Deployment of Remote Experiments

The OnPReX course at the TU Berlin

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Abstract—**The development of internet technologies leads to recent trends of online based education in universities. Remote experiments give the students the possibility to experience real physical situations and compare their experimental results with those of the physical models (simulation). Online learning based on remote experiments is capable of diminishing the scantiness in practical courses in the universities. In this work we present an online practical course based on Remote Experiments (OnPReX), interactive graphics and an online tutoring system organized at the Technische Universität Berlin. Furthermore we give background information about the development of our remote experiments. The remote experiments are real–life settings, designed and engineered at the solid-state physics department of the Technische Universität Berlin. We describe the development of two online practical courses, focusing on classical and modern physics, addressed at undergraduate engineering students. We ran the online practical course based on Remote Experiments in two test phases over two semesters and conducted an evaluation from which we improved technical and pedagogical aspects of the experiments and the course.**

Keywords-component; Remote experiments; online tutoring; online course; Physics in engineering education

I. INTRODUCTION

Learning by experimentation is a fundamental element in natural and engineering sciences. The involvement of science and engineering students in practical work is a fundamental precondition of understanding the concepts and processes of science. A practical course in undergraduate engineering and science studies requires large amounts of resources, equipment and manpower. Unfortunately many universities are not able to provide in engineering education the laboratory capacity for the numerous undergraduate students due to the high costs involved. At the Berlin Institute of Technology there are more than 500 students in an undergraduate physics course. In the learning process of physical phenomena elements of physics theory, physics models and practical experiments must be involved. Often theory, models and experiments are offered separately, with time shifts in the curriculum, leading to a discontinuity in the learning process. Also there is a set of physical experiments not included in physics curricula, because they have a unique or expensive setup (e.g. Raman spectroscopy). Some other experiments are too dangerous to be conducted by beginners (e.g. the experiments with radioactive sources). Due to the lack of possibilities to provide a practical course for these students we organized an online practical course based on Remote Experiments (OnPReX). Our Online practical course is a combination of the remote experiments with an e-learning software platform called Moodle [1]. Remote experiments are real-life settings, built up at the TU Berlin and connected to a PC. We named this setting Remote Farm [2]. These computers are also used as web servers, so everybody can get access to the experiments through a free browser plug-in and gain control over all devices. All data recorded during the experiment is stored online and is accessible for users. The course schedule can be explained briefly as following. After studying the fundamentals of physical phenomena the students perform the experiments in small groups with the help of available literature and an online tutoring system in an online learning platform (ISIS) [3]. The acquired data can be evaluated and analyzed with suitable data processing programs. The reports have to be sent for correction via email to a lecturing tutor (see II.B). The OnPReX participants have, due to the online character of OnPReX, the possibility to take part in the practical course at any time and anyplace. Khachadorian et al. [14] showed that the OnPReX course matches with the authentic online learning environment characteristics explained by Herrington et al. [5].

II. THE COURSE

Any effective learning process in science should be based on the theory, physical models and experiments. In general these three elements are offered in separate courses and consequently the learning process of theory and experiment lacks cohesion. The online practical course based on Remote experiments (OnPReX) offers the possibility to deal simultaneously with theory, experiments and also physical models producing deeper understanding of physics. The elective OnPReX is an optional course for bachelor and intermediate diploma students. The OnPReX course (see Figure 1) contains classical physics and modern physics parts. The duration for each of these courses is one semester and is offered by the Department of Solid-state Physics at the Berlin

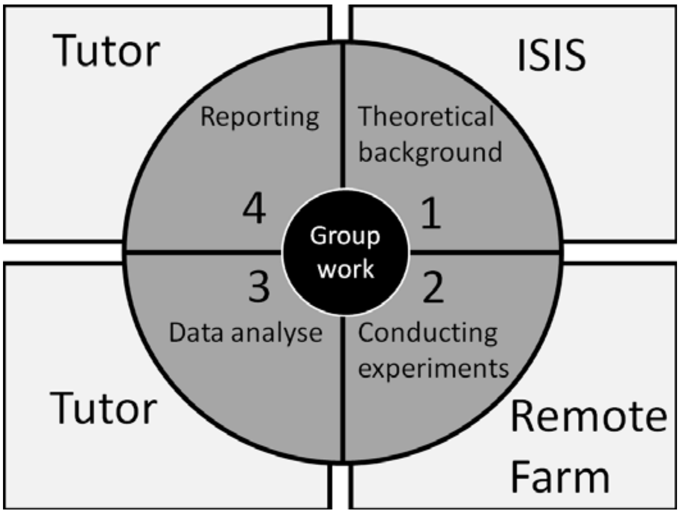

Figure 1. The four steps in OnPReX-course work flow are learning the theoretical background of experiments by information system for instructors and students (ISIS), conducting experiments via the web page of Remote Farm, data analysis with assistance of tutors and other work groups, and finally presenting the results of the experiment in form of a report

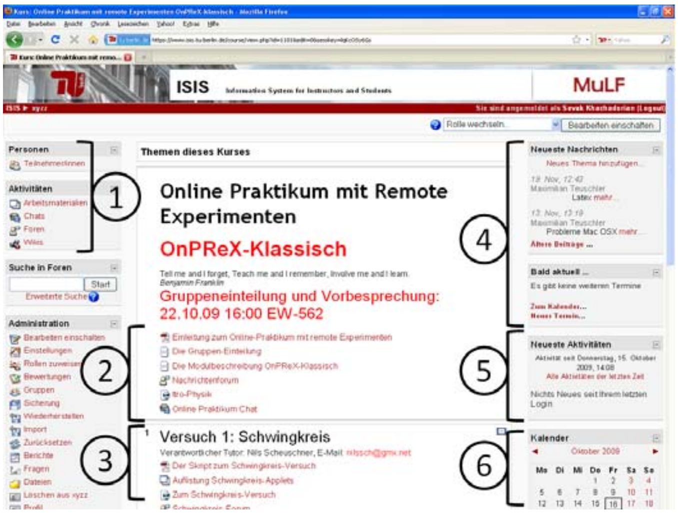

Figure 2. Information System for Instructors and Students (ISIS)-learning platform of OnPReX classical on the web page of TU Berlin. In OnPReX classical platform field showed with 1 to 6 are the list of participants, the general platform to the chats, forums and the wikis(1), general information about the course, the list of the participants groups, some organizational information and a forum and a chat room for the whole course (2), the field dedicated to first experiment explained in III.A.a) (3), the field for the coming appointments and latest news (4), latest activities field (5) and the course calendar (6).

Institute of Technology. The OnPReX-course was tested over a period of two semesters, and it has been operational for one year in a regular setting. The participants of this course, which are mostly undergraduate engineering students, work in groups of three. Each group conducts six remote experiments (via the Remote Farm [2]), analyzes the data obtained from experiments and writes six reports. Additionally every participant must take an oral exam to get the three ECTS (European Credit Transfer System) points. These courses are a challenge in the organizational and managerial sense. We offer the engineering students the opportunity to work at the same time with the physical phenomena through self managed learning and by means of theory, physical models (simulation) and experiments (remote experiments), whereby similarities and differences between the theory, the simulated model and the experiment can be studied. This leads to a better understanding of a given physical phenomenon through the analysis from various perspectives. The participants of OnPReX gain the following skills and abilities, which are qualified as the general goals:

- Learning of the fundamental physical phenomena by experiments and simulations.
- Learn to deal with remote-controlled experiments and with practice-related problems during the experiment.
- Learn to deal with text-editing and data processing programs.
- Improving the skills related to the IT communications and online competence and their integration in team working.

In Section V we show by means of an evaluation if the general goals of OnPReX are achieved.

To manage the OnPReX-course we needed two tutor teams: the technical support team and the teaching tutor team:

A. *Technical tutors team (Remote Farm):*

The tutors of this team design build and program the experiment. The maintenance of existing experiments and debugging the technical problems are part of their duties. This team consists of three tutors and two of them deal with the programming and the electrical part of experiments and one of them deal with designing and building the mechanical setup of the experiments. This team is responsible for the activities in the Remote Farm and work under supervision of a team leader.

B. *Teaching tutors team (ISIS platform):*

This team consists of three tutors. Every tutor is responsible for two of the remote experiments. The teaching tutors provide support to the OnPReX participants, understand the theoretical background of the experiments, analyze the data, and write the reports. They also correct the reports and consult the students to solve the problems. These tutors must answer the student’s questions in the forum regularly. This team works under supervision of the course instructor. The teaching tutors work in the ISIS environment.

III. The Course Cycle

The course cycle of OnPReX, as shown in Figure 1, contains four sections or four steps that the participants need to go through. The sections represent different learning activities: the first step focused on the theoretical background of the experiments using the Moodle [1] learning environment. Steo two is conducting experiments in the Remote Farm [2] via the Internet. Step three is the analysis of the obtained data in cooperation with the other group members and the tutors and step four is writing the scientific reports with the help of the tutors. We explain these processes below.

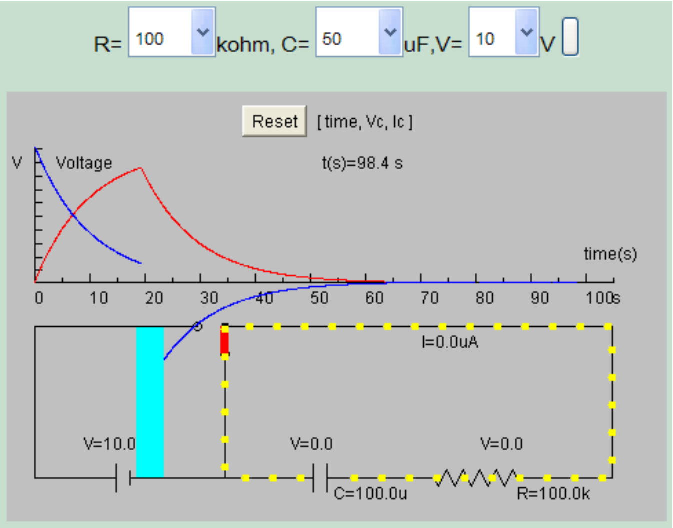

Figure 3. The simulation of a parallel plate capacitor taken from [4]

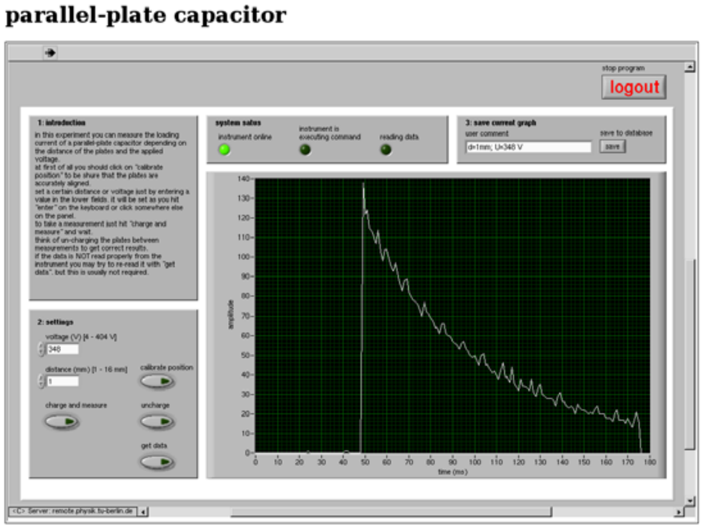

Figure 4. Front-panel of the Remote Experiment "parallel-plate capacitor". The graph shows the discharge curve of the capacitor for a given plate-distance.

A. *Learning the theory: Step 1 in the course cycle*

A well organized online course requires an efficient learning management system (LMS). We chose Moodle as our Virtual Learning Environment. The educational roots of Moodle as a learning management system is the "social constructionist pedagogy" [1]. Moodle is designed to help teachers create online courses with opportunities for improved interaction between students and tutors. The advantage of Moodle is that it is very flexible and can easily be deployed to thousands of students. Many institutions use it as their platform to conduct full online courses. Moodle offers series of activity modules such as announcements, course contents, documents, groups, project calendar, forums, wikis, databases to build richly collaborative communities of learning around their subject matter (in the social constructionist tradition). In Berlin we use a modified version of Moodle, called ISIS (Information System for Instructors and Students). The ISIS platform offers for each course an environment, where the whole course organized. We use two separate Moodle (ISIS) course environments, one for OnPReX classical and one for OnPReX modern. The ISIS environment in general on one hand due to its functionalities such as forums, wiki's and chat and on the other hand the various learning resources offer an efficient learning platform for the participants. The first step in the OnPReX course cycle is learning the theoretical background of remote experiments (see Figure 1). In Figure 2 we show the web page of ISIS for the OnPReX-modern physics. Each course management environment was divided into six parts. Every part, leading to a remote experiment contains the following learning resources and functionalities:

a) Learning resources:

The learning resources are listed for each remote experiment separately in the ISIS platform (see Figure 2). This includes the following elements.

- Script: a script contains the theoretical background of the experiment, the experimental setup, a guideline to conduct the experiment and the experimental tasks to be done. These scripts are an initial help for students and should facilitate the process of conducting experiments, data analyzing, and reporting.

- Simulation: Simulations of the remote experiment produce the same physical quantities for measurements as in real experiments. The theory, demonstration of similarities and differences between simulation and the experiment results in better understanding of the physics behind the experiments [11]. In Figure 3 we show a simulation related to discharging and charging behavior of a parallel plate capacitor [4]. The association of this simulation with the parallel plate capacitor remote experiment offered in the Remote Farm helps to understand the similarities and differences between simulation and real experiments.

- Remote experiment: The link from ISIS to the remote experiment. The remote experiment is the central point of the OnPReX. The course participants run the remote experiments through the web page of Remote Farm [2], which will be explained in Section III.B and IV.

b) Functionalities:

As shown in Figure 2 the ISIS platform of OnPReX classical [3] has some functionalities listed below.

- Forum: Each experiment has a separate forum, where participants discuss the experiment, its theoretical background and the experimental issues and problems. The questions and the comments can be edited and categorized every semester. The result of discussions can be also added to the wiki.

- Wiki: Every Experiment has a wiki page. This gives the participants the possibility to create and edit the contents and their gained know-how related to the experiment. With this functionality we aimed to provide the opportunity for participants to have a role not only as an user of learning resources but also as a content provider (a characteristic of the authentic learning environment [5]). These wikis should emerge as collections of learning resources and simulations and information about the theoretical background of experiments. The teaching tutors mentioned in Section II.B moderate the formation of the wikis in terms of categorization and sorting and also the editing of the contents provided by the students.

- Chat: Each experiment field has a chat room, where the student can chat about the experiments. We added this functionality to the ISIS page and motivated the students to use it and find out if this functionality is convenient for use in OnPReX. The evaluation of the course shows (see Section V) that this functionality is not used often by the participants. The participants of the course prefer to communicate via email, the forum or chat using other instant messaging services like Skype, Yahoo Messenger, etc.

B. Conducting experiments via Remote Farm: Step 2 in the course cycle

The second step in the course-cycle (see Figure 1) is conducting the experiments. The students use their web-browser (i.e. Firefox or Internet Explorer) to perform the experiments. The experiments of the Remote-Farm are real-life setups hosted at the TU Berlin. All variables can be manipulated via the server controlling the setup, which is realized by digital to analog converters, relays, stepping motors etc. For most of the experiments we also offer a video stream over the Internet to view the changes in the setup on-line. In Section IV we give a more detailed introduction to the implementation of our remote experiments. The control of the experiments, web-server and the browser plug-in are provided by a software called “LabView” [6] (by National Instruments). The plug-in is freely available over the Internet and is compatible with common operating systems (Windows, Mac and Linux) and browsers. So far the Remote-Farm offers 12 experiments with two additional setups in the construction-phase. One of the recently developed setups is the parallel-plate capacitor. In this experiment the students can study the discharging behavior of a capacitor with variable plate distance. Figure 4 shows the control-panel of this remote experiment. The setup of the experiment (shown in Figure 5) consists of two circular shaped aluminum plates with a diameter of 20 cm. The plates can be charged by applying voltages between 4 and 400 V. The capacity can be varied by changing the distance between the plates in a range of 1-16 mm. The students have to record discharging current curves, in order to determine the capacity for the given distance. The results can be compared to the theory studied in the first step of the course cycle or to related applets available on the Internet.

C. Data analysis: Step 3 in the course cycle

The ability of acquiring real experimental data is one of the many advantages of remote experiments. The ability to collect, analyze, and interpret data are the core-skills for scientists and engineers. Moreover, the engineers must learn to form and

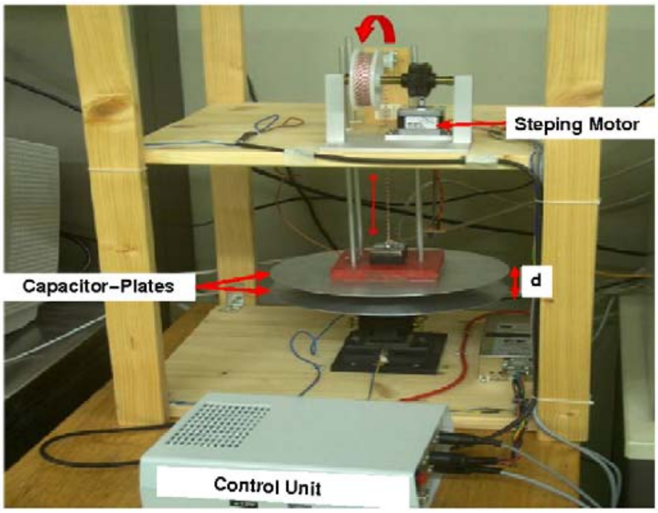

Figure 5. Photo of the parallel-plate capacitor. The circular plates are visible in the center of the image.

support conclusions and make order of magnitude, judgment and use measurement unit systems and conversions. This is important when reviewing experimental results and others work. Analyzing and representing the experimental results are one of the key skills taught in this course (see the OnPReX general goals in Section I). The measurement data must be evaluated and analyzed with the suitable data processing programs. The experimental data from the remote experiments are afflicted with experimental errors. The calculation of these errors, identifying unsuccessful outcomes due to faulty equipment, construction, process or designs are also skills that the students learn through OnPReX. To make the learning of "data analyzing basics" for OnPReX-participants easier we prepared an introductory script where the basics of data analysis and some data analyzing software products are introduced (see Section III.A.a)). As shown in Figure 1 (fourth step in the course cycle) we support the learning of data analyzing skills by online tutoring. As pointed out in Section II.B the teaching tutor team supports the OnPReX participants to solve the problems due to the data analyses. The OnPReX-participants exchange information and know-how among each other and also with the tutors via email, forum, chat and the wiki. The communication of the tutors and the students becomes easier through the ISIS Platform.

D. Reporting: Step 4 in the course cycle

The main purpose of writing scientific reports at universities is to communicate the results of experiments. The process of writing a scientific report also includes valuable practice in articulating the theoretical and empirical basis of a particular experiment, and the significance of the interpretation of results. With this training the undergraduate students are well prepared to produce reports for postgraduate studies and communicating their findings to the scientific/technical world. In an introductory script we give a general idea of the sections of scientific reports. The rest of this skill can be learned in the form of learning by doing with the assistance of tutors (teaching tutor team Section II.B).

IV. Technical details on Remote-Experiments

Our remote experiments are controlled with commercial software called LabView [6]. We currently use the version 8.20, which is not the newest version available. All devices manipulating parameters in our experiments are not directly connected to the server. For safety reasons we installed an additional microprocessor-board for each setup, which checks all critical parameters and is such able to prevent the setup from being damaged. The collection of data is in some cases performed by these micro-controller boards (connected to the server via RS 232), in other cases we use commercial meters controlled over RS232 or similar industrial standard interfaces. Examples for these meters are voltage, current, Geiger-Müller counter or charged coupled devices (CCD). A very important part of remote experiments is the ability to observe the experiment on live-pictures. To actually see the changes being made is one key learning experience. On the other hand, the live-pictures are the most important proof for the existence of real experiments. Most of the effects that can be studied with our experiments could be simulated by applets. We spent a considerable amount of time on the installation of a reliable video-system. After initial experiments with USB web-cams and software streaming solutions, we switched to commercial surveillance systems. The “AXIS 241Q Video Server” is a 4-channel video server providing Motion JPEG and MPEG-4 streams. It also provides JPEG still-images which we include in some of our LabView [6] front-panels, shown in Figure (control panel).

V. Course Evaluation

The practical course with remote experiments is a relatively new type of course, which still needs improvement. There is proof that student evaluations are good indicators of effective teaching (see, [7] and [8]). The process of (a) gathering information about the impact of learning and of teaching practice on student learning, (b) analyzing and interpreting this information, and (c) responding to and acting on the results, is valuable for several reasons [9]. We present the outcome of the evaluation for the 2008 to 2009 winter-semester. In this evaluation the questions are divided in two categories. In the first category we tried to find out if the general goals of OnPReX are achieved and in the second category of questions we tried to get responses from the participants in order to further develop and improve the OnPReX course. We used online evaluation software (Unizensus) to evaluate the OnPReX courses [13]. Unizensus is an evaluation-software, which has been used in the Berlin Institute of Technology (Faculty of science) over years. We present the major results of the evaluation in Table 1. 91% of the interviewees have not passed any physics practical course before and 63.5% had no experience with writing a report. This shows that the participants were beginners and were short on experience due to physics practical course. 81% and 55% of interviewees believe that the OnPReX helped to improve their text editing, and data processing skills, respectively. 73% of the participants believe that their online competence ameliorated through OnPReX. 64% of the participants believe that the skill of dealing with remote experiments is "very important" for a future occupation as engineer. They believe that this skill has real world relevance. The fact that the remote experiments can be conducted at any time and any place is considered "very important" by 73% of the interviewees. Finally 82 % of the interviewees would recommend OnPReX to other students. From the results and the comments of the evaluation we also learned, that some of the remote experiments were unstable. The control panels of some other remote experiments were rated as user-unfriendly. On the basis of the feed back from the participants we developed some solutions and modifications e. g. reconfiguration of control-programs, exchange of live stream structure, designing more user-friendly control-panels for remote experiments. Remote experiments are advantageous especially where the experiment is dangerous for the experimenter. For example 37.5% of interviewees raise concerns over working directly with dangerous experiments such as radioactivity. 62.5% of interviewees prefer to work with the remote experiment over the real experiment since in the case of remote experiments no device-damage can be inflicted. We mentioned the OnPReX general goals before (Section I) and in the first category of questions listed in Table 1. We show that the general goals of OnPReX, namely the improvement of text editing skills, improvement of data processing skills and the learning of the standards of reporting are partly achieved. These results show that the OnPReX must further be developed to provide better conditions for the students improving their text editing (mean value: 2.7) and their data processing (mean value: 3) and reporting (mean value: 3) skills.

VI. OnPReX and LiLa

Lila (Library of Labs) [10] is a project co-funded by the e**Content***plus* program of the European Commission. The major goal of this project is the development of an integrated platform for remote experiments and virtual laboratories. Eight European universities are involved this project and three companies. The project partners share their remote experiments, virtual labs and the learning resources in the LiLa platform. The LiLa project aims to create a repository of remote and virtual laboratories and develop educational formats and supporting media to ease the use of the repository and guaranty smooth access by means of a retrieval and access control system. This platform provides an efficient framework for online collaboration between the users and the instructors of online courses in each partner universities. Through the LiLa platform the users will be guided by the educational support system to use database of learning content. By means of the integration of OnPReX in LiLa on one hand we will be able to offer the students a better and a more diverse collection of remote experiments, simulations and learning resources and also gain through the collaboration and cooperation with the other LiLa partners more technical and didactical know-how for further improving the OnPReX. In particular our benefits as instructors of OnPReX from the integration in LiLa will be to use the Lila platform as a central starting point for finding remote experiments and virtual labs with the intent to implement them in the OnPReX. Secondly, get didactical support using the educational format and supporting media of

TABLE I. THE RESULTS OF EVALUATION: THE QUESTIONS ARE DIVIDED IN TWO CATEGORIES. IN THE FIRST CATEGORY WE TRIED TO FIND OUT IF THE OBJECTIVES OF ONPREX ARE ACHIEVED AND IN SECOND CATEGORY OF QUESTION TRIED TO GET RESPONSES FROM THE PARTICIPANTS IN ORDER TO DEVELOP THE ONPREX COURSE FURTHER.

Nr.	**Question[a] (objectives)**	**mean value**
1	improvement of text the editing skills	2.7
2	improvement of data processing skills	3
3	learning the standards of reporting	2.6
4	the importance of dealing with remote experiments as engineer	2.3
	Question[a] (experiences)	
1	usefulness of introductory script	2.5
2	usefulness of simulation, animation and interactive graphics	2.2
3	user friendliness of Remote experiments	2.4

a. Rating scale: 1= Excellent, 2 = good, 3= satisfying, 4 = acceptable, 5 = poor

this platform and thirdly getting new ideas from the use cases in the LiLa platform.

VII. CONCLUSION AND OUTLOOK

Presented was an online practical course with remote experiments for bachelor and intermediate diploma engineering students. We showed that the association of the remote experiments, online literature and simulation with an online tutoring system can result in an online practical course, which can be very useful in engineering education. We believe that the OnPReX can be very helpful for the engineering students through their academic studies and their career as an engineer. Clearly OnPReX support self managed online learning, as a valuable learning experience. Definitely we need to further develop OnPReX. Firstly the existing remote experiments need to become more stable and we need in parallel to design and build new experiments. Secondly we need to test the capacity of OnPReX concerning the number of participants to be served in a semester. In winter-semester of 2009 to 2010 we are aiming to offer the OnPReX as a compulsory subject choice for the students of "Natural Sciences in the Information Community". This is a bachelor course of studies where the students should pass during the first and second terms two physic practical courses with 12 ECTS points. We offer the students in the first term the OnPReX classical and modern course for 6 ECTS points. In the second term the students take the regular physics practical course offered by their faculty. Herewith we are going to test the capacity of OnPReX concerning the number of the participants. Further evaluation is needed to uncover if the OnPReX upgrades after the first evaluation were sufficient. We need to provide a simulation for every remote experiment to make the comparison of obtained data from remote experiments and simulation possible. Within the LiLa project we are aiming to get access to additional simulations and experiments in order to further improve the OnPReX course.

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