A LEARNING ENVIRONMENT FOR PHYSICS LABORATORY ACTIVITIES (LEPLA): A WEB BASED TOOL FOR PROMOTING LABORATORY WORK IN PHYSICS EDUCATION

Barbara Pecori, Bogdan Zoltowsky, Colm O'Sullivan

ABSTRACT
In this contribution the design, implementation, preliminary results, evaluation strategy and anticipated outcomes of the EU funded project LEPLA will be described and discussed. The design and implementation of this project is in response to evidence that the volume and quality of laboratory activities in secondary schools and universities across Europe is declining because of limitations of equipment costs, staff costs, maintenance, time constraints and accessibility. Project partners have found that such limitations can be reduced effectively by promoting the use of learning materials and experimental arrangements based on modern data acquisition technologies. The innovative features of LEPLA arise from the combination of two elements: (i) the communication and dissemination power offered by Internet; (ii) the educational power of the use of hand held technology in physics teaching. This combination can facilitate the job of both teachers and individual students by giving the opportunity of carrying out open ended lab activities based on inexpensive small-scale portable experimental set-ups and hand held technology in classroom, at home and in out-of-school settings. Collaborative activities of the partner institutions (Poland, Sweden, Ireland, UK and Italy) involve development of an Internet-based public resource providing a set of experimental modules on most standard Physics topics. LEPLA materials are based on an 'all in one' package concept. Each complete experiment, presented using modern multimedia techniques, includes relevant pictures, animations, MPEG movies, expected results, detailed description of setups, downloadable computing procedures, programmes and sample experimental data. The project also includes teacher training and dissemination activities, using the material developed by the LEPLA collaboration. Finally LEPLA creates a Forum and a trans-national cooperation network to promote exchange of experiences in experimental physics teaching and in educational uses of information technology.

KEYWORDS
Physics education, real time experiments, hand held technology, Internet, EU project

INTRODUCTION

The idea of designing and implementing a learning environment to promote physics laboratory activities is based on the evidence that the volume and quality of laboratory work in secondary schools and universities across Europe is declining dramatically. This is due to limitations imposed on equipment costs, staff costs, maintenance, time, location and accessibility. This issue is of a critical character in the case of under funded educational institutions, distance and vocational studies and especially for students disadvantaged because of social, economic or physical circumstances.

LEPLA project partners believe that the above limitations can be effectively reduced by developing Internet based multimedia learning materials to assist both teachers and students in performing experiments based on modern data acquisition technologies. In particular, they identified recently developed handheld technologies as the most suitable instrument for performing experimental activities at secondary school–and introductory university levels. By 'handheld technology' we mean portable, compact data-loggers with compatible sensors, controlled by and used together with programmable graphing calculators or computers (see Figure 1). These popular, versatile, inexpensive products of advanced information technology provide complete, modern, flexible and efficient data acquisition systems. Handheld technology enables basic experiments to be performed quickly and efficiently, by many students working in parallel with apparatus individually controlled (or shared within a small group), or by the teacher giving classroom demonstrations. Immediate access to the mathematical tools means that sophisticated analysis becomes a natural part of students' physics.

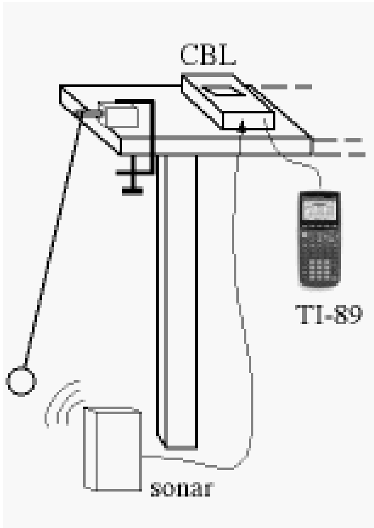

Figure 1. Example of experimental set-up with hand held technology.

Many studies have been made on the use of graphing calculators in physics teaching (Adie and Zoltowski, 1998; 1999; Torzo, Delfitto, Pecori and Scatturin, 2001; Pezzi, Pecori, Torzo, Foà, Rambelli, Rafanelli and Rizzo, 2001; Torzo and Pecori, 2001). The role of multimedia in flexible and open learning is well established (Mason, 1998) and approaches using multimedia in physics teaching have been tried (O'Sullivan, 1996). Instruction manuals are widely available to guide students through experiments (see for example: Gastineau, Appel, Bakken, Sorensen and Vernier, 1998). The problem is that these have to be very detailed, to enable students to work independently on the experiment. The advantage of a computer aided support is that problems can be set in a more open ended format and procedural information is given on student's request, according to his/her personal needs. Every student can therefore get individualized help and guidance.

PROJECT AIM, TARGET AND PRODUCTS

The main objective of the LEPLA project[1] is to develop an internationally available, innovative learning environment based on ICT, multimedia educational material and handheld technology, extending physics laboratory activities to open and distant learning.

LEPLA is targeted at teachers and students at secondary school and undergraduate level, in particular in contexts where experimental activities are absent or difficult to implement using traditional methods. Under funded educational institutions, distant learning and disabled students, in particular, will benefit from this approach. For this reason the use of sophisticated interfaces has been avoided and all technical choices were influenced by the necessity to make the platform accessible from any operating system, even on outdated machines and without requiring purchase of commercial software.

Collaborative activities have resulted in the development of an Internet-based public resource with about 30 experimental modules including multimedia learning material, downloadable computing procedures, programs and sets of sample experimental data to be used together with inexpensive small-scale portable experimental set-ups.

[1] See Appendix 1 for information about the LEPLA project Group

Most material on the platform will be available in English, Italian, Polish and Swedish together with a CD-ROM version of the material for standalone use.

Structure of the LEPLA web-site and modules

The LEPLA web-site is found at: http://www.lepla.edu.pl
or at the mirror site: http://lepla.padova.infm.it
The entry page, shown in Figure 2, is divided into four sections each leading to a different home page according to the selected language.
A *Guided Tour* of the site is available without registration, advertising the main features of the LEPLA platform: information on the project and partners, list of experimental modules, information about hand held technology and multimedia resources of LEPLA, students' activities with LEPLA materials, data analysis with graphing calculators and MS Excel.

Figure 2. Entry page of the LEPLA vortal

The complete menu is always available on the left side of the window; some general items are available also for non registered visitors. A limited menu is available also on top of the window.
Access to the modules describing the experimental activities is restricted to registered users. To register as a user of LEPLA only a nickname and e-mail address are strictly required. The use of the LEPLA platform is free of charge and none of the personal information given through registration can be sold or communicated to anyone else.
By clicking on *Experiments* in one of the menus a *List of experiments* screen appears as shown in figure 2. The top part is called *Exercise* where five activities are presented. The purpose of these is to give an introduction to the use of handheld technology and to the basic functions of Excel spreadsheets for those who are not familiar with them. Further down follows the list of experiments where each module is labelled according to the difficulty level of the experiment and to the equipment needed.

Legend
Equipment
B - basic equipment (voltage probe, temperature probe, accelerometer, light probe, pressure probe, force meter) A - additional equipment
Difficulty Level
S - basic C - advanced

	Exercise
1.	Introduction to the handheld technology (TI83 and CBL)
2.	Introduction to the handheld technology (TI89 and CBL)
3.	Experimental testing and curve fitting
4.	Errors and statistics

	Experiment	Calculator	Level	Equipment
1.	Toy car on an inclined plane		S	B
2.	Amusement Park		C	A
3.	Jumping on a scale		S+C	B
4.	Mass-spring oscillations		S+C	B
5.	Simple pendulum		S	B
6.	Real pendulum		C	A
7.	Coupled oscillators		C	A
8.	Impulse and momentum collision		S	A
9.	Accelerating objects - car		S	B
10.	Accelerating objects - elevator		S	B
11.	Accelerating objects - aeroplane take off		S	B

Figure 3. Excerpt of the List of experiments available in LEPLA
(complete list contains up to 30 modules)

The experiment *10. Accelerating objects – elevator* will be presented as an example to show the structure of the modules.

All experiment modules have the same layout. In the first page the objective of the experiment is presented together with some historical notes associated to the experiment. Figure 3 shows the first page of the experiment on the elevator ride.

At the bottom of the page a menu offers the following choices leading to different sections of the module:

- *Theoretical model*: Description of the physical phenomena and the theory behind the experiment (not available in all experiments)
- *Apparatus set-up and data acquisition*: A guide on how to arrange the apparatus and to perform the experiment.
- *Data sample*: If unable to perform the experiment (for example, because apparatus is not available) the students can download real data from the experiment here and go on analysing it.
- *Data analysis (TI-83 and/or TI-89)*: A guide on how to analyse your data with questions that lead you to interesting conclusions. For inexperienced users help is available for example to do regressions and statistical plots. In most modules at the end of this section there is a link to a *Complete analysis* where an example on how it should look is provided Data analyses can be made either with collected experimental data or with downloaded data.
- *Data analysis (MS Excel)*: Same as above, but with Excel instead of graphing calculator.

• *PDF-version of the module* (not available for all modules): This can be used to print hardcopy instructions.
• *Evaluation form*: For feedback from students using the LEPLA project
• *Teachers guide*: For feedback from teachers using the LEPLA project.

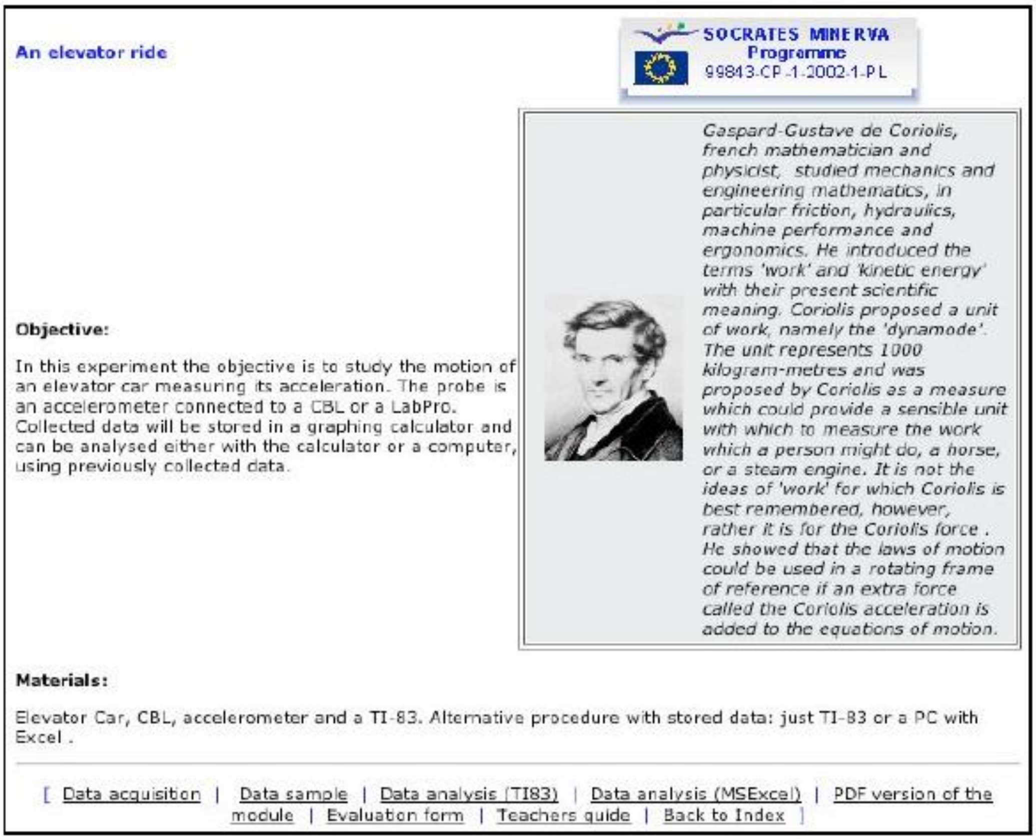

Figure 3. First page of the module on the experiment performed during an elevator ride.

In order to give an idea of how guidance on performing the experiment can be obtained some examples from the available choices are given below.
By choosing *Data acquisition* a window like the one of Figure 4 will appear.
In the pop-up window necessary steps for the set-up of the experiment are described and programs needed to perform the experiment can be downloaded. Scrolling down the pop-up window the opportunity is given to download data in order to allow data analysis without performing the experiment.

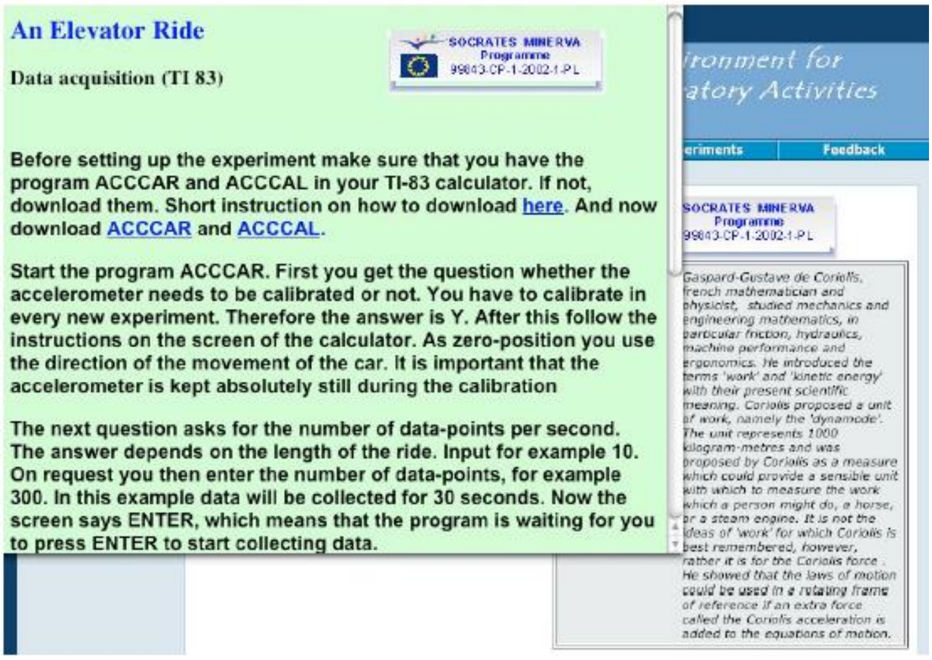

Figure 4. The *Data acquisition* window.

Another option is a link to data analyses using either TI-83 or Excel. MS Excel has been chosen as an alternative tool for data analysis since the program is available in most schools and students are usually confident in working with it. Figure 5 shows the beginning of the TI-83 data analysis.

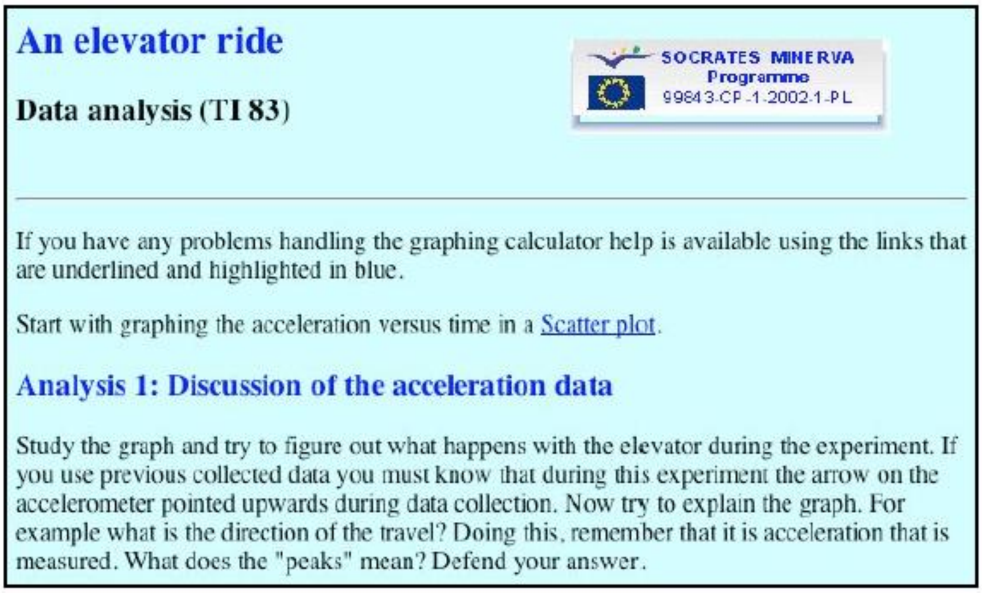

Figure 5. Start screen of the guide to *Data analysis* with graphing calculator TI-83

The highlighted and underlined text, *Scatter plot*, is a link to a help text where an extensive description including many screen shots from the calculator will guide the user through the process of making a scatter plot on the calculator. Help of this kind is present all through the text of this section.
At the end of the guide a link to a complete analysis section provides an example of outcome of the analysis. This link can be made inactive in off-line use of the platform by the students.
All these features of the data analysis are available also in the MS Excel section.

Examples of the content of the *Complete analysis* for the elevator experiment with TI-83 (Figure 6) and with MS Excel (Figure 7) are given below.

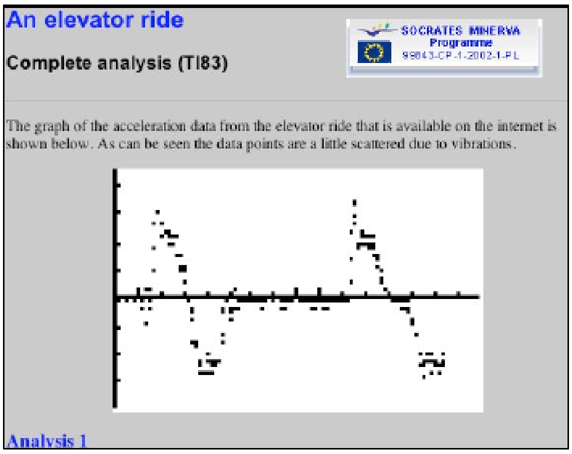

Figure 6. First step of *Complete analysis with TI-83*

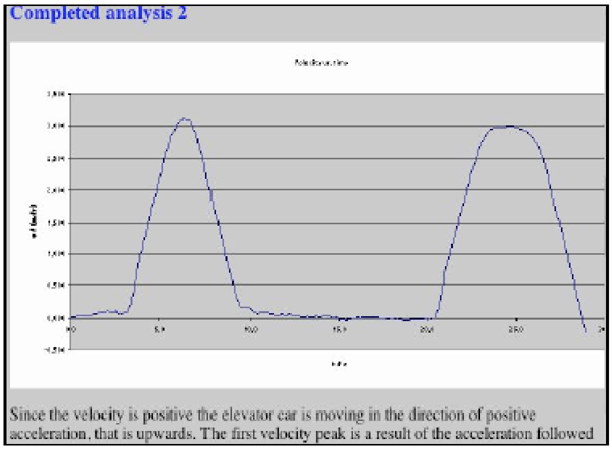

Figure 7. Second step of *Complete analysis with Excel*

PROJECT EVALUATION

A plan for evaluation of the LEPLA materials has been made during the last two meetings of the Steering Committee (August 2004, February 2005). This includes:

- module testing in secondary teaching, university introductory courses and teacher education activities in the countries involved in the project;
- collection of evaluation data by the administration of written questionnaires to students and teachers;
- direct classroom observation in a few selected contexts both by researchers involved in the project and by external observers;
- external evaluation of the LEPLA modules by university colleagues.

Table 1 shows the plan for evaluation: numbers of students involved in each country who will respond to written questionnaires, number of reports to be collected by different kinds of evaluators.

Table 1. Evaluation plan

	PL	IE	IT	SE	UK	tot
Students' questionnaires						
Lower secondary		60				60
Higher secondary			55	15		70
University	80		200		20	300
Teacher training		15		15		30
Type of report						
Teacher of the class	1	3	4	2	1	11
External observation	2	2	4	1	1	10
External expert	2	2	4	2	2	12

The *Students' questionnaire* aims at investigating whether the students find the material useful in performing the experiments, how easy are instructions to follow and to what extent independent use of the materials is allowed, which aspects of LEPLA the students find most interesting and which ones they appreciate less, to what extent they perceive that working with LEPLA can affect their ideas about physics and about experimental activities.

The *Teacher's report* is intended to evaluate the LEPLA project through the eyes of the teachers whose classes used the LEPLA materials. It is divided into two sections. In the first one feedback on the teacher's personal experience and background is required, including information on previous experience with technology, the subjects taught and at what level, information regarding previous experience with LEPLA, if they had any, and what they consider to be the strengths and weaknesses of the material. The second section of the report should provide feedback on the teacher's experience within the classroom, including information regarding the impact of this style of teaching on both the learning outcomes and additional cognitive skills, together with comments on whether or not using this type of material could influence their teaching methodology.

The *Classroom observation report* is meant to be filled by an external observer of the students' classroom work while using LEPLA materials. Beside some general information about the group under observation, it will include comments on the behaviour of the students related to the different stages of the work with the LEPLA materials (the setting of the experiment, data acquisition and analysis, etc.) and some more general comment on the role of the teacher and the attitude of the students during the activities.

Finally an external evaluation of single modules is being asked from university collegues and experienced teachers. The *Expert report* is designed to collect comments on the different sections of each module, allowing to asses the appropriateness of the theory presented and of the experimental procedures suggested, the level of detail provided for the students to perform the experiment, the appropriateness of the methodology proposed for the data analysis, the usefulness of the sample data, and more in general the pedagogical/didactical value of the LEPLA approach and the potential of the LEPLA approach for promoting physics

At present the evaluation process is in progress and an overview of results will be ready before Summer 2005.
An example of the kind of feedback that is being collected through the students' questionnaires and the classroom observation reports is given in Appendix 2 and 3.

CONCLUSIONS

First feedback collected from different sources seems to indicate that students are comfortable with the web format of LEPLA: most of them find the instructions easy to follow and the experiments interesting and easier to perform with the guidance provided by LEPLA
Some of the comments indicates that students appreciation of physics increased, although young students may find it difficult to answer to questions requiring some sort of meta reflection on one's own learning. There are also evidences that the open ended format of questions within LEPLA modules encouraged students to think and reflect more and stimulated a more independent approach to physics investigation.
Quite soon more evaluation data from different sources and contexts will be available allowing a reliable picture of the educational potential of LEPLA to be presented. Initial evidence seems to suggest that the project modules can be of great use in physics teaching and we are looking forward to the final results of the evaluation process.
For the future it is our hope that LEPLA will continue to live and grow after the end of the EU funded project and will be disseminated to physics teachers in all European countries. The project has provided valuable opportunities for the people involved to get to know educational contexts different from their own and to establish important research contacts with researchers and institutions in the four other countries. We hope to share this enriching experience with teachers and educators from all Europe.

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Barbara Pecori
Physics Department
University of Bologna
Viale B. Pichat 6/2
40127 Bologna (Italy)
E-mail: pecori@df.unibo.it

Bogdan Zoltowski
Institute of Physics
Technical University of Lodz
Wolczańska 219
93005 Lodz, Poland
E-mail: bezet@p.lodz.pl

Colm O'Sullivan
Department of Physics
National University of Ireland, Cork
Cork
Ireland
E-mail: ctosull@ucc.ie

APPENDIX 1: The LEPLA Group

LEPLA is a Socrates-Minerva project (99843-CP-1-2002-PL-M) sponsored by the European Union. The project is a joint venture between several Universities in Europe:

- Technical University of Lodz, Lodz, Poland (Bogdan Zoltowski). Coordinating Institution.
- University of Bologna, Bologna, Italy (Barbara Pecori)
- University of Padova, Padova, Italy (Giacomo Torzo)
- National University of Ireland, Cork, Ireland (Colm O´Sullivan)
- University of Ulster, Jordanstown, United Kingdom (Ken Houston)
- University of Malmö, Malmö, Sweden (Lars Jakobsson)

The project contract covers the two and a half year period from October 2002 to March 2005.

APPENDIX 2 : Example of students' answers to questionnaire

A class of 24 Italian students have answered to the questionnaire after working on three modules about light propagation and absorption.
The answers collected from this class though reflecting the opinions of a very small group of students do not appear to be peculiar of this group. They have been found to be in agreement with other feedback collected from students who had worked with modules on mechanics.
The answers to the questions of importance for the quality of the project can be summarized as follows:

Question 7: Did you find the web format of the LEPLA material helpful in performing the experiments?
23 Yes and 1 No.
Most comments are positive, here are some examples:
Yes, because it helped me step by step in performing experiments
Yes, because it makes practical work quicker, though commands on the calculator are not easy to remember
Yes, because everything is explained in details
Yes, because it makes things easier and more enjoyable
No, because the calculator does everything and one does not get the meaning of the experiment

Question 8: Where the instructions given in the LEPLA material easy to follow?
1 Very easy, 20 Easy, 3 Difficult and 0 Very difficult.

Question 9: When using the LEPLA material how often did you have to ask for help from your teacher?
0 Very often, 6 Often, 18 Not very often and 0 Never.

Question 11: Which aspects of the LEPLA experiments did you find most interesting and useful for your learning of physics? Please explain.
There are 15 answers out of 24 questionnaires
Among the aspects put forward we quote some:

- *Real time data acquisition*
- *Real time graphic construction*
- *Physics theories in practice*
- *The combination of classical physics and new technologies*
- *Easy to use materials, data accuracy and easy instructions*
- *Experiments that are not usually performed in lab*
- *Constructing and performing the experiment on one's own*

Question 12: Did the use of LEPLA materials change the way you think about physics? Please explain your answers.
2 Yes and 22 No
No, to perform and understand experiments the study of theory is necessary
No, physics is always the same
Yes, making experiments is more fun and it allowed me to do experiments I thought were not possible
No, it has always been one of my favourite subjects
No, we made experiments anyway
Yes, not completely, but it made it more involving

Question 13: Did the use of LEPLA materials change your approach to scientific experiments?
14 Yes and 10 No
No, we always made experiments
Yes, it made experiments more interesting
Yes, I felt more in charge of the experiment
Yes, because data were easy to collect
Yes, because it made the job quick and easy
Yes, they are less complicated because there are step by step instructions
Yes, because instruments are more accurate
Yes, because more room is left to the data analysis

APPENDIX 3: Example of Classroom observation

The following report is based on direct observation performed by one of the authors of this paper (BP) in a Swedish introductory physics class.

The classroom observed in Malmö (Sweden) was made of 17 students (13 girls and 4 boys) divided randomly in 6 groups.
The students had worked with TI83 also before, whereas they were at their first experience with the Lepla materials. The teacher had selected the module on *Ball bouncing* for the students to work with and saved the corresponding pages on CD-rom for off-line use. Each group had his own computer and TI83.
The teacher made a very brief introduction to the experiment which was new to the students. The students were supposed to gather all necessary information from the LEPLA materials.
The students put up the experiments using the materials provided by the teacher. They did not appear to have problems in arranging the experiments, although some groups were slower and more uncertain on how to proceed. They appeared to have understood the objective of their work, and showed confidence in using the graphing calculator. The intervention of the teacher did not seem fundamental in this phase.
All groups repeated the acquisition more than one time. They were clearly committed to performing the experiment, they strove to get satisfactory results and looked very happy when they finally managed to.
They had not been previously instructed on the aims of the data analysis. They then proceeded step by step performing the suggested calculations on the TI83 and trying to answer to the questions.
The section on energy appeared to be the most challenging both for conceptual and computational abilities required: The aim of the analysis became clear only during data reduction and the intervention of the teacher at this step appeared to be crucial. The students showed enough confidence with the graphing calculator for basic calculations whereas they were less confident on curve fitting.
In general all students except one looked very involved and willing to show a good performance (the exception is a student who attended the class irregularly). There were lively discussions in the groups and the students collaborated to find solutions.
In the end they looked pretty satisfied of their work, though some regretted to have spent so much time in doing and re-doing calculations that they could not complete the data analysis. They did not seem to blame the LEPLA guide for this but simply admitted to have been too slow on calculations.