The laboratory in your hand
Making remote laboratories accessible through mobile devices

Dominik May/Claudius Terkowsky/Dr. Tobias Haertel
Center for Higher Education
TU Dortmund University
Dortmund, Germany

Christian Pleul
Institute for Forming Technology and Lightweight Construction
TU Dortmund University
Dortmund, Germany

Abstract - Within laboratories in Engineering Education students have the chance to do own experiments and by that gain own experiences in their learning processes – means that they are an adequate opportunity to implement experiential and research based learning. Recently finished research projects - e.g. like the PeTEX project done by universities in Dortmund (Germany), Palermo (Italy) and Stockholm (Sweden) – implemented an opportunity to do experiential learning by using real laboratory equipment without being physically in the laboratory but having access via the internet. A question in this context is, how students can document their learning process and show to others (teachers and/or other students), what they have been doing. Making the whole environment available for mobile devices so that students have access from virtually everywhere and every time is the consequent further development. With this work in progress paper we show what kind of role e-portfolios can play in the learning process and which kind of scenarios are possible using the software on mobile devices. Furthermore, we show that the combination of experiential learning and the use of e-portfolios offer a great potential to promote the learners’ creativity. This unique combination of topics is realized within one subtask of the project “ELLI – Excellent Teaching and Learning in Engineering Education” at TU Dortmund University.

Keywords - engineering education, e-portfolios, mobile learning, remote laboratories, tele-operated laboratories

I. INTRODUCTION TO TELE OPERATED LABORATORIES AS A PLACE FOR LEARNING

Engineering students once they graduated will work on solving real problems creatively and they will work with real technical equipment - doesn’t matter if they go for a career in a company or in the academic sector. But do they get into contact with it during their studies? In most cases we would definitely say, no! Most of their time engineering students are sitting in the lecture hall following the presentation in which the professor explains to them the course’s content. In other words: The students try to understand and memorize what they have to know in order to pass the course’s exam. This means in many cases that the teacher is showing them results of research activities without giving them the greater context and the research questions which were important at the beginning of the research process. Even if he would like to do so, in many cases there is simply not enough time for it. In “classical” lectures there is only little space and time for the students to understand the big picture of the subject and the inherent research process with its questions, research activities and result interpretation. Furthermore there is seldom enough open space for the students to work creatively with the course content and get in contact with real technical equipment of their future profession [1]. One possibility to change this fact is the use of laboratories in teaching and to implement experiential [2] and research based learning in the teaching and learning process [3]. To bring the students in contact with laboratory equipment means bringing them in contact with the technical equipment of their future profession and giving them the chance to develop central technical competences for the technical part of their future career. In addition to the technical competences, for us the students’ work in laboratories offers the opportunity to add aspects of

- systemic thinking,
- problem definition,
- responsibility,
- innovation, and
- creativity to the learning process.

The work presented in this paper will base on the achievements of the PeTEX project, will deploy its technological infrastructure, and will optimize it. By this we will extend the possibilities innovate the existing concept. The main conception of the further development is the combination of the topics virtual learning environment, mobile learning, and creativity. All this work will be carried out as a subtask of the new project ELLI–Excellent Teaching and Learning in Engineering Education. ELLI is funded by the German Ministry of Research and Education until 2016.

A. Constraints and solutions for the use of laboratories in education

A very important factor that hinders the use of laboratories by students in teaching is the cost of such equipment and the organizational aspect of co-locating students, equipment and supervisors. Especially small universities often face the situation that they neither can afford all the laboratory equipment nor allow the students to use it because of the risk to damage it. That means in many cases that lab experiments, if the professor tries to integrate them into the lecture, are either only shown via video or that the faculty’s staff shows the
equipments during guided tours through the laboratory. This is a real dilemma for modern engineering education.

One way out if this dilemma - wanting the students to develop technical competences on the one hand and having them done experiments but not being able to use the equipment on the other hand - are tele-operated (called “remote”) and virtual laboratories. With them the laboratory equipment can be used by different universities from different places or very risky experiments can be done completely virtually.

B. PeTEX – Platform for eLearning and Telemetric Experimentation

Important research on the use of remote laboratories in teaching engineering aspects was done by the universities from Dortmund (Germany), Palermo (Italy), and Stockholm (Sweden) within a project called PeTEX – Platform for e-learning and Tele-operative EXperimentation. The technical part of PeTEX was carried out at TU Dortmund University by the Institute of Forming Technology and Lightweight Construction (IUL, Prof. Tekkaya) and integrated in close cooperation with the Center for Higher Education (former Center for Research on Higher Education & Faculty Development, Prof. Wildt). Within this project comprehensive research in using remote laboratories in teaching was carried out. Therefore a network of three prototypes in the field of manufacturing technology was developed [4], [5], [6], [7], [8], [9], [10], [11], [12], [13], [14].

The overall context for our work is the implementation of research based and experiential learning by using laboratories in higher engineering education at universities. As explained above, our aims are that students get into contact with real technical equipment, understand the greater context of their learning objects while constructing its knowledge inside an active process.

Facing the problem that laboratory equipment is expensive and some experiments even can be dangerous for students, we will explain why and how remote laboratories should be integrated in teaching. (chapter II)

Up to today a weakness of such teaching approaches is the need for an open designed learning environment in which the students can act independently on the one hand and can be guided through the learning process on the other hand. We will also show the potential of remote laboratories to foster creativity. We will work out how e-portfolios can help in this context and how they can be used to document and reflect on the learning process. (chapter III)

As a final step we will change over to the topic mobile learning. In order to support the students’ learning process as much as possible and giving them the opportunity to use the software virtually every time and from everywhere we will open the software for the use from mobile devices, such as smart phones and tablets. By showing different scenarios we explain how the use of mobile devices can support the learning process significantly and how they can help to promote creativity. (chapter IV)

• At the end of the paper we will explain shortly what our future steps will be in order to put our plan into action. (chapter V)

II. LEARNING WITH REMOTE LABORATORIES

Learning through experiments in general has become a central part in modern higher engineering education [15]. Implementing experiential learning and research based learning by the active use of laboratories in higher engineering education by students is a teaching and learning concept which supports the constructivist approach. The learning arrangement is designed from the learners’ point of view, because the user is the one to design his learning process and “walk” through the learning objects while constructing its knowledge inside an active process.

As mentioned in the introduction, by the use of laboratory equipment in teaching the students have the opportunity to get into contact with the physical equipment of their future professional life as well as to make practical and theoretical experiences with equipment, methods and processes of empirical research. That is why doing technical experiments in a laboratory is an adequate way of applying, enhancing and testing knowledge the students have acquired during the lecture and developing central competences by doing so.

A. Kolb’s Experiential Learning Cycle

The use of laboratories in teaching and learning environments can basically be traced back to understanding of learning explained by Kolb: “Learning is the process whereby knowledge is created through the transformation of experience” [2]. Kolb states that learning involves the acquisition of abstract concepts that can be applied flexibly in a range of situations. In Kolb’s theory, the impetus for the development of new concepts is provided by new experiences. Kolb's concept of experience is defined in his experiential learning theory consisting of a four phase cycle in which the learner traces all the foundations of his learning process:

• Concrete Experience: A new experience of situation is faced, or a reinterpretation of an existing experience takes place.

• Reflective Observation: The new experience is analyzed, evaluated, and interpreted. Of particular importance are any inconsistencies between the experience and the understanding of it.

• Abstract Conceptualization: Reflection gives rise to a new idea, or a modification of an existing abstract concept.

• Active Experimentation: Transforming the new abstract concept into operation, the learner interacts to the world around him to check what emerges.

In his four-step learning cycle Kolb explains that at the beginning of each learning process there is a real learner’s experience (step 1) which is followed by a reflective
observation (step 2). From that point on the learner tries to conceptualize what he has experienced (step 3), starts to experiment actively (step 4) and generates new experiences. This is the start of a new cycle. With every loop - from the simple to the complex - the student enhances his experiences. Thus, the learning cycle transforms learning activities into a helix of experience-based knowledge, skills and competencies.

B. The learning process in the light of research processes
Since its beginnings university always has been a place not only for learning but for research, too. In order to be more concrete, at university these two processes always were thought and implemented together so that they could be inspired be each other. For both, learning and researching, explicit steps can be defined, that describe the process’ sequences. For the learning process we explained the sequences above by showing Kolb’s learning cycle. For the research process a first approach can be to define the following steps: Make a practical experience, define the research question, implement research activities and interpret the results. If you now look at the learning as well as the research process and define both as a circle, then you will see that both can be synchronized. Wildt [16] did this and showed clearly that very similar steps can be identified (see Fig. 1).

Surprisingly this fact has never had a very strong impact on the way teaching is done at universities. As mentioned above, especially in engineering studies classical lectures are the most often used teaching method. This is the fact although there are some alternatives, which allows combining the learning and research process.

C. Research based learning
Research based or experiential teaching and learning in higher education is one adequate way of implementing learner centered teaching. In addition to that Herrington and Oliver worked out the importance of an authentic learning environment for a successful learning process [17]. This authentic learning environment can be offered by teaching and learning activities in laboratories. In these laboratories the students can face a real context and do real activities. By connecting the actions in laboratories in a next step to real problems - e.g. from current research or from the industry - the students are able to go the whole way from the question at the beginning of an experiment to the final use of the results and they can see the relevance of their work.

D. Fostering creativity
Going the whole way of a research process corresponds to another important aspect of engineering education: fostering the students’ creative potential. Industrial nations are facing tremendous problems. For example, new techniques to tackle climate change, new ideas on how to retain mobility of people or new concepts for energy production without fossil fuels are urgently needed. Engineers play an important role in addressing these challenges. Future prosperity and wealth will depend on their inventions and creativity. In higher education, students’ creativity can be fostered in six different facets [18], [19], [20], [21], [22]:

(1) Self-reflective learning – learners break out of their receptive habit and start to question any information given by the teacher. An internal dialogue takes place and knowledge becomes “constructed” rather than “adopted”.

(2) Independent learning – teachers stop to determine the way students learn. instead, students start for example to search for relevant literature on their own, they make their own decisions about structuring a text or they even find their own research questions and chose the adequate methods to answer it.

(3) Curiosity and motivation – this aspect relates to all measures that contribute to increased motivation, for instance the linking of a theoretical question to a practical example or presenting.

(4) Learning by doing – students learn by creating a sort of “product”. Depending on the discipline, this might be a presentation, an interview, a questionnaire, a machine, a

![Figure 1: Synchronized learning and research process [16]](image-url)
website, a computer program or similar. Students act like “real” researchers.

(5) Multi-perspective thinking – learners overcome the thinking within the limits of their disciplines or prejudiced thinking. They learn to look automatically from different points of view on an issue and they use thinking methods that prevent their brain from being “structurally lazy”.

(6) Reach for original ideas – learners aim to get original, new ideas and prepare themselves to be as ready-to-receive as possible. Getting original ideas cannot be forced, but by the use of appropriate creative techniques and by creating a suitable environment (that allows making mistakes and expressing unconventional ideas without being laughed out or rejected); the reception of original ideas can be fostered.

A first, small study indicates that especially the facets 2, 5, and 6 might be fostered insufficiently in engineering education [23]. With an appropriate didactical scenario, learning in laboratories provides the potential to foster students’ creativity in facet 6, which usually is hard to implement. If students are enabled to evolve their own research questions, to chose a suitable experimentation design and finally to perform the experiment, they will be able to develop some kind of “spirit of research” [ibid.]. This spirit is one important premise for trying to get original ideas (facet 6).

E. Active experimentation using tele-operated equipment

Using remote and virtual laboratories in teaching gives a whole range of opportunities to implement experiential learning in the field of mechanical engineering following the path of research based learning [6]. To be clear at this point; in the following we will explain how a remote laboratory was put into practice. There is a discussion going on in the community whether remote labs can and/or should replace real laboratories. This is not our concern in this paper. We do not want to advocate for or against one or the other laboratory solution without looking at circumstances. There are and there always will be situations in which the use of real or remote laboratories makes more sense than the other.

One example in the context of manufacturing technology, namely forming technology, can be the use of remote lab concept for material characterization. This could be organized in addition to a normal lecture or to enhance traditional hands-on labs during the phase students prepare themselves for the lab or when they would like to rework some of the test steps while writing the lab report.

Following the approach based on Kolb’s experiential learning cycle, students can deal with basic concepts of metal forming during the lecture and test and see what they discussed in class by doing experiments on their own in order to create their own knowledge, using the remote experiential equipment. Another opportunity could be that students are given a real engineering problem related to material behavior. They are asked to work on this problem in small groups by planning and carrying out experiments using the tele-operated equipment. Finally they have to present what they’ve explored and what they would suggest to deal with the problem [6]. One important aspect in order to support this entire process and especially the step of “active experimentation” an appropriate level of clear interaction and feedback needs to be integrated to the tele-operated experimental setup. In the PeTEX project a complete experimental setup (Fig. 2) has been moved to a new level using innovative engineering design, modern concepts of automation, measurement technology and robotics as shown in Fig. 3.

All aspects have been brought together by developing a clear and interactive user interface providing real time feedback of the running experiment. In Fig. 4 the “window” to the uniaxial tensile test is shown. When using the live camera stream (1), users can investigate the surrounding test apparatus, e. g. sensors or clamping devices. Afterwards, the learner

Figure 2: Testing machine

Figure 3: Robot positioning a specimen
initiates the preparation of the experiment (2), using the integrated 6-axes robot to select and check an appropriate specimen. To freely configure the experiment, relevant test parameters (3) can be filled in. When the test is started (4) the robot positions the specimen to the fully automated clamping device. The developed innovative concept of the fully automated clamping process and parallel measuring of relevant values is a different story. [4]

Also during the test, a high level of interaction is provided to the user by manipulating the camera view or pausing and continuing the test. Pausing the test – which means the load is not further increased for that moment – causes a reaction by the material. This phenomenon is graphically visible in the real time diagram (6) and also in the real time test data at the header bar (5). Comparisons with prior test data are available by using the data base (7) and the graph (6). After the experiment is finished, learners are provided with data package including all the results for further analysis and investigation.

Additionally the entire tele-operated experimental environment was made available with the learning content management system Moodle. There, we cared on the alignment of four, for us elementary, areas for this kind of socio-technical system. This socio-technical alignment for tele-operated laboratory learning consists of the adjustment of the technical, didactical,
media and social level. By the implementation into Moodle as shown in Fig. 5, this socio-technical alignment was put into a usable as well as flexible environment.

An often formulated challenge to such open designed learning concepts is that it turns out that a very sophisticated concept is needed to document and evaluate the learners’ behavior and achievements during the learning process using the laboratory by the teacher. It is obvious that such a concept requires different systems for the instructor to accompany the learner through the learning process and - above all - to evaluate the achieved learning outcome. The following passages present the future thoughts concerning a concept for the learning process’ documentation in context with the use of remote laboratories in combination with e-portfolios. This will be followed by explanations on the use of mobile devices in this context.

III. E-PORTFOLIOS AND THEIR USE IN EXPERIENTIAL LEARNING

In addition to the open learning concept which is supported by the use of laboratory equipment in general, the use of remote laboratories within the PeTEX project was designed for the usage by a very heterogeneous learner group composed of students and professionals [24], [25]. That means that the software for the learning process’ documentation as well must be designed very open in order to prevent system based barriers for different learner types. In this context it is important to keep in mind that the PeTEX system wants to bring higher education and the workplace together and wants to create an international learning community which is not limited to one institute. These 3 aspects – document the learning process, build a learner community and connect the students’ work with their future professional work - are requirements the software has to address and accomplish (see Fig. 6).

Software which seems to be adequate and which is frequently discussed in similar contexts is the e-portfolio [26]. E-portfolios are based on the general idea of portfolios, which means to collect different kinds of documents in a folder in order to reflect on own learning process and present it to others [27]. E-portfolios support the same, but they are made online and provide the collection of different kinds of data like texts, tables, photos, videos, and audio [28]. E-portfolio software could be added technically to the Moodle environment - which is already used in the PeTEX context - very easily because an online e-portfolio application especially designed for Moodle already exists – it is called Mahoodle. In the following we will explain why e-portfolios fulfill the three main requirements in the new PeTEX context [29].

A. E-Portfolio as a learning process documentation

The user – doesn’t matter if in higher education or in professional further education - can arrange all the data he wants to document or show in different ways in order to create his own portfolio just like his personal page in any social network. He can present experiments and its results, show photos from the test set-up, explain his thoughts on the research, and so on. Add to this he can allow other users - other learners or teachers - to see his e-portfolio. By creating such an e-portfolio the learner can document his own learning and research process and start reflecting on the experiments he does during his research based learning process [30]. This reflection is an important aspect because he needs this step in his personal learning circle and especially for students the e-portfolio can give a kind of orientation or checkpoint in the own field of research [2], [30], [31]. By the same way the teacher can evaluate the learner’s action by looking at the portfolio, too. Because other persons are able to see the collection in the portfolio it can be said that it is not only a way of documenting the learning process but as well it is a way of communicate it so that a collaborative learning process can be achieved. This leads to the next use of E-Portfolios in the PeTEX context.

B. E-Portfolio as a learning community software

Taking the e-portfolio as software for documentation and evaluation is just one use of the system. A constructive enrichment in using the e-portfolios is the community building. Every author of an e-portfolio is able to allow other user to see all or just one part of his portfolio and he can see the others’, too. That means that learners, who are doing experiments in the PeTEX system and filling their e-portfolios, can get into contact with each other via the portfolio software. They can see what others are especially interested in, start discussing about it, give comments and help each other in the case of a problem during the experiential learning process. By this way emerges a specialized community on remote laboratories within the PeTEX context. This possibility is also very important for creativity. In order to fostering students’ creativity, it is strongly recommended to promote social interaction. With regard to fifth facet of creativity in higher education (multi-perspective thinking, which usually is, like facet 6, hard to implement in engineering education), they should get used to deal with different perspectives. This naturally requires exchange of information, discussions and cooperative problem

Figure 4: Requirements for a software system documenting the learning process in remote laboratories
C. E-Portfolio as a bridge between the university and the workplace

The PeTEX system is designed for the usage in higher education and in workplace learning. That means in a first step that both user groups can use the e-portfolios for the explained way of use. A further future thought is to use the e-portfolio as a lifelong system to document the own competences from the university on and during the whole professional life. This should be explained by an example in three steps:

Step 1 - An engineering student starts working with the PeTEX system at the university. He uses the system in order to document his experiments. During his studies he does different experiments, compares them and collects all his research documentation in his e-portfolio in order to scientifically describe a certain material behavior which was observed (e.g. while pausing the test for a couple of seconds), and reflects on his own way of learning. The teacher is able to evaluate his learning behavior. This can be seen as the main use of e-portfolios at university.

Step 2 - Because the PeTEX system as well addresses workplace learning the e-portfolios can be seen as a bridge from university to professional life. Depending on the concrete use of the e-portfolios by the student he can take his portfolios to present himself to potential employers. They can see what the students did in this field of his studies and if he fits to the company’s needs. In this context the e-portfolios can support the process of applying for a job.

Step 3 - Once the former student - now employee at a company - starts working at a company he must not stop working with his portfolio. He still can work on his collection by documenting new experiments as well as gained knowledge and competences in his job. By doing so, the employee doesn’t stop reflecting on his learning process. His e-portfolio grows and with every year it becomes a better presentation of his professional life and his competences. Especially the last aspect works perfectly together with the advantages of the PeTEX system, that small and medium sized companies use the system to enhance their technological skills by doing research with the PeTEX hardware. In addition to that they can use the e-portfolios to implement a system for the documentation and measurement of the employees’ skills and competences. This could be supported by the lifelong use of e-portfolios.

Summing up all these aspects it can be said, that the use of e-portfolios in the PeTEX context can support the idea of experiential and research based learning even if there are a couple of challenges to meet [30]. The portfolios can be used to document and present the research and learning process, to build up a special focused learning community, and to bring university learning and workplace learning together. Above that, working with e-portfolios fosters the fourth aspect of creativity in higher education: to create something. An e-portfolio is a type of a "product". While working on their e-portfolios, students anticipate that their "product" will be valued by others. Therefore, they will seek to make them more attractive for others, for example by bringing in new aspects or by considering that their ideas must be understood by others as well, which requires a non-contradictory and simple presentation. It will be a future task to integrate the e-portfolio work in the PeTEX learning concept and evaluate the performance.

IV. SCENARIOS OF USING MOBILE DEVICES IN COMBINATION WITH E-PORTFOLIOS

Another frequently mentioned new concept in context with higher education is mobile learning. Mobile learning means the use of mobile devices - like cell phones, smart phones or tablet-computers - in the learning process [32]. Only one of the advantages of mobile learning is that not planned time periods can be used for learning and that the learning process can be initiated virtually everywhere [ibid.]. In our context we will focus on the fact that the user carries his mobile device normally at every time and because of that he can use it frequently in order to work with the portfolio software and laboratory equipment.

In addition to that using mobile devices can support the creativity process, because new ideas mainly come spontaneously and having the mobile device with you makes it possibly to at least put down a note with an idea and work on it later or work on it immediately as we will explain in the scenarios. Bringing e-portfolios on tablet-devices for example could be an opportunity to combine the concepts presented in this text with mobile learning. In the following we will present different scenarios how the use of mobile devices can enrich the concept of remote laboratories in higher engineering education. These scenarios differ mainly in terms of individual or collaborative learning processes and self-directed or teacher directed learning processes. These four aspects in different combinations lead to the scenarios, so that it becomes obvious how flexible the use of e-portfolios is in our learning concept. As we wanted an open learning environment for working with the laboratory equipment remotely it seems that the e-portfolio software fulfills this requirement perfectly. Fig. 7 shows the following four scenarios.

Figure 5: Four scenarios for using mobile devices in combination with remote laboratories
four scenarios that are explained in the following.

A. Possible scenarios

Scenario 1 “Using the software in creative moments” - A first scenario could be that a student is thinking about his experiments while sitting at home and watching TV or while he went out with his friends. He is really struggled by his research work, thinks about his parameters, his results and why his experiments offer the results they showed up. Suddenly he has an idea on a hypothesis and wants to check it by rereading his last experiments in the portfolio or doing a new experiment. Because he can use the software for connecting with the experiential environment by using his tablet computer he doesn't need to wait until the next day for doing the experiment at the university but he can stay where he is and even can stay sitting on the sofa for checking his hypothesis. The new result he can immediately put in his portfolios so that he documents his new step within his research process. Using a simulation in a virtual laboratory instead of the remote experiment can be a method to (pre)-check the hypothesis first and then carry out the real experiment remotely.

Scenario 2 “Using the software to bring student researchers together” - With his mobile device (it doesn't matter if smart-phone or tablet PC) the student can access his personal e-portfolio in which he documents his experiments and his personal competence development in this sector from wherever he wants to. Sitting in the train on the way to or on the way back from the university he could skip through his experiments and look what he found out as different results. At the same moment another student looks on the first student’s portfolio. He finds out that his own research had quite the same results even if he used different parameters or - even more challenging - he used the same parameters and material but had different results. Knowing this he contacts the first student via a chat or e-mail, as well using his mobile device, and they can communicate about their common results at this very moment and work together on future experiments.

Scenario 3 “Using the software to overcome cognitive blockades” - A third scenario could foster the students' ability to think in different perspectives about their questions: After performing an experiment that was given to him by the teacher, the student possibly doesn't know why he didn't get the expected results or doesn't know how to interpret the results. He asks himself why the experiment didn't work as it should have, but he can't find the answer. While writing his e-portfolio as documentation for the teacher’s evaluation, he could start the "creative-help-app”, which helps him to use different perspectives on the problem: Firstly, he is asked to make a (mental) headstand following the question “What else could I do to get the wrong results from experimenting?” If that doesn't help to find the answer, he secondly will be asked to describe his experiential design and his assumptions in a way that a ten-year-old could understand it. If those methods, which are rather close to the problem, still can't help him, the "creative-help-app” will suggest a force-fit technique by showing a picture that doesn't have anything to do with a problem (for example a lady beetle, a daisy chain, a bottle of wine) and asking the student to find relationships between the picture and his experiment. This method helps to leave the well-trodden paths and forces the students to look from completely other perspectives on their problem. It often results in very unconventional or provoking ideas, but rethinking the obviously unsuitable solutions sometimes leads to the one really good idea, that would not have come to mind without making the detour.

Scenario 4 “Using the software for collaborative learning processes” - The fourth scenario could be provoked by the teacher, too. He can give the students - as a kind of homework - to check an explicit hypothesis by implementing adequate experiments. Using the e-portfolios the students can stay in contact without being forces to meet at the university and in combination with mobile devices they can be virtually be anywhere going through a collaborative learning process. Because the e-portfolios software has a connection to the experiential environment the students as a group can do the experiment and discuss the results with regards to the homework's hypothesis in one go and without changing the learning environment.

B. Proof of concept

In order to put the plans explained above into practice different research already has been realized. Our work on remote laboratories and on creativity bases on finished research projects at TU Dortmund University and several other European universities. Based on this research we developed a first proof of concept for the mobile devices running with Android. The software allows the user to do a remotely run experiment by checking the parameters, starting the experimentation process and following the results. The next technical step is to bring the software from the proof of concept status to a level on which it can be tested and improved with students. Than it has to be connected with the e-portfolio software and it has to be worked out for iO's devices, too. These are the steps for the coming year.

V. CONCLUSION, DISCUSSION, AND FUTURE PLANS

With this paper we explained 5 different but in our project newly connected aspects:

- Firstly we discussed why laboratories are a place for conducting experiments and why they are important for modern engineering education. The central idea is to engage the students in teaching and learning environments which are connected closely to their future working environment.
- In addition to that, we discussed the aspect of student centered learning environments in general and why they are very important in higher education. They are central for having the students do the things they have to learn by themselves. In our context we showed that with the example of the synchronized learning and research process. This is the only way for the students to develop central competences and reach a high level of learning outcomes.
• Furthermore, we showed the importance of creativity in engineering education and we discussed the potential of our approach to foster the learners’ creativity.

• The learning environment was the next aspect we focused on. If students are learning in laboratories or with the help of laboratory work it is obvious that they need a special learning environment in order to reflect on their learning process. Questions like “How can I document my learning progress for other learners or the teachers?” or “How can I communicate during the learning process with others?” are becoming more and more important. We want to address these questions with the use of e-portfolios as a place to document, communicate and connect the university with the later workplace.

• Finally we explained our plans in context with the use of mobile devices. There are several scenarios thinkable (we concentrated on four of them) in which the use of smartphones and/or tablet-pcs extend the opportunities of learning environment substantially. With the use of mobile devices learning scenarios become designable which were just not possible before. The fact that these devices are highly portable of course plays a central role in this context. We finished with a technical proof of concept for Android devices.

All these aspects - they can be trimmed down to the three basic aspects of ‘virtual learning environments’, ‘creativity’, and ‘mobile devices’ - we are combining in our work. In order to innovate the teaching and learning in engineering education we will design the “Mobile Lab Portfolio”. This environment combines the use of remote labs, e-portfolios, and mobile devices. See in the following the central advantages of the presented concept:

• As the equipment of laboratories is either very expensive to have it at every university or not always available for the students the use of remote or virtual laboratories is good opportunity to face this dilemma.

• Using the equipment virtually in simulations or remotely from wherever they can help the students to do experiments just as a pre-check on personal hypothesis or even when they are not physically in the laboratory.

• Learning processes that are achieved by the usage of the laboratories can be documented in e-portfolios.

• These portfolios are a good opportunity in order to document the experiments for the personal use or for the evaluation by an instructor. Looking at the portfolios the instructor can either see what kind of experiments the students have done and what they learned from it.

• If the portfolios are not kept hidden from other students but are open for other users to look at them and comment on the achievements, there is the opportunity for a community to evolve working together on the experiments. The e-portfolio software should be made accessible from mobile devices, too.

• This opens the door to mobile learning, which means that the learning process is not bound to any location. From virtually everywhere and at every time the user can work on their portfolios and communicate with each other.

• With the possibility to promote multi-perspective thinking and a “spirit of research”, vital facets of creativity in higher education can be fostered.

As this is a work in progress paper we primarily worked out which opportunities and advantage the use of e-portfolios and mobile devices add to the learning process. The step for the coming year will be to implement the e-portfolio software in the system and make it accessible for the students’ mobile devices. Once this has been achieved, first tests with students can be carried out and the system can be evaluated and improved.

Of course technical problems will arise during the implementation and they may be even quite difficult to solve. But at the end they stay just technical and during the PeTEX project it became obvious that every technical problem will be solved sooner or later. At this moment we concentrate on the concept and first technical steps for our future work. During the whole work we want to concentrate on the didactic background for this. The question if any of the explained will help the students to learn more and gain real competences during their studies is and will stay our main focus. Not everything which is possible from the technical point of view or even can be technically designed does make sense for the learning process and higher education. So we look at teaching and learning from the students’ perspective. That leads us to our concepts explained above first, without asking in detail about how everything can be implemented yet. We want to support better engineering education. That is what our focus lies on.

VI. REFERENCES


ACKNOWLEDGEMENT

Parts of the work have been funded with support from the European Commission and the KARL-KOLLE-Stiftung, Dortmund, Germany for the project “PeTEX – Platform for e-learning and tele-operative experimentation”. The project ELLI, in which context the current research is done, is funded by the German Federal Ministry of Education and Research.