More Than "Did You Read the Script?"

Different Approaches for Preparing Students for Meaningful Experimentation Processes in Remote and Virtual Laboratories

Daniel Kruse[1(✉)], Robert Kuska[1], Sulamith Frerich[1], Dominik May[2], Tobias R. Ortelt[2], and A. Erman Tekkaya[2]

[1] Ruhr Universität Bochum, Bochum, Germany
kruse@vvp.rub.de
[2] TU Dortmund University, Dortmund, Germany

Keywords: Preparational activities · Remote lab · Interactive training · Online learning

1 Introduction

Project ELLI (Excellent Teaching and Learning in Engineering Science) is a joint project of the three German universities RWTH Aachen, TU Dortmund University and Ruhr-University Bochum. Considering teachers' and learners' perspectives, the project aims to improve existing concepts in higher engineering education and to develop new innovative approaches. In the past years, a pool of remote and virtual labs has been developed and set up in order to gain flexibility in the usage of experimental equipment in different pre-set scenarios. Teachers can either use these virtual and remote laboratories in class for demonstrating engineering practice whereas the labs can support students to individually discover scientific concepts.

2 Virtual Learning Environment

The use of labs in general can be distinguished in research, development and training purposes. In engineering education, labs are often used to introduce students to experimental work or explain a phenomenon in a realistic way. The project ELLI aims for several improvements in the field of teaching and learning in engineering science. A main aspect is to establish remote learning experiences.

2.1 Remote Labs Setting Local Bochum

The Project ELLI started a virtual and remote lab project in 2011. At the Ruhr Universität Bochum, a call for ideas enabled interested professors to hand in their ideas of a lab with the use of remote or virtual technology. Within all suggested ideas, 10 were selected through an independent jury and received an investment support. These ideas had to describe a concept in which the lab should be used. The selected ideas usually focused

M.E. Auer and D.G. Zutin (eds.), *Online Engineering & Internet of Things*,
Lecture Notes in Networks and Systems 22, DOI 10.1007/978-3-319-64352-6_16

on a specific group with a well-known educational background. Nowadays, the Project ELLI at the Ruhr Universität Bochum provides a pool of more than 10 remote or virtual labs in different disciplines and teaching environments [1]. Each lab was built under the responsibility of a scientific chair with differences in the curriculum of the three participating faculties on three different universities. Therefore, the authors defined a remote learning processes in its different steps to allow a more modular and interchangeable development of the provided resources. With labs in material science, e-mobility or process technology, each lab was built under at least one certain idea of its usage. This usually aimed for a specific target group of users, in a specific relation to the lab's discipline.

2.2 Remote Labs Setting Local Dortmund

At TU Dortmund University, another approach has been followed. In a strong cooperation between the Institute for Forming Technology and Lightweight Construction and the Center for Higher Education, a remote lab for manufacturing technology has been developed. This work is based on successful outcomes achieved within a prior project called PeTEX [2]. The developed laboratory gives both students and teachers the opportunity to conduct experiments in the field of manufacturing technologies especially for material characterization. Figure 1(right) shows the laboratory with two testing machines for sheet metal forming and tensile tests. In addition to that, the lab is equipped with an industrial robot with several grippers for the specimen handling and the needed equipment for the experiment's automation and control. In the recent years, the tensile test has been in focus for its implementation into educational contexts. This test is one of the most common and efficient tests to get the material properties of the tested specimen [3]. The determined properties describe the behavior of such material. Furthermore, the properties can be used in forming applications like FEM-Simulations (e.g. simulation of forming processes or production processes). This is why it is a very basic but also an important test in the context of manufacturing technology. The developed remote lab has been introduced in several educational contexts so far. Now it is used in lectures as well as in practical training courses and even in completely online delivered

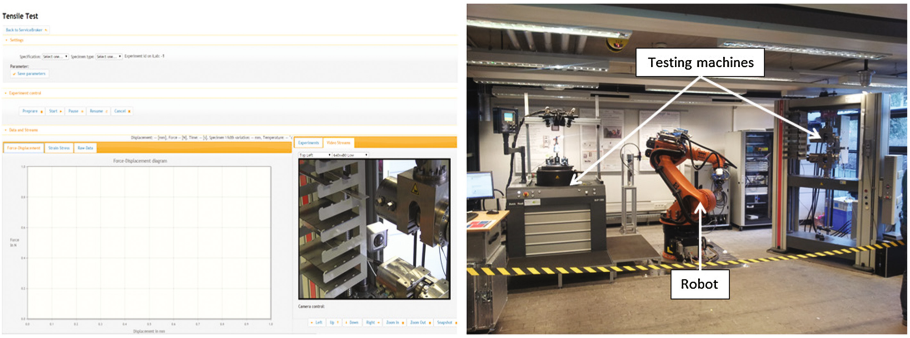

Fig. 1. Remote laboratory at TU Dortmund (right) with the graphical user interface for user-experiment-interaction (left)

courses. In order to perform experiments in the remote lab the user can use the specially designed graphical user interface. Using this interface, it is possible to prepare, start, pause, stop, watch, and even analyze the ongoing experiment (Fig. 1, left part).

3 Learning Processes in Remote and Virtual Experimentation Environments

Introducing experimentation exercises with the help of remote or virtual equipment into educational processes is different to the instruction on classical hands on labs. Whereas in hands on labs normally a scientific assistance guides or supervises the experimentation process (and the learning process, too), in some of its parts, the essential of a virtual or remote lab learning is the non-guided and non-supervised process. This process can be seen in the following stages:

(1) Orientation
(2) Preparation
(3) Performing an experiment
(4) Report experimental results.

Before performing any type of experiment, preparation is needed [4]. A classic hands on lab preparation is often based on a scriptum or any kind of document that has to be read by the students before coming to the lab. Such a scriptum contains the theoretical background and used methodology as well as technical characteristics and at least the task that should be performed. The students have to get familiar with the content and to be prepared to be tested on the experimental content. In virtual or remote labs, things are a bit different. As the whole experience is meant to be highly independent, all aspects of the process must work in an intuitive and helpful way, without lowering the necessary effort for the student's performance. One of the main differences is the feedback on the student's preparation. In a classic hands on lab, this is 'assessed' by a supervisor during a short interview, a discussion or the observation of the physical preparation of the experiment. Whereas these aspects are fitting for the hands on lab, the lack of a supervisor in a remote or virtual setting leads to new challenges [5]. Here the two main challenges are the examination of the necessary preparation and the option of giving feedback about the process of flexibly setting up an experiment. The following approaches are dealing with these challenges. As the remote laboratories are developed independently at the two locations, the student's preparation will be explain separately.

3.1 Preparation for VRL (Bochum)

While offering remote learning resources, there is the question if a scriptum is still the best way of preparing students for a remote experiment. The balance between a challenging task and a guided experience is crucial for the whole remote learning process. Therefore, the preparation phase has to be rethought. A setup for performing experiments in the field of process technology can contain several apparatus and instruments. For gaining experience in setting up an experimental plant, it must be possible to change different designs. In a process technology experiment, a pressure drop should be measured in different flow states. If this task is performed in a classic hands on lab, the students may be able to choose the necessary equipment like pumps, pipes and pressure gauges. Offering a similar experiment in a remote environment leads to the problem that the plant hast to be put together in advance and standby till it is accessed [6]. In this simple case, the student would not be able to work out their own setup, maybe make mistakes and learn about the physical relations between the separate parts of the setup. To remove this lack of experience in a remote scenario and allow the students to reflect their knowledge about the upcoming task, a virtual work bench was considered to be helpful to develop a virtual process scheme.

Process schemes contain a lot of information about a technical setup. There are several disciplines and different layers that could lead to one main scheme, which describes the whole setup. As the users of the ELLI remote lab pool are engineering students, they are familiar with process schemes from different lectures or trainings. Even if they do not create a scheme on their own, they know about the symbols, connection types and how to read flow schemes [5]. Based on the remote scenario and the assumed fact that a student is already familiar with the task of measuring the pressure drop of a fluid, the virtual process scheme is used to reflect the student’s state of understanding and preparation.

The virtual process scheme is built to be a virtual experiment developing environment (see Fig. 2), like an interactive content object described in [7]. A number of devices and equipment can be chosen by its schematic symbol. The number of available equipment is larger than required by the aligned task. First, the students have to identify the devices necessary for their respective task. In case of a flow testing rig, a pump, pipes and pressure gauges are needed as well as a device to cause the pressure drop needed to observe different states of operation. If a schematic symbol is chosen to be used in the virtual process scheme, it can be located all over the virtual workbench. At least two symbols need to be placed on the virtual workbench before a connection can be created. The symbols can accept four connections but only one at each side. A connection is

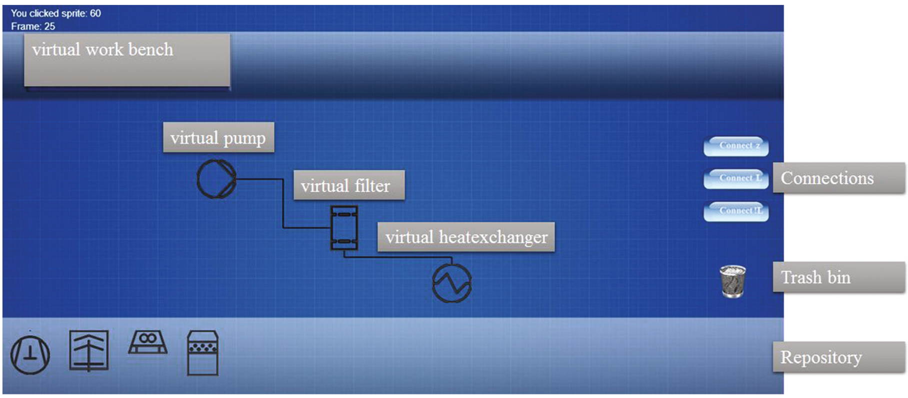

Fig. 2. A virtual workbench for developing, the repository area at the bottom and the connection control area on the right side.

created by choosing the type of connection, choosing its starting point and selecting its end point. During the process of creating a connection, the symbols placed in the work-bench indicate their ability to accept or decline a connection on one of the four sides with green or red dots, respectively (see Fig. 3).

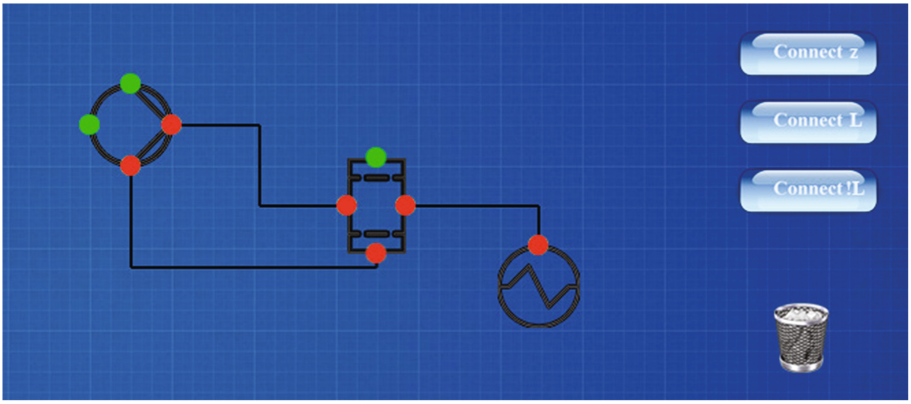

Fig. 3. Symbols on the virtual workbench during the connection creation process.

In case of a student needing assistance or having finished the setup of a virtual process scheme, a consistency test runs and checks the flow scheme created. For a virtual process scheme of a flow testing rig there should be at least one suitable pump, pressure gauges and a regulation valve connected in one loop. Open connections or missing equipment is recognized and can be displayed to the student with a hint about how to complete the setup. A flow scheme containing all necessary equipment with correct connections is reviewed and reported as complete.

This consistency test can be adjusted in its complexity by adding more information to each symbol available. Parameters like flow direction, generated pressure, pressure drop or process fluid parameters can be reviewed in the consistency test. The more information is respected, the more complex the review process is. However, the accuracy of the enabled feedback can be enhanced and individualized with this enlarged information [5]. The results of such a consistency test can be used to allow the student's access to a real remote lab control or give them advice to review several parts of the experiment's documentation [4, 8].

The virtual process scheme is created by using an html 5 framework called phaser (www.phaser.io). A more common use for this framework is known to develop computer games for web or mobile applications. Therefore, the functionality of this framework was highly useful to develop the virtual process scheme. As the code works well on mobile devices, the virtual process scheme can easily be adapted to mobile use for even more flexibility.

The explicit example of preparing the remote learning experiment about the measurement of pressure drop at flow testing rig can be easily adapted to other experiments. The idea of the virtual process scheme works in each discipline that uses schemes or drawings to show interaction and connectivity. Examples of use can be electrical circuit drawings or drawings of mechanical balance of forces. The virtual process puzzle eliminates some of the drawbacks of remote experiments in the field of independent experiment development and reflection about the state of the student's preparation. While eliminating some challenges, it also creates new ones, especially with the consistency test and its usage to create a meaningful feedback.

3.2 Preparation for VRL (Dortmund)

The Remote Lab of the TU Dortmund University was developed on basis of a classical hands on lab. As all these achievements are based on this existing lab, the preparation procedure will be explained in the following in order to show how preparation for non-remote labs worked so far. In this lab, the students had to determine material parameters for different materials (steel or aluminum) with a uniaxial tensile test. Therefore, the students were divided into groups of four students each. Each group was supported by a research assistant. The lab experience was divided in four steps. In the first step "Preparation", a script (up to 20 pages) was given to the students. This script provided a small repetition of the basic facts and theoretical background in material characterization. With this in mind the students were able to conduct the experiment and understand its context as well as its application. The second step "Experiment" started with a little oral assessment in form of a discussion. During this discussion, the students' knowledge about the basic facts was tested. In addition to that, the students were questioned about safety concepts of the used machines due to safety reasons. After this oral exam, the students were introduced to the machine and the used software. With this information, the students conducted their experiments basically on their own, if needed with the help of a student assistant. During the experimentation, they tested different materials in different rolling directions to determine material parameters. Afterwards, the data was stored on an USB-stick. In the next step "Analysis and Interpretation", the students determined the material parameters on their own using their own personal devices, like pc or laptop. The calculated material parameters and their interpretation were the basis for the next task, a lab report. This written reports consisted of up to ten pages and an appendix with different plots for example. The report had to be handed in to the supervisor three weeks after the lab session. The last step "Examination – Presentation" started with a check of the lab report by the supervisor. In a short presentation, the students presented the main output of the experiments to the supervisor and a second examiner. After a final discussion the lab was over and the final grades were announced to the group.

The explained procedure could not be adopted one-to-one to the remote lab context. Especially the face-to-face contact between the students and the supervisor is missing in the remote context or has to be organized differently. Therefore, new procedures were developed. On the one hand, an online scenario was developed. On the other hand, a combination between online and offline preparation was developed.

As indicated above, the remote lab is used in different educational settings so far. The above-explained type of preparation was put into practice in context of classical on-campus training courses. The combination of online and offline preparation is divided into several steps. In this case, the use of the remote lab is shown in the lecture. The task of this lab is the determination of material parameters. This material parameters are needed to conduct a FEM simulation in the next step. Therefore, a first run of the experiment using the remote lab is conducted in a lecture or exercise. The lecturer controls the experiment during lecture in front of the audience. The students can ask questions and discuss their needs in interaction with the lecturer. In a second step, the students need to book a time slot to conduct the experiment using the ilab server. In order to help the students and make a smooth start using the remote lab possible, an online video explains the most important steps. This video is available without any registration to the ilab server (see: http://iul.eu/remotelabs/). With this information and help, the students can conduct their experiments using the remote lab. After conducting the experiments, the data can be downloaded and the material parameters can be calculated on their own devices.

Another course context, in which the remote lab plays a crucial role, is a completely online delivered course for international students, which is taken in advance of their stay in Germany for the master study program [9]. Part of this course is to conduct online experiments in internationally mixed students groups using the universal testing machine in the remote lab for a tensile test. As the students are coming from all over the world, one of the challenges is that their knowledge and competence in experimentation theory and practice may differ significantly. Whereas for some of the students independently performed experimentation processes may be normal and largely trained, this is not the case at all for others. It may be even the case that some students are introduced to experimentation equipment for the first time in their lives. Nevertheless, for the experimentation with the remote lab at TU Dortmund, it is important to bring the students on an adequate level of competence in experimentation and material characterization. The Authors decided to make use of the differences and build heterogeneous and internationally mixed students group for the important preparation phase. Within these phase, the students did not receive a written script with all the important information, but they were asked to do their own individual research about material characterization, based on guiding questions. Figure 4 shows pictures given to the students as a starting point for their research.

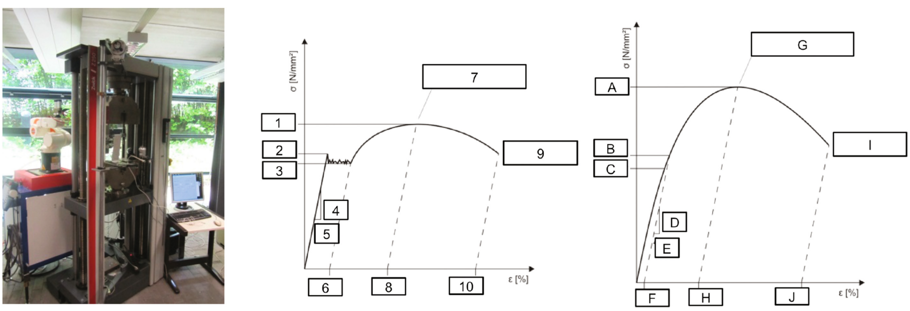

Fig. 4. Pictures used to guide students in their research process for material characterization

Taking the pictures shown in Fig. 4 as a starting point, the students are asked to answers questions as follows:

1. In the first picture, you see the universal testing machine used at the IUL.
   1.1. What are important parts?
   1.2. How does such a machine work?
   1.3. What is the theoretical background of the tensile test?
   1.4. What is it used for?
2. The following pictures show stress strain diagrams.
   2.1. What do they show?
   2.2. What is the difference between the two diagrams?
   2.3. How are they worked out?
   2.4. What are important areas?
   2.5. Which material properties can be gained through the connected data and how?

Using this approach for experimental preparation, it is possible on the one hand that students themselves can directly develop knowledge about the respective experimentation process. On the other hand, they see and learn where they may have important gaps in knowledge, especially in comparison to other students. Furthermore, and this may be the most important aspect, they can learn from each other. As they do have totally different educational backgrounds, they recognize while answering these questions in their respective group how far their personal concepts in experimentation differ from the others' concepts. With the help of each other, the students can leverage their individual knowledge about tensile testing and are finally on the same and needed level for successful experimentation. To make sure that all students really are on the same level, they have to present their research results in the following course meeting, and the most important aspects are discussed again in the whole group. Observing the students during the following experimentation process and assessing their results, it becomes clear that they are well prepared for the experimentation by going through the procedure explained above. Especially during the discussion of the experiment's results, they benefit from their former research in advance of the experimentation. Furthermore, they show good abilities to connect their results with the explanations given in the literature.

4 Actual and Anticipated Outcomes

Using remote learning processes in higher engineering education allow a flexible and individual learning process. Due to the boundary conditions of the physical pre-set setup, a creative discovery of scientific concepts lying behind the experimentation process is limited. With different approaches for student activation and preparation, such as virtual process schemes (VPS), static remote laboratory setups can be used in scenarios that give a more flexible experience. With this, students are asked to take more personal responsibility for their research, their personal learning process and gained knowledge. They can prove it with several creations in VPS, getting feedback about their ideas by the system. In a next step, such approaches even can be used for organizing the access to the laboratory environment based on students' performance during the preparation process. For example, the access to the remote lab could be allowed only to those students who received an adequate reflection/feedback to the tasks before the experimentation.

Even if there is existing research on the usage of preparation activities, there is still work to be done. Since the ELLI project starts its second runtime of five years in 2016, the presented approaches are put into practice and evaluated within the next two years. Hence, research results are expected to be looking at the question how different students react on different preparation activities and in which intensity different kinds of such activities are more or less suitable for different types of remote labs.

5 Summary

With a combination of different preparation activities, the experience of pre-set remote experiments can be improved in the area of individual, flexible and/or research based learning. Tools like virtual process schemes allow flexible usage and individual feedback on the student's process of learning and understanding. The absence of a procedural manual for the experiment with all information ready to use triggers a scientific way of approaching necessary information by research and self-learning. The paper presented different remote laboratories at the ELLI universities, explained the different preparation activities, their respective grades of implementation and first evaluation results about their success.

References

1. Frerich, S., Kruse, D., Petermann, M., Kilzer, A.: Virtual labs and remote labs: practical experience for everyone. In: Proceedings: IEEE Global Engineering Education Conference (EDUCON), pp. 312–314 (2014)
2. Terkowsky, C., Jahnke, I., Pleul, C., May, D., Jungmann, T., Tekkaya, A.E.: Pe-TEX@Work: designing CSCL@Work for online engineering education. In: Goggins, S.P., Jahnke, I., Wulf, V. (eds.) Computer-Supported Collaborative Learning at the Workplace - CSCL@Work, Computer-Supported Collaborative Learning Series, vol. 14, pp. 269–292. Springer, New York (2013). ISBN 978-1-4614-1739-2
3. Tekkaya, A.E.: Metal forming. In: Grote, K.-H., Antonsson, E.K. (eds.) Handbook of Mechanical Engineering, Chap. 7.2, pp. 554–606. Springer, Heidelberg (2009)
4. Bochicchio, M.A., Longo, A.: The importance of being curricular: an experience in integrating online laboratories in National Curricula for High Schools. In: Proceedings of 11th International Conference on Remote Engineering and Virtual Instrumentation (REV), pp. 450–456 (2014)
5. Graven, O.H., Samuelsen, D.A.H.: Remote laboratories with automated support for learning. In: Proceedings of 10th International Conference on Remote Engineering and Virtual Instrumentation (REV), pp. 1–5 (2013)
6. Kruse, D., Frerich, S., Petermann, M., Ortelt, T.R., Tekkaya, A.E.: Remote labs in ELLI: lab experience for every student with two different approaches. In: Proceedings of IEEE Global Engineering Education Conference (EDUCON), pp. 469–475 (2016)
7. Wuttke, H.D., Hamann, M., Henke, K.: Integration of remote and virtual laboratories in the educational process. In: Proceedings of 12th International Conference on Remote Engineering and Virtual Instrumentation (REV), pp. 157–162 (2015)

8. Dias, F., Matutino, P.M., Barata, M.: Virtual laboratory for educational environments. In: Proceedings of 11th International Conference on Remote Engineering and Virtual Instrumentation (REV), pp. 191–194 (2014)
9. May, D., Tekkaya, A.E.: Using transnational online learning experiences for building international student working groups and developing intercultural competences. In: Proceedings of American Society for Engineering Education's 123rd Annual Conference and Exposition "Jazzed about Engineering Education", 26th–29th June 2016, New Orleans, Louisiana, USA (2016). doi:10.18260/p.27171