Bringing Remote Labs and Mobile Learning together

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***Abstract* - Within (remote) laboratories in Engineering Education students have the chance to do own experiments and by that gain own experiences in their learning processes. Apart from technical questions, one of the most intriguing aspects in this context is how students can document their learning process and show to others (teachers and/or other students) what they have achieved. Another aspect concerns the question of learner's mobility during the learning process. If the laboratory can be accessed remotely, why do we constrain learners in their level of liberty by forcing them to sit in front of a fixed computer to use a location-independent environment for experimentation? Therefore, rendering this environment available for mobile devices is the logical consequence. Furthermore, integrating mobile devices into the course's technical environment means to take a whole new approach to the teaching and learning process itself. It is especially a question of embedding mobile devices into the users' workflow (or better "learn flow") rather than a simple question of accessibility. The following article features an example of how remote laboratories can be linked with mobile devices and e-portfolios, thus creating a unique learning environment helping learners to document their personal learning processes and to exchange them with others while at the same time being flexible in means of time and place. This combination of topics has been realized within one subtask of the project "ELLI – Excellent Teaching and Learning in Engineering Education" at TU Dortmund University.**

***Index Terms*—engineering education, e-portfolios, mobile learning, remote laboratories, tele-operated laboratories**

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

Once having graduated, former engineering students will work on solving real problems creatively and they will work with real technical equipment- regardless if they head for a career in a company or in the academic sector. But do these people get into contact with this equipment during their studies? 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. 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. Hence, not few lectures feature results of research activities without providing their greater context or the research questions which were important at the beginning of the research process. Even if a professor would like to do so, in many cases there is simply not enough time for it. One possibility to change this fact could be the use of laboratories in teaching and to implement experiential [1] and research based learning in the teaching and learning process [2]. 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

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** which 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 effort of co-locating students, equipment and supervisors. Especially small universities often face the situation that they neither can afford all the laboratory equipment nor can allow the students to use it by themselves as it might get damaged. This 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 equipment during guided tours through the laboratory. This means a real dilemma for modern engineering education.

One possible 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 of Dortmund (Germany), Palermo (Italy), and Stockholm (Sweden) within the project *PeTEX* – Platform for e-learning and Tele-operative Experimentation [3], [4]. The technical part of PeTEX was carried out at TU Dortmund University by its Institute of Forming Technology and Lightweight Construction (IUL, Prof. Tekkaya) and integrated in close co-operation with the Center for Higher Education (former Center for Research on Higher Education & Faculty Development, Prof. Wildt) [5], [6]. Within this project comprehensive research on using remote laboratories in teaching was carried out. Therefore a network of three prototypes in the field of manufacturing technology was developed [7], [8].

Our work's overall context 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 research and gain technical competences for their future work. In this context we will proceed as follows:

- Considering 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 until today a weakness of such teaching approaches is the need for an open designed learning environment in which the students can act independently while at the same time can be guided through the learning process. 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)
- In 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 to leave them the choice of using the software virtually every time and from everywhere we will open the software for the use from mobile devices such as smart phones and tablet computers. 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 [9]. 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 his knowledge inside an active process.

As mentioned in the introduction, 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 by the use of laboratory equipment in teaching. 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" [1]. Kolb states that learning involves the acquisition of abstract concepts which can be applied flexibly in a range of situations. According to 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 competences.

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 in unison, hence they inspired be each other. For both learning and researching, explicit steps can be defined which describe the process' sequences. For the learning process we already explained the sequences as mentioned 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

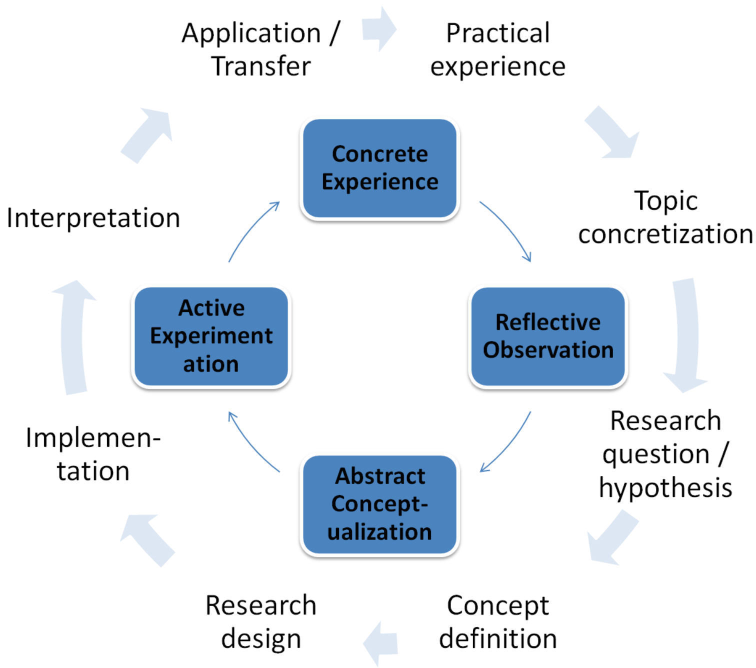

Figure 1. Synchronized learning and research process [16]

at the learning process as well as the research process and define both as a circle, you will find discover that both can be synchronized. Wildt [10] did this and showed clearly that very similar steps can be identified (see Fig. 1).

Surprisingly this fact has never had a severe 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 would permit a combination of learning- as well as research processes.

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 [11]. According to them, this authentic learning environment can be achieved by teaching and learning activities in laboratories in which students can face a real context and carry out 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 can experience the relevance of their work.

D. *Active experimentation using tele-operated equipment*

Employing remote and virtual laboratories in teaching provides a vast range of opportunities to implement experiential learning in the field of mechanical engineering following the path of research-based learning [5]. In the following we will explain how a remote laboratory was put into practice. We noticed a discussion within the community whether remote labs can and/or should replace real laboratories. This may not be our concern in this paper as we do not want to advocate for or against one or the other laboratory solution without looking at its circumstances. There are and there always will be situations in which the use of real or remote laboratories makes more or less sense than the other.

One example in the context of manufacturing technology, namely forming technology, can be to use the remote lab concept for the purpose of material characterization. This could be offered in addition to a conventional lecture or in order to enhance traditional hands-on labs during the phase in which 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 to test and see what they discussed in class by doing experiments on their own in order to create their own knowledge as well as 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 tele-operated equipment. Finally they have to present their explorations and and suggestions on how they would deal with the problem [5]. 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 screen for the uniaxial tensile test is shown. While using the live camera stream (1), users can investigate the surrounding test apparatus, e. g. sensors or clamping devices. Afterwards the learner initiates the preparation of the experiment (2), using the integrated 6-axis 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 mentioned in [3].

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 since 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 within the data base (7)

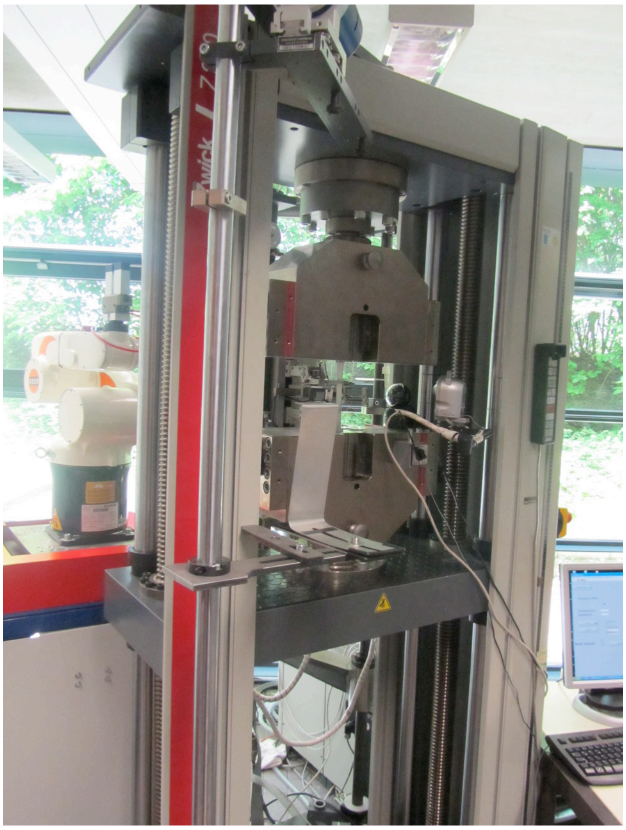

Figure 2. Testing machine

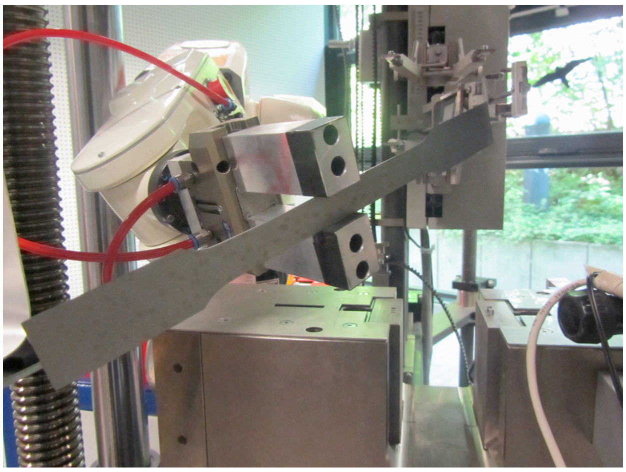

Figure 3. Robot positioning a specimen

and the graph (6). After the experiment is finished, learners are provided with a data package including all results for further analysis and investigation.

Additionally the entire tele-operated experimental environment was made available with the learning content management system Moodle. Within Moodle, we conducted 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 integrating the tensile test environment into Moodle, this socio-technical alignment was put into a usable as well as flexible environment.

An often quoted challenge to such open designed learning concepts is that it turns out that a very sophisticated concept is needed for teachers to enable them to document and evaluate the learners' behavior and achievements during the learning process using a virtual laboratory. 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 [12]. This means that the software for the learning process' documentation as well must be designed very open in order to prevent system inherent barriers for different learner types. In this context it should be mentioned that the PeTEX system intends to merge higher education and the workplace as well as to create an international learning community not being limited to one institute. These 3 aspects—documenting the learning process , building a

Figure 4. Interface to the tele-operated experiment [4]

learners' community and connecting the students' work with their future professional work—are requirements the software has to address and accomplish (see Fig. 5).

Software which seems to be adequate and which is frequently discussed in similar contexts is the e-portfolio [13]. E-portfolios are based on the general idea of portfolios, referring to the idea of collecting different kinds of documents in a folder in order to reflect personal learning processes and to exchange them with others [14]. 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 [15]. 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 by the name of Mahoodle. In the following we will explain why e-portfolios fulfill the three main requirements in the new PeTEX context [6].

A. *E-Portfolio as a learning process documentation*

The user, regardless whether in higher or in professional further education, can arrange all the data he wishes to document or to 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. Additionally, he can permit other users, learners or teachers, to view 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 [16]. This reflection is an important aspect as it corresponds to his personal learning circle. Especially for students the e-portfolio can serve as a means of orientation or checkpoint in the own field of research [1], [16], [17]. By the same way the teacher can evaluate the learner's action by regarding a learners' portfolio. 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 a way to 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*

Considering the e-portfolio as software for documentation and evaluation is just one application of the system. A constructive enrichment by using e-portfolios is the community building. Every author of an e-portfolio is able to allow other users to view various parts of his portfolio as well as to view others' portfolios. This means that learners who are doing experiments in the PeTEX system and filling their e-portfolios have the chance to 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 case of an emerging problem during the experiential learning process. Along the course of this interaction, a specialized community on remote laboratories evolves within the PeTEX context.

C. *E-Portfolio as a bridge between the university and the workplace*

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

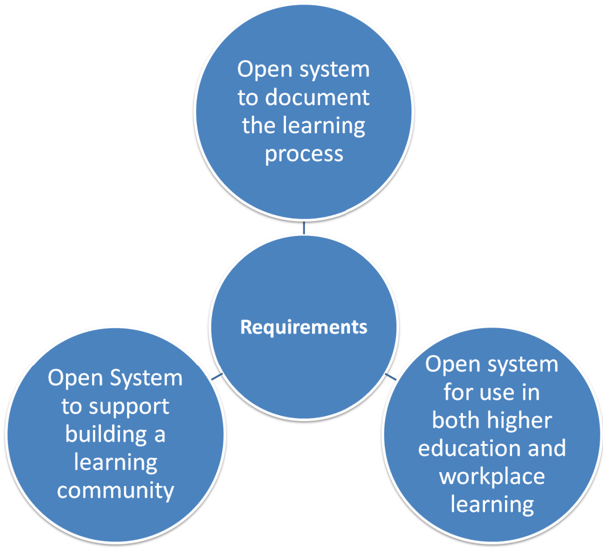

Figure 5. Requirements for a software system documenting the learning process in remote laboratories

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 conducts different experiments, compares them and collects all research results and data 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 regarded 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 viewed as a bridge from university to professional life. Depending on the specific use of e-portfolios by the student he can take his portfolios to present himself to potential employers. Hence, they can see what the students did in this field of his studies and whether he accords with the company's needs. In this context the e-portfolios can support application processes.

Step 3 - Once the former student pursues his career as an employee, there is no need to stop working with his portfolio. He still can work on his collection by documenting new experiments as well as gained knowledge and competencies from his new occupation. By doing so, the employee does not stop reflecting on his learning process. His e-portfolio grows with every year and successively becomes a better representation of his professional life and his competences. Especially the last aspect matches perfectly with the advantage of the PeTEX system as small and medium sized companies use it 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 concluded 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 [16]. The portfolios can be used to document and present the research and learning process, to build up a specially focused learning community as well as to merge university and workplace learning.

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

Another frequently mentioned new concept in context with higher education is mobile learning. From a technical perspective mobile learning means to integrate mobile devices like cell phones, smart phones or tablet computers in the learning process [17]. Among others, one of the advantages of mobile learning is that previously unplanned time periods can be utilized for learning and that learning processes can be initiated virtually everywhere [ibid.].

In addition to that using mobile devices can support the creativity process because new ideas mainly come spontaneously and the fact of carrying a mobile device throughout the day makes it easily possible to put down a note with an idea and to work on it later or to 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. 6 shows the 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 goes out with his friends. He is really struggled by his research work, thinks about his parameters, his results and why his experiments offered the results that 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 there is no need to wait until the next day for doing the experiment over again 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 can immediately be put in his portfolio 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 to carry out the real experiment remotely [18].

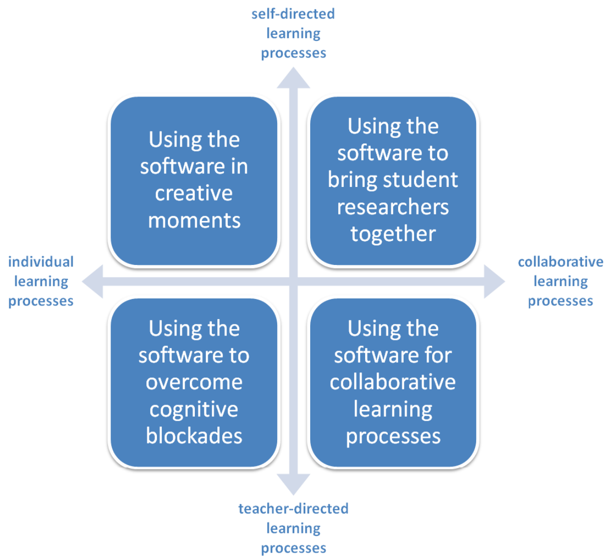

Figure 6. Four scenarios for using mobile devices in combination with remote laboratories

Scenario 2 "Using the software to bring student researchers together"- With his mobile device (regardless if smart phone or tablet PC) the student can access his personal e-portfolio in which he documents his experiments and personal competency development in this sector from wherever he wants to. Sitting in the train on the way to or on the way back from university he could flip 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 similar results even though 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 [19].

Scenario 3 "Using the software to overcome cognitive blockades" - A third scenario could foster the students' ability to consider different perspectives about their questions: After having performed an experiment that was given to him by the teacher, the student possibly does not know why he did not get the expected results or does not know how to interpret the results. He asks himself why the experiment did not work as it should have, but he cannot 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 does not 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 cannot help him, the "creative-help app" will suggest a force-fit technique by showing a picture that does not 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 appeared to his mind without having made the detour [20].

Scenario 4 "Using the software for collaborative learning processes" - The fourth scenario could be evoked by the teacher. He can give the students—as a kind of homework—the exercise to check an explicit hypothesis by implementing adequate experiments. Using the e-portfolios the students can stay in contact without the necessity 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 pass and without changing the learning environment [21].

B. *Proof of concept*

In order to put the plans explained above into practice different research has been carried out. Our work on remote laboratories and 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 permits 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 on a larger scale. As a consequence thereof it would have to be further connected with the e-portfolio software and it has to be worked out for iOs devices. These are the steps for the coming year.

V. CONCLUSION, DISCUSSION AND FUTURE PLANS

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

- We discussed why laboratories are a place for conducting experiments and why they can be 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 vitally important in higher education. They are essential for having the students do the things they have to learn by themselves. In our context we underlined this statement by the example of the synchronized learning and research process. This is the only way for students to develop competences and to reach a high level of learning outcomes.
- 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 with my classmates during the learning process?" are becoming more and more important. We want to address these questions with the use of e-portfolios as a place to document and to communicate learning processes as well as to merge studies at university with the later workplace environment.
- 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 smart phones and/or tablet PCs extend the opportunities of learning environment substantially. With the use of mobile devices previously impossible learning scenarios become feasible. 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 the aforementioned aspects are combined in our work. In order to innovate the teaching and learning in engineering education we will design the "Mobile Lab Portfolio". This environment integrates 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 purchase and maintain at every university or not always accessible for students the use of remote or virtual laboratories is a good alternative 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 personal use or for evaluation by an instructor. By looking at his students' 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 for mobile devices, too.
- This paves the way 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.

As this is a work-in-progress paper the upcoming step for this year will be to implement the e-portfolio software in the PeTEX system and to 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 difficult to solve. But in the end most problems stay simply technical and it became obvious in the PeTEX project that every technical problem will be solved sooner or later. At this moment we focus 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 aspects will help the students to learn more and gain real competencies 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. Therefore 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. Our team strives to support a better engineering education- that is what our focus lies on.

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