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e*Content*plus

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[1] OJ L 79, 24.3.2005, p. 1.

Contents

1. What is LiLa all about?

Project Objectives

LiLa, the Library of Labs, is an EC funded project that aims to foster and enhance the learning of the natural sciences and engineering. These subjects are crucial for the economic future of Europe, however the numbers of young people interested in studying these subjects are steadily decreasing in most of its constituent countries . It has often been assumed that the study of the natural sciences and engineering is perceived by students to be too demanding and theoretical. Some university courses have therefore developed simulation, known as 'virtual laboratories'), to help make abstract concepts more graphic and concrete. Similarly, experimental apparatus is being made accessible online as 'remote laboratories' in order to provide practical experience in a more flexible way. LiLa aims to make as many of these virtual and remote laboratories centrally accessible as possible.

To understand the added value the LiLa project provides for teachers and students, it is important to recognise the advantages of virtual and remote laboratories. Universities have developed virtual laboratories for a number of reasons:

- they illustrate abstract algorithms and mathematical descriptions of nature, thus making them understandable in a more vivid way;
- students can adjust parameters observe the resulting changes, in much the same way as a real lab;
- some environments allow easy developmentof new simulations;
- under some circumstances, real experiments are too complex, too expensive, or too dangerous to be used educationally;
- virtual experiments can tolerate mistakes that would lead to severe and expensive damage to real apparatus;
- experiments can be customised to suit the students' needs and setups are more flexible than for real apparatus;.
- . Simulations provide experiments that cannot be observed in physical reality;
- virtualexperiments can be performed by many students concurrently.

Remote experiments have somewhat different advantages:

- they are useful incircumstances where equipment for hands-on experiments or laboratory capacity is limited;

- they allow greater flexibility concerning time and location than conventional labs;
- Students have the potential to access a greater number of experimental setups;
- Apparatus setup time and effort is reduced, allowing the students to focus on the actual scientific or engineering principle that the lab aims to demonstrate;
- processes found in today's industry are usually operated remotely from control rooms using computers communicating in networks, so remote experiments can prepare students for situations they will encounter later in their professional life;
- sharing of equipment is especially important if the equipment is not affordable by every university, given that it is difficult for individual institutions to use the apparatus to its maximum capacity.
- In some cases remote experiments are preferred for security reasons, for example if radioactive substances are involved.

It is important to note that remote experiments are not designed as a substitute for real laboratories, as they cannot replace hands-on lab experience. Nevertheless, they are well suited to complement real labs and may be a useful pedagogical alternative in many cases, as well as offering an alternative if these are not available. .

The latter argument, i.e. the sharing of resources, is a key principle behind the Lila project. It is currently difficult to envisage a single institution financing the development of all the virtual laboratories and remote experiments necessary to cover their curriculum. Whilst this goal might be achievable at a national level, the limited number of experiments currently available means that European-level collaboration is highly desirable in order to build an adequate community of interest.

Sharing of this content still only occurs rarely because:

- The existence of the content is often not known and cannot be retrieved easily, since there is neither a central record nor an appropriate means of indexing it;
- Lecturers often work in isolation and are unaware of colleagues at other universities;
- Even if found, the material can often not be used because a scheduling system is missing (important for remote labs) and authentication mechanisms for students of other institutions do not exist;
- Co-operative work is not supported by most online laboratories, but is desired by most students and university teachers.

The core objective of LiLa is to build an infrastructure to provide the above services, avoiding the need for each to do this independently.

The ways in which of Lila aims to address the situation described above are summarised as:

- creation of a technical and organizational framework for the mutual exchange of experiments across Europe (and beyond);
- building a repository of experiments on a central server where experiments can be retrieved;
- offering the experiments as reusable modules which can be run on local Learning Management Systems as well as on the LiLa portal;
- equipping the experiments with describing data (metadata) and integrate them into library catalogs, thus making them retrievable in library systems;
- making the experiments accessible via an access control and a booking system that allows reservation of experiments by lecturers and booking of experiments by students;
- facilitating the creation of courses and allowing users to supplement and change courses;
- integrating the LiLa experiments into a framework that fosters collaboration between students and discussion on experiments;
- providing the necessary technical framework to download and embed the experiments into learning management systems of any university interested in their use;
- disseminating the LiLa network across Europe.

2. Who is participating in the Library of Labs Project?

The LiLa consortium consists of eleven partners from higher education and industry, who perform different tasks in the project: some provide the experiments that are made available through the Library of Labs ('content providers'), some cater for the technology that is used for making content available on the internet ('technology providers'), and others are 'scientific advisors' who provide valuable information about how to design the LiLa infrastructure.

Figure 1: Distribution of LiLa partners among Europe

The content providers include:

- The **Technical University Berlin** provides 'RemoteFarm'; an online laboratory of remotely controlled physics experiments used in undergraduate education.
- The **University of Cambridge** provides a reconfigurable chemical reactor 'Weblab' which can be used for teaching several subject on the Chemical Engineering curriculum.
- The **Aristotle University of Thessaloniki** contributes the Nanotechnology Remote Lab (NRL).

- Other content providers have developed virtual experiments or simulations which give access to experiments which cannot easily be performed in reality. Among them are the Universities of **Stuttgart** and **Basel**, the Cambridge-based company **CMCL innovations**, and the **University of Linköping** with its OpenModelica simulation language.

The second group of partners is formed by the technology providers. Experts in their respective fields, they develop the technical infrastructure needed for the LiLa environment:

- The core technical infrastructure is set up and run by the Computing Centre of the **University of Stuttgart**.
- Design and implementation of access control and scheduling systems is carried out by the Telematic Systems Engineering Department of the **Polytechnic University of Madrid**, who have significant expertise in this area.
- The **Technical University Berlin** provides search functionalities and a metadata structure by which experiments and supporting materials can be easily found.
- SUN Microsystems Germany (now **ORACLE Germany**) provided the "Wonderland" 3D software environment, used for modelling some of the experiments, and contributed valuable know-how for the technical implementation of the LiLa portal.

The scientific advisors contribute towards the following fields:

- The **Technical University Delft** is an experienced creator of online courses and materials and adds pedagogical expertise to the consortium, in order to give students the best learning experience possible.
- Evaluation tools are developed by the **University of Thessaloniki** and the Technical University Berlin.
- The Library of **the University of Stuttgart** provides knowledge on metadata and e-publishing of traditional media.

	Partner	*Participation Type*	*Contribution*
	Universität Stuttgart	Coordinator Content Provider Technology Partner	VideoEasel Simulation Environment
	Technische Universität Berlin	Content Provider Scientific Advisor	RemoteFarm Remote Experiments
	ORACLE Deutschland BV & Co. KG	Technology Partner	Wonderland 3D Environment
	Technische Universiteit Delft	Scientific Advisor	Didactics, Evaluation

	Linkopings Universitet	Content Provider	OpenModelica Simulation Language
	Universität Basel	Content Provider	NanoLab
	Universidad Politecnica de Madrid	Technology Partner	Access Control
	Aristoteleio Panepistimo Thessalonikis	Content Provider Quality Management	Remote Labs, Evaluation
	University of Cambridge	Content Provider	WebLabs
	CMCL Innovations	Content Provider	SRM Websuite
	MathCore Engineering AB	Technology Partner	3D Modelling

3. Status of the LiLa portal at the end of 2011

For the users, the LiLa portal (www.library-of-labs.org) is the single point of access to all available content. In the portal, users can search for the content they need; usuallywith a keyword search, but browsing by subject fields is also possible. The results list gives the most important information about an experiment. By selecting one of these experiments the usercan gain more detailed information, such asan abstract, the author, a screenshot whichshows whatthe experimental interface looks like, and the conditions of use. From this page the experiment can be run directly on the portal, either to get an impression what can be done with the experiment before uploading to an LMS,or simply to conduct the whole experiment.

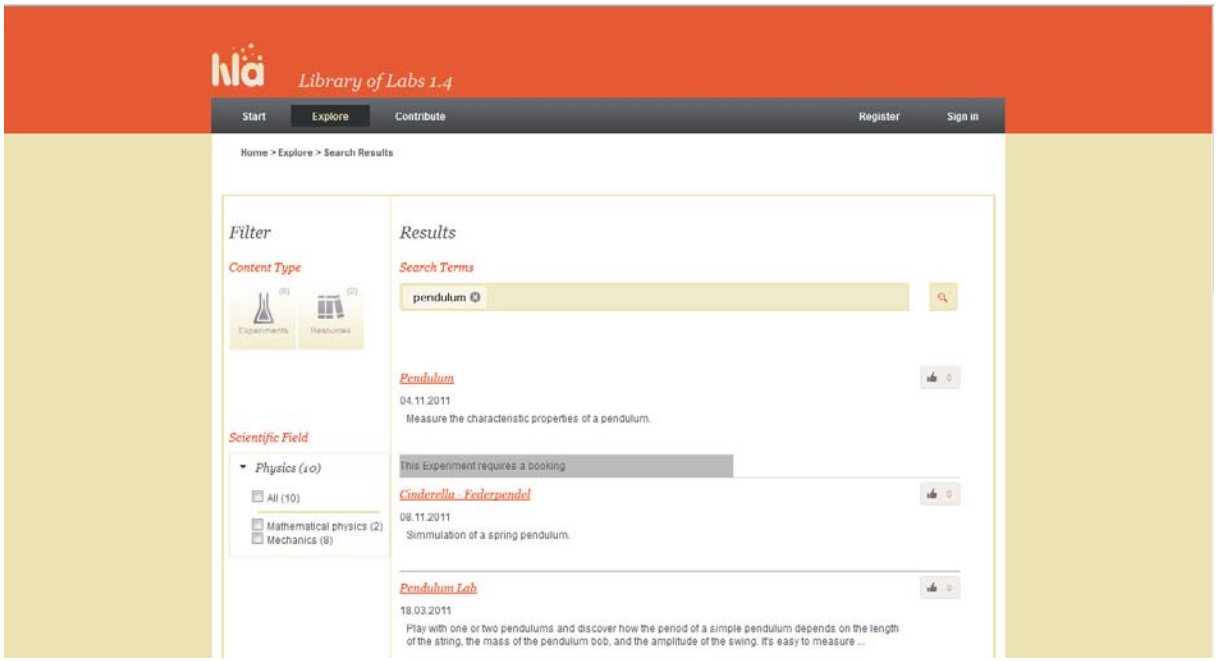

Figure 2: LiLa portal; search result for "pendulum"

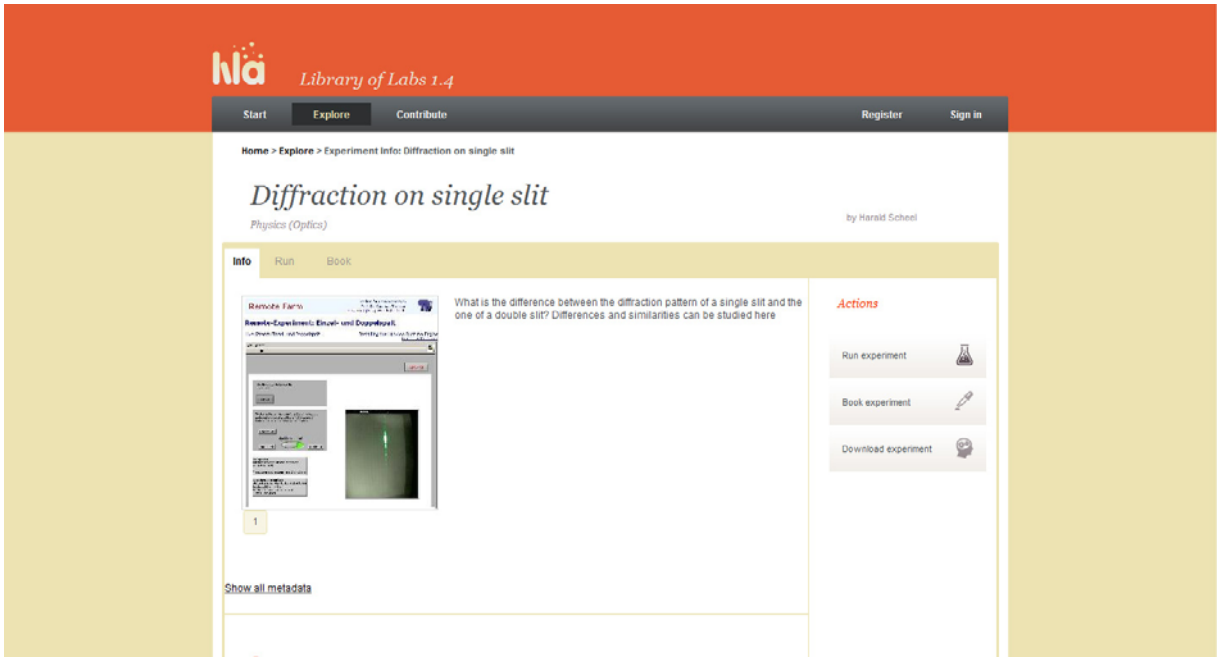

Figure 3: LiLa portal; example of an experiment description

The option to download an experiment is made possible using a SCORM compliant package (a zip-file) known as a 'LiLa Learning Object' (LLO). This means that the experiment can be uploaded to Learning Management Systems of the users using the "upload-SCORM-module" functionality that almost all Learning Management Systems (like ILIAS, Moodle, or Blackboard) offer. Hence teachers or students can aggregate the experiment with additional learning material in their courses. Some experiments also allow the download of measurement data that can be used for further calculations by the students; who in turn can upload the results of their calculations to the Learning Management System again to share them with others.

In summary, that the LiLa portal is for most use cases a repository for experiments that are used in local learning Management Systems. Execution of experiments and student interaction would normally take place in the latter. Initially it was planned that LiLa would also support collaborative work of students in the virtual 3D-world OpenWonderland. But since tests of scalability and stability of the Wonderland environment showed this to be unrealistic, this idea was abandoned: teachers and students must be sure that the technical environment works reliably whenever they need it. A portal functionality that will be available soon is a tool for the creation of lessons (learning units).

The bulk of the experiments currently in the portal belong to the subject area of Physics. But other fields are represented as well. At the end of the LiLa project experiments were distributed as follows:

Physics:	150
Mathematics:	75
Computer Sciences:	21
Chemistry:	6
Engineering:	7

41 of these experiments are remote experiments, 218 are virtual experiments/simulations. 157 are provided by partners of the LiLa consortium, 102 from other institutions. As can be seen , the LiLa initiative has developed quite some momentum already.

In the LiLa project the partners tried to make online laboratories as easily accessible as possible. Considering the technological diversity of the content this was a challenging task, however the partners succeeded in bringing all content into a consistent and uniform "wrapping" in compliance with the SCORM standard); allowing use with every standard web browser. In most of instances a 'Java Runtime Environment' needs to be used, however this is preinstalled on most PCs sold on the market. Nevertheless, it might be missing on standard configurations of computers used within institutions.

Many simulations are downloaded and run on the computer of the user. Others just provide an interface and send user information (like parameter settings) to a backend server that carries out the calculations and sends back the results. In the context of the modeling language "Modelica", the software development environment is web browser-based and allows students to develop their own code for simulations. This code is sent to a backend server which compiles the code and sends back the results (often graphical representations of the simulation). Currently this facility is used for

learning the Modelica language. In future a graphical interface will be developed to allow flexible modeling of simulations without programming knowledge of Modelica.

If the online experiment is a “remote experiment” all software that is needed on the user side to control the remote equipment is wrapped into an LLO. In some instances, like the Cambridge Chemical Reactor Weblab, this would mean that the user would be given access and control over a ’virtual machine’ via a “remote desktop” from where the experiment is controlled. This variation had to be introduced for security reasons. Remote experiments also require prior booking. The first step in this process is for the content provider to be contacted by a teacher. Once this has taken place, the teacher can offer a calendar with predefined time slots which the students can book. This booking can take place on the LiLa portal, i.e. the booking system is a service for content providers and users alike, howeverthe system will also work if the experiment is provided on a local learning management system to the students. The wrapping mechanism will redirect the students to the booking system before they can access the experiment, thus making sure that only the students that are entitled to access the experiment can do so.

Most experiments are freely available for non commercial use. They are published under a Creative Commons” license with the additions “attribution” (BY), “non commercial” (NC), and “no derivates” (ND). This means that users are allowed to download experiments and share them with others as long as they credit the author of the experiment, but they can’t change them in any way or use them commercially (see http://creativecommons.org/licenses/?lang=en). Associated learning resources are distributed under a Creative Commons license that allows users to adapt the resources to their needs, but requests them to re-contribute it to the community (“share alike”). Content from companies is distributed under the license of the respective company.

4. The dissemination of online laboratories in universities

The LiLa project has shown that online laboratories are undergoing a transition from being a tool for specialists to becoming an accepted method in engineering and science education. There is still quite some faculty resistance against online laboratories and new media in general and there are justified concerns concerning the time effort to introduce these new technologies. Nevertheless, the introduction of online experiments in the courses of teachers who never had to do this before can be successful and it can be facilitated by portal functionalities and organizational measures.

Among the major problems of dissemination of eLearning in general is the fact that from a personal perspective of an assistant professor who is still looking for a tenure time, investments in teaching are not very rewarding. Scientific reputation is important to make a career ("publish or perish"), not effort (or success) in teaching. Mitigating this problem, the LiLa project has developed a workflow that allows the publication of online experiments and learning modules using online experiments in library catalogues, thus making them quotable as publications in literature lists of an academic.

The discussion about the usefulness of online laboratories often focuses on the improvement of students' learning outcome. Nevertheless, the impact the use of online laboratories has remains unclear compared to the other online resources involved. Student motivation can be a very good indicator of learning success, and early indications are that online experimentation has a very positive impact in this respect (see 5. Evaluation Results).

If teachers experience deficiencies in their teaching situation that could be mitigated with the use of online experimentation, they are quite open to the adoption of new teaching methods. In our experience this was most often the case in connection with very big classes (a couple of 100's of students). Under these circumstances students are merely lectured and remain passive. Online experiments offer the opportunity to initiate interactivity and active reasoning on the subject. In case of remote experimentation a laboratory experience - even if it is limited - can be facilitated that would otherwise be absent completely.

An important argument for the use of remote experiments, though, is the absence of the equipment. Often universities would rather try to set up the equipment themselves than to use the existing equipment of another institution remotely. In case this is absolutely impossible, the openness to use the equipment of another university is comparatively good. Here the successful dissemination of remote experiments occurs not within a university, but between universities within a specific field. Simulations are very useful for the visualization of complex phenomena. This is reflected in the LiLa online survey where "lecture demonstrations" featured as most popular scenario for the use of online labs (see figure 4). Simulations of this kind mostly allow for a change of parameters that can be viewed immediately, but do not provide any measurements. Furthermore, simulations, especially those running on the client system, are often very easy to use, have a simple interface and can be used without much training effort for the students on how to use them. Hence they are most often used in first year undergraduate classes. Nevertheless, their integration into curricula can take quite some time and effort for the teacher.

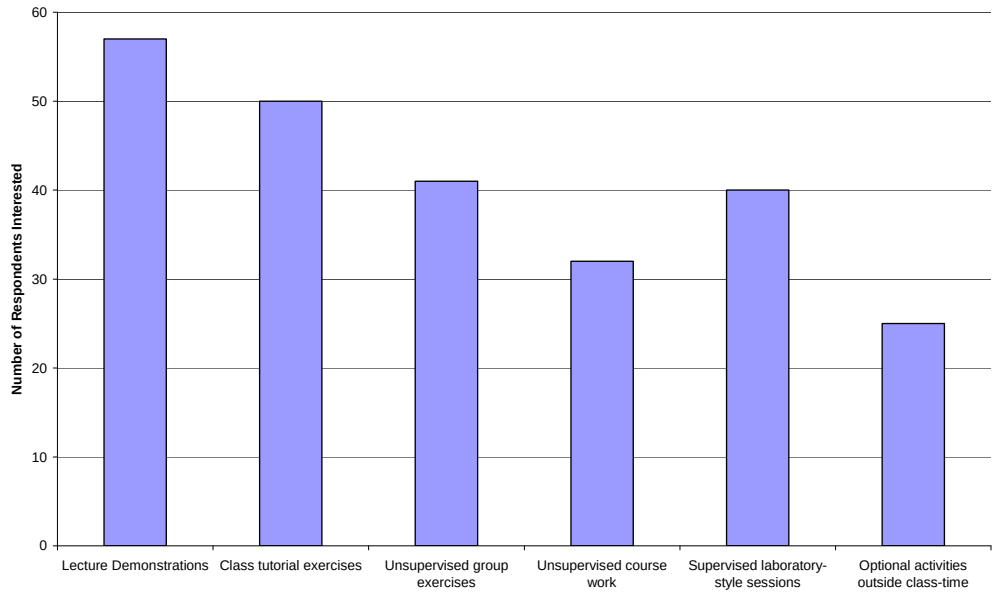

Figure 4: Usage scenarios for LiLa content

The LiLa survey among users showed that there was a clear demand for all of the main types of LiLa content available, although as figure 5 shows, there is a particularly strong interest in virtual/remote hybrid laboratories.

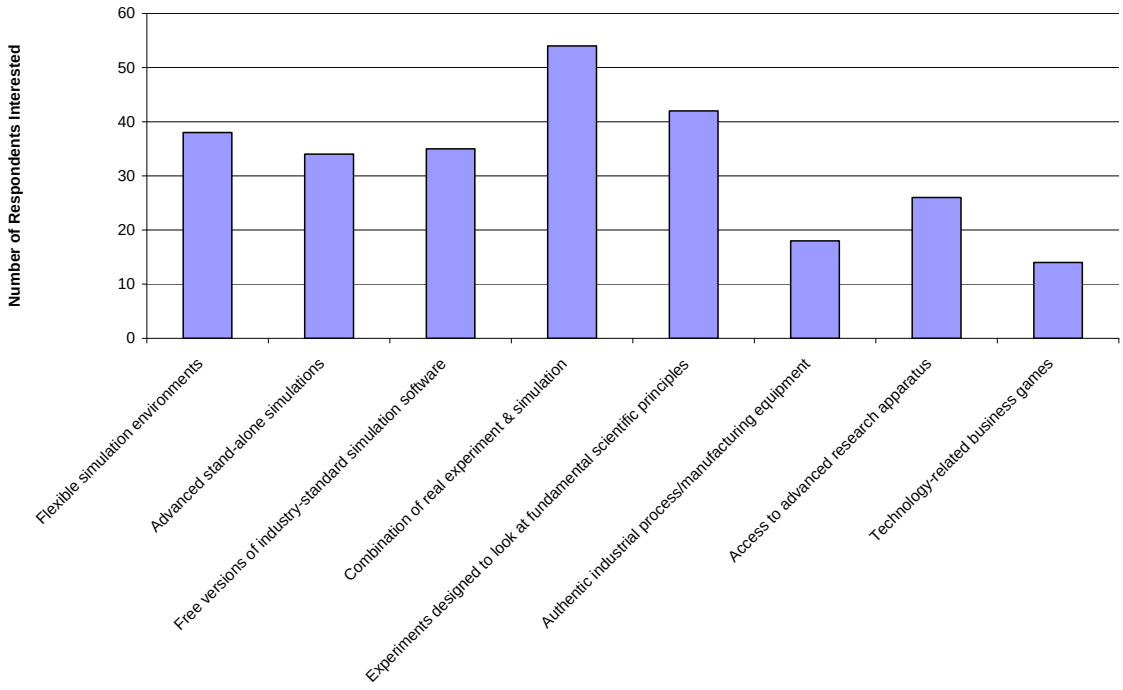

Figure 5: What categories of online experiment or activity would be useful additions to the course(s) you are involved in?

The most significant factor in the 'perceived ease of use' of online laboratories is the effort in time needed to integrate them into curricula. This does not just require new learning materials such as assignments to be developed; the whole procedure of teaching and learning has to be adapted to a

more student focused and independent learning scenarios – which implicitly induces a paradigm shift in the way courses are run. This effort in time is seen as the most important obstacle to the introduction of online laboratories, even among teachers who are otherwise open and positive towards the idea. Thus, only a small proportion of those who are generally in favor of using online laboratories in their classes have actually implemented them. While most remote labs and simulations are quite easy to use and teachers understand the principles and possibilities of an online experiment quite quickly, there are technical, organizational and political concerns about remote labs: will the client work for all students? How much support is required? Will the experiment be available when needed? Wouldn't it be better to have our own remote experiment instead? If so, who would maintain it? Technical reliability of the experiment is also a potential issue, with apparatus such as the Cambridge Weblabs being under maintenance for as much as 25% of the year. The most important measures that need to be taken to allow better dissemination of online laboratories are:

- More information about their proper use, i.e. acollection of surveys on learning impact and students' learning experience, good practice examples including the description of learning objectives)

- The possibility to exchange learning resources like assignments, meaning that it would not be necessary for every teacher to develop them from the beginning.

Both issues are tackled within the LiLa portal with features either already implemented (like exchange of assignments, realisation of web access to different kinds of labs, the LiLa booking system) or in the course of development (exchange of whole lessons and publication of information on the portal). With this, teachers who are open for the introduction of online laboratories in their teaching get the best possible support.

5. Evaluation results

Besides regular user feedback during the course of the project an evaluation was conducted near the end. In this evaluation the important user groups of the LiLa portal, i.e. teachers and students were asked about the usefulness of the LiLa portal and their satisfaction with the portal functionality. For example teachers were asked if in their opinion the “Explore” facility makes it easy to find relevant content. The result is to be found in figure 6. While the result is certainly already satisfying for the portal designers, it must be seen how improvements can be made since the successful search of content is a core use case of the portal.

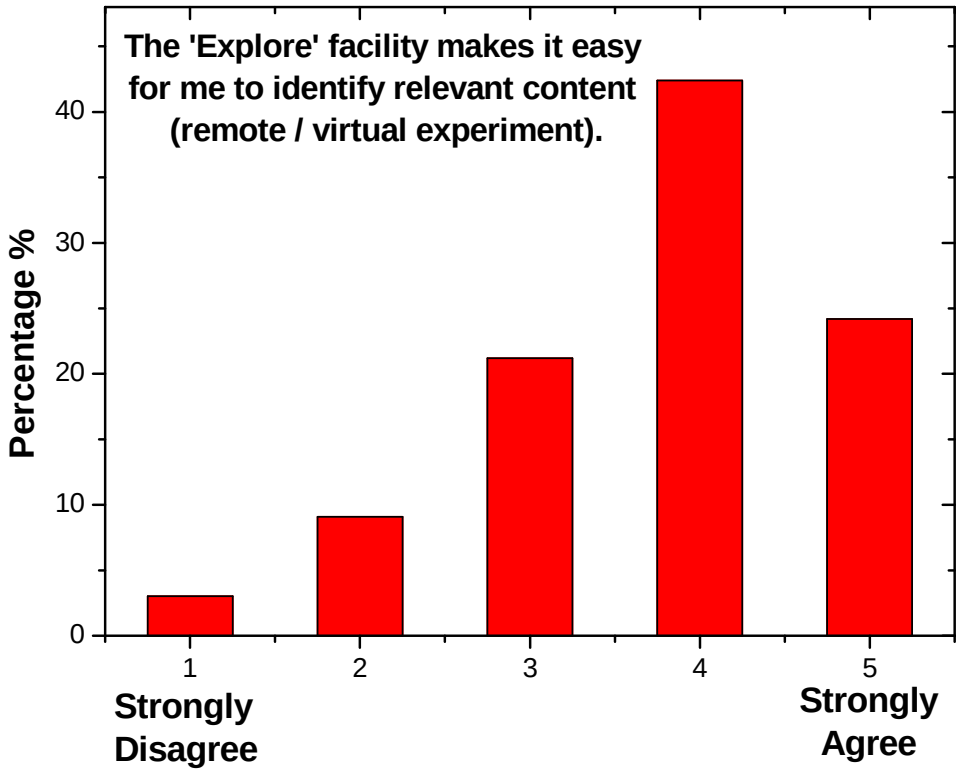

Figure 6: evaluation of “Explore” facility

About 40 percent of the teachers would prefer their students to perform the experiment directly on the LiLa portal, whereas 60 percent prefer to download the experiments and use their institution’s Learning Management System. This result is a good corroboration of the “parallel approach” taken by the project to make both possible: usage of experiments on the portal *and* in Learning Management Systems.

A more difficult issue is the booking system, since it covers comparatively complex communication involving the content provider and a teacher, and the teacher and his students. While 25 percent of the teachers still had problems using the booking system, the booking process for students seems to be quite straight forward.

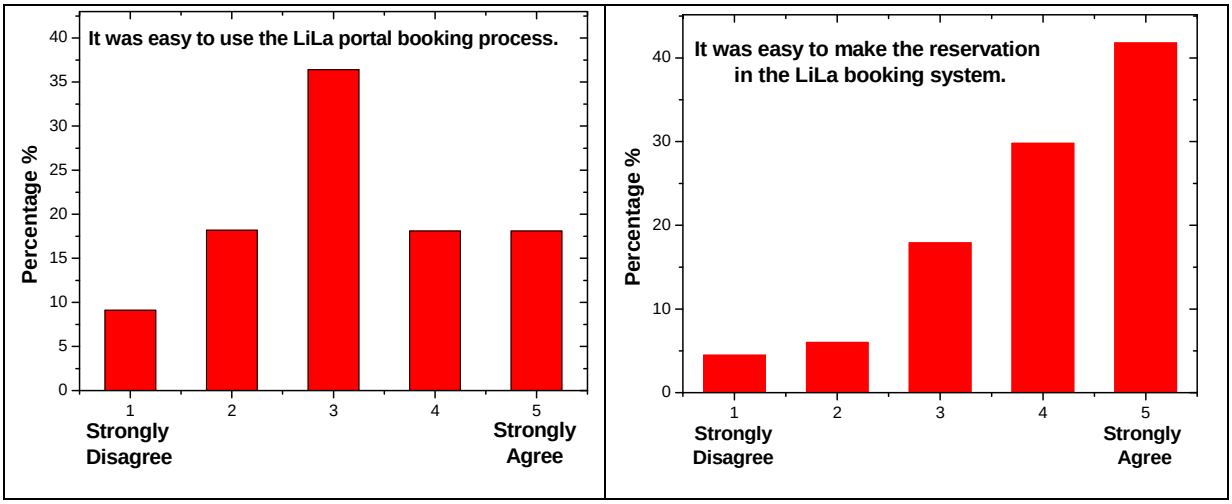

Figure 7: The LiLa booking system in the eyes of teacher (left) and students (right)

One of the most important questions for the impact of the LiLa project is the acceptance and perception of the online experiments by students. The students' answers throughout the courses and countries were unequivocal: they enjoy running online experiments and many say that their interest and motivation increased by using the online experiment. This result is especially motivating for the teachers since experience has shown that the subject matter is difficult for the students to understand, and the increase in motivation is expected to correlate with learning success (studies to prove this are very complex and were out of scope of the LiLa project).

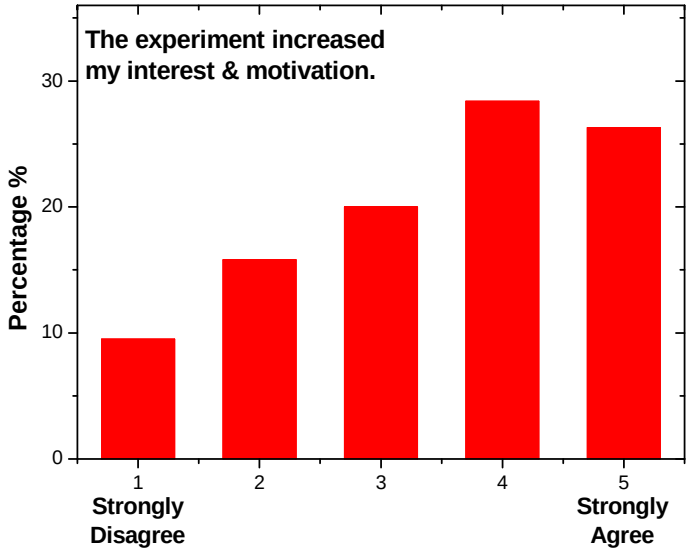

Figure 8: Increase of student motivation through the usage of online experiments

While the learning experience is very good for the students, only one third of them explored the content of the LiLa portal further. This shows that formal teaching is still widespread and independent learning is only of interest to a minority. Nevertheless, the LiLa portal allows and supports independent student learning; not discriminating between the roles of a teacher and a student. Every student can take over the role of a teacher any time.

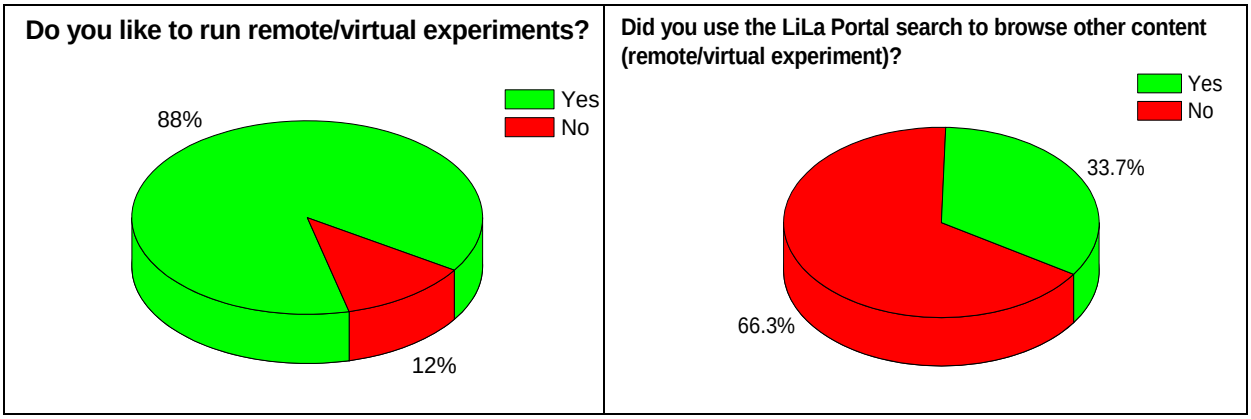

Figure 9: Students' enjoyment to run online experiments (left) and individual exploration of experiments (right)

6. The future of LiLa: A federation of labs and a community of lab users

In order to identify the best organizational framework to continue work after the end of the project, users were surveyed about their willingness to pay for content or the infrastructure, as well as what other commitments they would be willing to offer the community. It was found that very few of the potential users of online laboratories would be willing to provide any monetary payment for use of such resources (see Figure 10). A high proportion of respondents were nevertheless willing to offer some form of assistance or payment in kind in return, such as reciprocal usage of experiments or assistance in developing teaching materials.

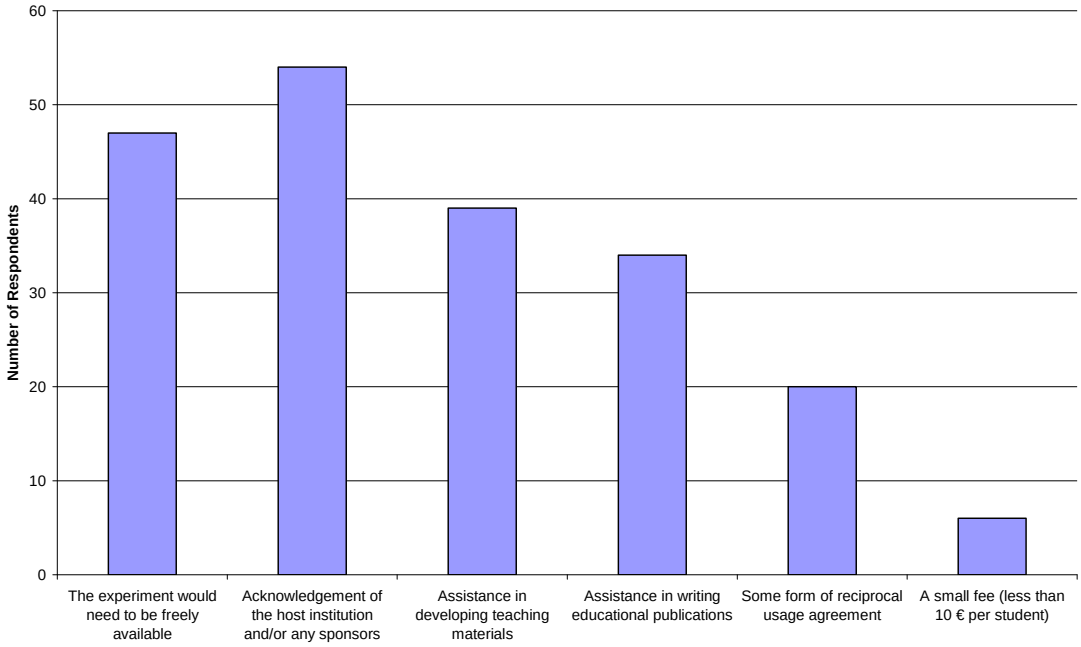

Figure 10: Assuming that the value delivered by the online experiment was sufficient, what (if anything) would you be willing to offer in return?

Of the individuals surveyed, it was found that less than 20% were willing to participate in core activities required to sustain the LiLa organization, such as being on the steering committee, contributing to portal development or providing technical support. Figure 11 shows that the number of respondents willing to engage in more peripheral roles is nevertheless relatively high.

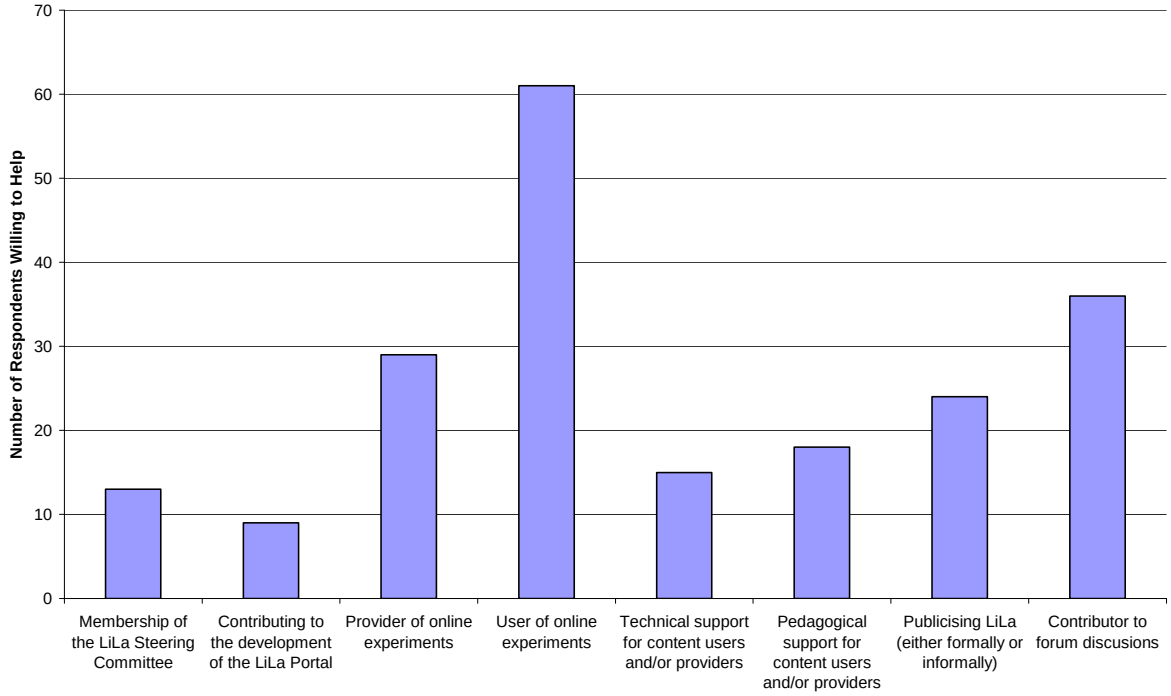

Figure 11: In which capacities would you envisage yourself contributing to LiLa?

Notwithstanding the limitations of the survey, there are good grounds for believing that the LiLa project can be successful and sustainable in the long term if the correct organizational model is adopted. Whilst some central organization will still be necessary, it is likely that an adequate number of volunteers would be willing to contribute to sustaining and developing the portal based on the evidence in Figure 11.

In order to provide a sustainable central organization for LiLa, it was decided to enter into a partnership with SEFI, the European Society for Engineering Education (www.sefi.be/). LiLa will either form an independent working group or a special interest group within the ICT working group. The decision depends on the future direction of the ICT Working Group which will be made by the end of 2011. Most partners of the LiLa consortium are members of SEFI, so their institutions will not have to join and pay for membership in a new organization, however individual membership is inexpensive for partners who are not members. With more than 150 member institutions (mostly Technical Universities) from 27 European countries SEFI is an excellent forumfor further dissemination of online experiments.

For at least the next 2 years, the portal will continue to be developed by the LiLa partners; primarily the University of Stuttgart, who will retain two full-time software developers during this period. Among the next features that are planned for the portal are:

- the “Lesson Creation Tool” - a tool for assembling online experiments with other learning resources in learning modules);

- the “Learner Support System” - an extension of the Lesson Creation Tool allowing the individual changes and amendments of a lesson as well as the start of learner discussions at different points of the course of the lesson;
- communication facilities;
- tools for exchanging usage experiences;
- further minor adaptations of the portal;
- the realization of emerging standards in the field of online laboratories.

It is expected that further content will be included in the portal as new partners become involved.

Global affiliation is an important topic as well. The University of Stuttgart is representing the interests of the LiLa community within the Global Online Laboratory Consortium (GOLC). GOLC is a new global initiative in the field of online engineering “focused on promoting the development and sharing of, and research into remotely accessible laboratories for educational use” (http://online-lab.org/). The GOLC homepage states:

> “As the usage of online experiments gains traction in the educational community, there is increasing interest in developing online labs on a common infrastructure. A unified and interoperable architecture is essential to convert the current tremendous interest for online experiments into an economy of labs that can be efficiently shared around the world.”

It is expected that this topic will play a very important role in the future development of the LiLa portal. This common vision is expected to drive the LiLa community, together with other European partners, especially the Massachusetts Institute of Technology in the US and the University of Technology Sydney in Australia.

As many users are interested in using LiLa, subject to the right content being available, it seems likely that the LiLa organization could impact upon the studies of tens, if not hundreds of thousands of students worldwide. Furthermore, the quality and quantity of content available will grow significantly over the coming years. Do you have experiments suitable to be published on the LiLa portal? Are you willing to share your learning resources on online laboratories with others? Are you interested in teaching technologies and pedagogy in engineering and science education in general? Then you too should get involved in LiLa!

7. Where can I learn more?

Further Information

For further information, please visit the LiLa portal (www.library-of-labs.org) and the LiLa project website (www.lila-project.org).