E-LEARING SUPPORTED LABORATORY COURSES IN CORROSION EDUCATION

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The combination of practical laboratory work with multi-media guidance and preparation can help to make better use of a laboratory's capacity, especially when there is only a limited number of supervising staff available. Modern forms of instruction like video clips and interactive animations can provide information to the students that is much harder to convey by traditional teaching. Within the corrosion curriculum at Aalen University of Applied Science, two laboratory courses on electrochemistry and corrosion failure analysis have been created that make use of this blended learning concept. The concept is suitable for a new teaching approach in both content and form, and it allows students to improve their personal skills through independent, active work, while gaining methodology and expertise.

1 Knowledge transfer during laboratory work

The traditional transfer of knowledge at universities takes many different forms. The established types consist of lectures, seminars, exercises or tutorials, practical training, project work and colloquiums. In these types, three different teaching procedures can be put into action by methodical conception: presentations, course work, and explorative teaching procedures.

In science and engineering programs, practical, hands-on laboratory work is just as important as lectures and seminars. In laboratory work, students use expert methods, carry out experiments and measurements, and thereby gain practical and methodological skills. The students require a very high degree of independence, by carrying out or guiding themselves through experiments. In addition to having a sense of achievement, they practice their most important non subject-related personal skills. [1]

In some cases, the practical laboratory work might be integrated into modules of multidisciplinary projects. Some lab classes, which were usually spread over the whole semester, take place in blocked seminars during the semester or even during the semester break. Preparation, experiments and post processing are offered in a relatively short time. If practical experience and exercises are part of a study project, for the students it should be possible to choose a time at their own discretion [2].

2 Corrosion Education at Aalen University

Corrosion Education at Aalen University is part of the bachelor's curriculum in Surface Sciences and Materials Engineering. It consists of a sequence of lectures and lab courses in Thermodynamics, Electrochemistry, Corrosion Basics and Corrosion Control, which are taught between the first and the seventh semester. A total credit of 18 points is given. Aside from these specifically dedicated classes, the students learn the various methods of metallic and organic coatings, as well as the basics in Metallurgy and Materials Science and Engineering. The lab classes in Electrochemistry and Corrosion Basics are taught in sequence after each having been introduced in a lecture in the preceding semester. The seminar on corrosion protection in the 7th semester is dedicated to project work in corrosion engineering, that is, in complex engineering projects from the real industrial world like materials selection for complete process plants, and defining strategies for corrosion protection in automotive industries or machine building.

1st Sem. **Thermodynamics** (Lecture, 3CP)	2nd Sem. **Electrochemistry** (Lecture, 3 CP)	3rd Sem. **Electrochemistry** (Lab, 3 CP)		
		3rd Sem. **Corrosion Basics** (Lecture, 3CP)	4th Sem. **Corrosion Basics** (Lab, 3 CP)	7th Sem. **Corrosion Control** (Lab, 3 CP)

Figure 1: Sequence of corrosion courses at Aalen University

In the Electrochemistry lab the students learn all the basic techniques on ionic charge transfer and electrode reactions, along with standard experimental techniques like potential measurements, use of reference electrodes, potentiostatic and galvanostatic techniques.

In the corrosion lab the students get acquainted with all the forms of corrosion, from general uniform corrosion, pitting and crevice corrosion, and galvanic corrosion, to stress corrosion cracking. They also learn how to determine corrosion rates and critical conditions and how to run standard corrosion tests according to common national and international standards.

Unfortunately, the number of supervising staff is rather limited lately. This means that instruction and support, as well as guidance through the preparation process for practical work, has to be done differently. Well-structured guidance with self-control and further hints towards the original literature can compensate at least partly for laboratory assistants. By making use of interactive multimedia instructions like video clips and animations, the effects and phenomena behind the experimental work can be explained in a much more concise way than by using just written material.

Corrosion failure analysis is most useful in order to collect experience with the various forms and appearances of corrosion. However, doing this in an ordinary way requires a lot of time to prepare the samples and the real failing parts, as those are destroyed during the analysis. Therefore, making a single analysis can easily take an entire week. Combining pre-prepared specimens with multimedia instructions and background information is a way to do a reasonable number of analyses within a relatively short period of time, thereby permitting a researcher to do many different investigations and see the details of a multitude of corrosion appearances.

Adapting the hardware in a kit-like manner by assembling all the bits and parts used into containers, the students can pick up such a container and complete their lab work independently at their own discretion.

3 The challenge of media knowledge transfer

The use of digital media in laboratory classes opens new possibilities and can create different goals. First, students can carry out costly or risky experiments virtually and get the possibility to review them many times, independent of place and time. Second, the combination of practical laboratory work with multimedia guidance and preparation can help to make better use of a laboratory's capacity, especially when there is only a limited number of supervising staff available. Third, students can be prepared for their practical experience via media and can test themselves before entering the lab, as to whether they are able to conduct the experiment [3].

For corrosion education at Aalen University, two e-learning supported laboratories have been realized. All media content is integrated in an e-learning system, which gives the students a structured, guided and quickly familiarised learning environment. This environment not only helps and guides the students to learn independently; it also offers extensive information and organizes dates and communications. Both courses are divided in four learning modules:

- **Activating previous knowledge:** During a self-study period the students review specialized knowledge (facts, terms etc.), which they have already learned. Students review by means of exercises und self-tests the already learned knowledge of the face-to-face lecture, which takes place in the second semester. The self-tests include automatically corrected questions such as multiple-choice, matching, calculated, short answers etc. The learning environment corrects the answers and gives feedback immediately. In case the students do not give the correct answer, they are redirected to learning information and not just given the correct answer. They learn to work with different media types to achieve the lacking knowledge they need for the experiments. After three days, they can repeat the test. The second time, the student get other questions and a different order of the questions. They can repeat those self-tests as often as they wish and see how they get along.
- **Documentation:** Documentation: Working and writing scientifically is an important subject in the study. This module teaches how to document the work and results in a lab diary and to write technical reports.
- **Working instructions and simulations:** In this module students learn from video-based or animated operation instructions the use of the equipment and understand the phenomena behind the experiments in an illustrative way.
- **Practical lab work:** This module is the core of this laboratory course. Working in peers students perform the various actual experiments. They get a rough time schedule and have to organize their practical work with the supervising staff of the lab. For effective practical work the students need to be well-prepared. This module is structured differently in both laboratory courses; therefore it will be described in the following.

4 Open Lab Electrochemistry

The laboratory course “Open Lab Electrochemistry” offers students the possibility for intensive laboratory work in a combined form of guided lab and open lab.
Adding to the lecture in the preceding semester the media knowledge transfer constitutes an important part in teaching electrochemical theory. The self-study period and the preparation of practical work in the lab is carried out with the assistance of medial knowledge transfer. The learning environment provides the itemized learning modules (see Figure 2), which the students work through independently. The students receive a learning schedule, which guides them to the learning target.

Module 1: Basics	**Module 2: Documentation**	**Module 3: Laboratory work**	**Module 4: Experiments**
– Exercises – Self-test – Liturature – Definitions – Formula	Basics on writing lab diary with negative and positive examples.	– Use of technical equipment – Use of chemicals – Precondition for being admitted to practical work	Learning-by-doing: 1. Introduction 2. Agenda 3. Virtual experiment procedure 4. Test 5. Lab Report 6. Review/Control Question
Display Format: Words, pictures	*Display Format: Words, pictures*	*Display Format: Words, pictures, streaming video*	*Display Format: Words, pictures, animations*

Figure 2: Learning modules in laboratory class Electrochemistry

The main part of this laboratory is the specific experiments. While working in peers students carry out eight different experiments. The learning environment guides the student through their practical work and therefore, every single experiment is divided in five steps:

Step 1 – **Introduction:** The students review theoretical basics and an introduction to this specific topic.

Step 2 – **Agenda:** The students receive instructions on the various tasks to be performed.

Step 3 – **Virtual experiment procedure:** Before the students carry out their experiments in peers, they receive a printable execution of the experiment and a animated virtual experiment procedure. This alleviates the understanding of the phenomena which are happening throughout the experiment. In this animation students also see, which equipment they need and how to set up the experiment.

Step 4 – **Test:** Having worked trough this, the students have to pass a test before they are allowed to run the experiments.

Step 5 – **Report:** The students have to write and eventually upload their lab report.

Step 6 – **Review/Control Questions:** Every single student is requested to answer some question about the experiment. Those questions will be corrected after all students have delivered in their lab reports and answered their questions.

Finally, the students meet up with their tutor face-to-face and talk through their lab work and lab report.

The learning-environment offers additional information e.g. operation instructions, formula, literature, and glossary. A calendar organizes the meeting dates and the lab work between the groups.

Additionally, the students find an e-mail-tool and discussions for different topics, which is administered by the supervisor.. Therefore, the students can communicate, discuss topics and arrange meetings among each other or with the supervising staff, tutor and professor.

5 Corrosion Failure Analysis

This project is an attempt to make the best possible use of the concept "Learning from (negative) experience" which is essential in corrosion education. It combines learning of methodology of failure analysis with hands-on experience of actually failed parts from the real industrial world. The combination of pre-prepared failure cases with the guidance and backing-up from the e-learning platform permits performing failure analysis in a limited time frame and also without consuming the failed parts. The students work independently on a very high level which enhances their core competence. The learning environment represents the itemized learning modules (see Figure 3), which the students work through independently. The students receive a learning schedule, which guides them to the learning target.

Module 1: Basics	**Module 2: Documentation**	**Module 3: Laboratory Work**	**Module 4: Failure Analysis**
– Self-test – Theory – References – Definitions – Formula	Basics on writing failure document-tations with negative and positive examples.	– Safety instructions – Use of technical equipment – Performing various investigation techniques (microscopy, SEM, hardness measurements etc.)	Learning from examples: 1. Description 2. Failure history 3. Failure hypothesis 4. Individual examinations 5. Identification failure cause 6. Failure correction 7. Failure report
Display Format: Words, pictures, streaming video	*Display Format: Words, pictures*	*Display Format: Words, pictures, streaming video*	*Display Format: Words, pictures, animations*

Figure 3: Learning modules in laboratory class Corrosion Failure Analysis

Module 1 “Basics” helps to review the various forms of corrosion with emphasis on their characteristic appearances. It also provides references to textbooks and previously learned subjects.

Module 2 “Documentation” teaches the specific approaches of collecting and documenting results when making failure analysis. It is closely related to procedures recommended by bodies and authorities.

Module 3 “Laboratory work” provides in a concentrated form all information needed to do the practical work, from safety instructions, equipment manuals, preparation procedures, various data sheets etc.

Module 4 “Corrosion Failure Analysis” is of course the most important. At the start there is an example which guides the learner through the systematic approach of failure analysis. The e-learning platform permits to flip momentary between the guidelines of the standard and their adaptation on the actual case. Along with that the actual pieces and preparations are available for hands-on work.

Further on, the students have to apply this approach on a specific number of other failure cases selected by the supervisor from the fund. The pre-prepared parts are available in a container and only need to be quickly re-prepared for microscopy or other investigations. The e-learning platform provides all the background information of the case, data of origin and environment, pictures from the original parts, in cases in form of multi-perspective 3D views, descriptions of location from where the prepared specimens have been cut from etc.

The e-learning system also guides again through the distinct steps of systematic work. It requires to upload a hypothesis for the failure and finally to upload the report. Once this is done the students have access to the correct solutions and a model-report which are released automatically from the e-learning system. This assists in preparing a final discussion with the supervisor.
Of course all the organizing features of e-learning systems can be used in order to facilitate the work of and enhance the communication between students and supervisor.

Acknowledgement

The authors gratefully acknowledge the financial support by the state Baden-Wuerttemberg through GHD-Geschäftsstelle der Studienkommission fuer Hochschuldidaktik in the frame of the LARS-program.

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