issues remained – some reports said that the Computer Application was not stable and sometimes slow. It was argued that a CD-version should contain a full runtime version and run without installation of other software.

4.8.2 Computer Application – specific modules

Magnetism: A number of reports asked for additional explanations, and were often quite specific about what was needed. One report asked for an introduction about field lines, and topics needing additional explanation that were mentioned in one report or another included: magnetic field of moving charge; moving charge in magnetic field; Hall effect; magnetic field of toroid, Earth magnetism superposition principle, Pohl experiment, and the differences between F and B.

There was also a request for change in colours of magnetic poles: S- red, N – green.

Electromagnetic induction: One report suggested changing the order of presentation of: types of materials, resistance, Ohm's Laws, resistivity. Another asked for short video or pictures of things such as generators, transformers, and electromotors. Additional material requested included self-induction and practical applications in technique and technology. Additional explanation was suggested for Joule's Law

Electric conduction: One report said that the module about conductivity was quite simple and even easily understood by 8th graders (though whether this is a criticism or praise it is hard to say!). New or additional explanation was suggested for: electrolysis, thermal effect on electrons, and resistors with colour codes. There was a suggestion for the creation of interactive tasks for virtually creating electric circuits with fixed total resistance.

Introduction to Superconductivity: Most reports said that further explanation of superconductivity was needed, in particular further explanation of how Cooper's couples work, improved animation on Cooper's couples and a more careful explanation of the Meissner effect. Animations such expelling magnetic field lines, should be made as explicit and illustrative as possible. A number of reports asked for the explanations to be somewhat more quantitative and to incorporate more formulae. A small number of reports asked for more films showing high-tech experiments, and for additional text on the application of superconductors

History of Superconductivity: As indicated earlier this module was not very popular, suggestion for improvement included that it should be more clearly linked to applications of superconductivity. In terms of presentation it was suggested that the pictures should be bigger, and that there should be more photos of high temperature superconductors and their applications.

4.8.3 Hands-On Kits

There was widespread support for the Hands-On Kits. A number of reports asked for a closer and more explicit linking between the Computer Application and the Hands-On-Kits. A couple of reports asked for more video of the experiments, and others for more explanations and practical hints. It was clear that a number of groups who wanted to use these kits felt that they needed help in order to be able to do so effectively.

5 Recommendations

Sections 3 and 4 have included sets of specific recommendations arising from the National Testing Reports, in this section I set out the overall recommendations to the project, based partly on the recommendations from the partners, but also going beyond those to consider somewhat wider issues and what I see as the main directions forward indicated by the range of evaluation activities that the project has undertaken.

5.1 Teacher Seminar and Guide

The general opinion is that these materials are good, but need further development both in terms of deepening of the explanation of superconductivity, and in terms of greater explicitness about the pedagogic messages (so that they are seen as relevant by all physics teachers). This later goal can probably best be done by the development of pedagogic case studies. There needs to be a clearer relation between these two elements of the materials and there needs to be possibilities for teacher trainers to tailor the balance in accordance with the skills of their audience.

There is some advice for detailed changes in section 3.3.4.

5.2 Computer Application

The presentation, organisation and navigation of the materials need further improvement. The materials also need to incorporate greater student interaction, incorporating such things as notebooks, calculators, or alternatively pedagogic guides should be produced on how to use the application alongside other software tools. There is now a distinct Web 1.0 feel about the materials, and future developments will need to move this more into a Web 2.0 world, incorporating opportunities for student annotation, tagging, linking to other resources etc.

Whilst the animations are very useful, there is a need to step back a little from these and take on board the comment made in one report that the animations as they are at the moment often seem to attempt to recreate actual experiments, whereas a better role for animations is to integrate thinking about a phenomenon, and to focus on the role of scientific models.

There is a need to focus more clearly on pedagogy, and to ask where learning gains might reasonably be expected and where they might not. There is a need to ask more clearly just how we expect learners to learn from such materials, and how they can be integrated into effective and goal-directed learning. At the moment the materials remain somewhat agnostic on pedagogy and rely on the user to incorporate them as a resource within their own pedagogic structures. The PEC cycle (prevision, experiment and comparison) discussed in 4.2.2 shows one way in which this has been done. In taking forward the future development of these materials it will be necessary to confront the issue of to what extent they are to be seen as resources for people to fit into their own pedagogies and to what extent they are seen as leading on pedagogic issues.

The *Introduction to Superconductivity* module was widely recognised as needing further work, and the *History of Superconductivity* probably needs total reworking – at the moment it is not really history in any meaningful sense but a string of facts connected by a time line. I would recommend dropping this module altogether.

There is some advice for detailed changes in 4.8.1 and 4.8.2.

5.3 Hands-On Kits

There is great enthusiasm for the Hands-On Kits expressed in the reports, and there can be little doubt that these will be important and successful. However, there is a sizeable minority of reports that express reservations about these kits, and it was not totally clear what the source of these reservations was, and so more work is needed to explore and address this issue. As with the Computer Application there is a need to clearly articulate the use of the Hands-On Kits with pedagogy, and not just assume that the use of experiments will in itself result in greater or deeper learning.

There is some advice for detailed changes in section 4.8.3

5.4 On-line communities

The attempt to establish on online community as a basis for teaching through Physible was not successful, and only one report refers to its use. This contrasts markedly with the interesting use of freely available software (Yahoo! Groups) by a group of three Italian Schools (described in 4.1) in a well thought through pedagogic initiative. It is not software that makes on-line communities work but ideas.

6 Conclusions

The majority of the National Reports expressed strong agreement with the proposition that the SUPERCOMET materials as a whole (i.e. the Teacher Guide and Seminar, the Computer Application, Low-Tech Hands-On Kit, and High-Tech Hands-On Kit) constituted a valuable and useful addition to the available physics education resources. The least positive assessment saw the materials as having promise, but felt that the present versions were not sufficiently motivating for their students or teachers. The most positive assessments described the materials as of high quality, and as provoking new approaches to teaching because of the ease with which they match with the curriculum whilst also making it possible for highly motivated teachers to go beyond the curriculum, and touch frontier science with students.

Many of the reports were confident about having seen improved learning as a result of using the materials in the classroom, and students were reported as reacting very positively to the materials.

The learners' views expressed in questionnaires were positive, though they suggested that whilst the materials were interesting and attractive they failed to meet the highest aspirations that the project was setting for the materials.

Interestingly superconductivity seems not to have been of specific interest to students, it tended to be rated as less interesting than physics itself.

The teachers' views expressed in questionnaires were quite consistent across the various reports. The Hands-On Kits were very well received and generally rated as very useful and very attractive. The Computer Application was well received and generally rated as useful and attractive. Open ended questions provided responses which indicated that although some saw some need for improvement in the materials most thought that the topics were well explained, and that the interactive animations were much appreciated.