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Instructional Design Guide: Didactics of Media Learning Environments

Partnership for Virtual Laboratories in Civil Engineering (PARFORCE)

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University Handbook

ERASMUS+ Strategic Partnerships 2020 for “Digital Education”

Disclaimer

The Instructional Design Guide will be in the form of an online and printed handbook containing the results of the work conducted, including analyses, developments, insights, and digital learning recommendations within the PARFORCE Project. The creation of these resources has been funded by the ERASMUS+ grant program of the European Union under grant no. 2020-1-DE01-KA226-HE-005783.

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Preface

The sudden change in teaching from classroom to online because of the Covid-19 pandemic has shown that digital teaching is in general possible. However, difficulties in the rapid practical implementation of digital teaching coming from the lack of clear digital teaching and evaluation concepts have become apparent. Particularly, courses dealing with laboratory experiments and practice are among the most challenging aspects of digitalization in teaching. This is especially true for the university research-oriented study of civil engineering, where participation in laboratory experiments is a natural part of classroom teaching. To overcome the issue with such courses, the use of mixed and virtual reality is foreseen as tools providing students the possibility to attend laboratories virtually and, thus, broaden digital teaching of civil engineering courses. In the case of digital learning, the student evidently cannot participate in laboratory experiments, and the real laboratory experience cannot be fully replaced by a video or online translation, whereas virtual and augmented reality techniques provide excellent opportunities to replicate real laboratory experience in a virtual environment.

Within the PARFORCE project – an Erasmus+ Strategic Partnership 2020 for “Digital Education” project (grant no. 2020-1-DE01-KA226-HE-005783) by Ruhr University Bochum (Germany), University Aveiro (Portugal), University Osijek (Croatia), Institute of Earthquake Engineering and Engineering Seismology (North Macedonia) and Bauhaus-University Weimar (Germany) – significant contribution to establishing virtual experimental setups (which are not a part of standard education at each university but are carried out at specialized institutes), as different laboratory equipment (shaking table, wind tunnel, and fire resistance laboratory) are brought together and used by students of all partners. The virtual experimental setups are accessible to external interested parties in order to broaden the reach of resources and foster a more inclusive and collaborative environment.

The report presented herein constitutes the first in a series of three accomplished project reports:

- Instructional design guide – didactics of media learning environments – describing the derived methodological framework.
- Methods and algorithms for digital learning tools evaluation -proposing a set of guidelines for evaluation, including measures and tools for quantitative analysis.
- Remote-access Experiments in Structural Engineering – describing the elaboration of created virtual tours.

The results are an added value for all partners and Europe.

Project leader

Lars Abrahamcyzk

Table of Contents

1. Introduction

In this report of Intellectual Output 1 (IO-1), considerations for planning a virtual lab and didactic aspects are outlined, discussed and examples are given. The considerations presented in the scope of IO-1 cover: Digitally assisted teaching design in engineering education, Physical and Virtual Laboratories in engineering education, Mobility in learning and teaching, Basics and collaborative Moodle tools, and Supporting measures. These aspects are also discussed as a form of document in relation to the main purpose of IO-1: "*The instructional design guide for virtual laboratories in civil engineering based on the PARFORCE Project*". The aim of this instructional design guide is to provide a methodological framework for the implementation of virtual labs in engineering education, specifically in the international learning environment.

Figure 1.1 illustrates how each aspect must be considered and adapted altogether to conceptualize the methodological framework of the virtual laboratory and classroom within the PARFORCE Project.

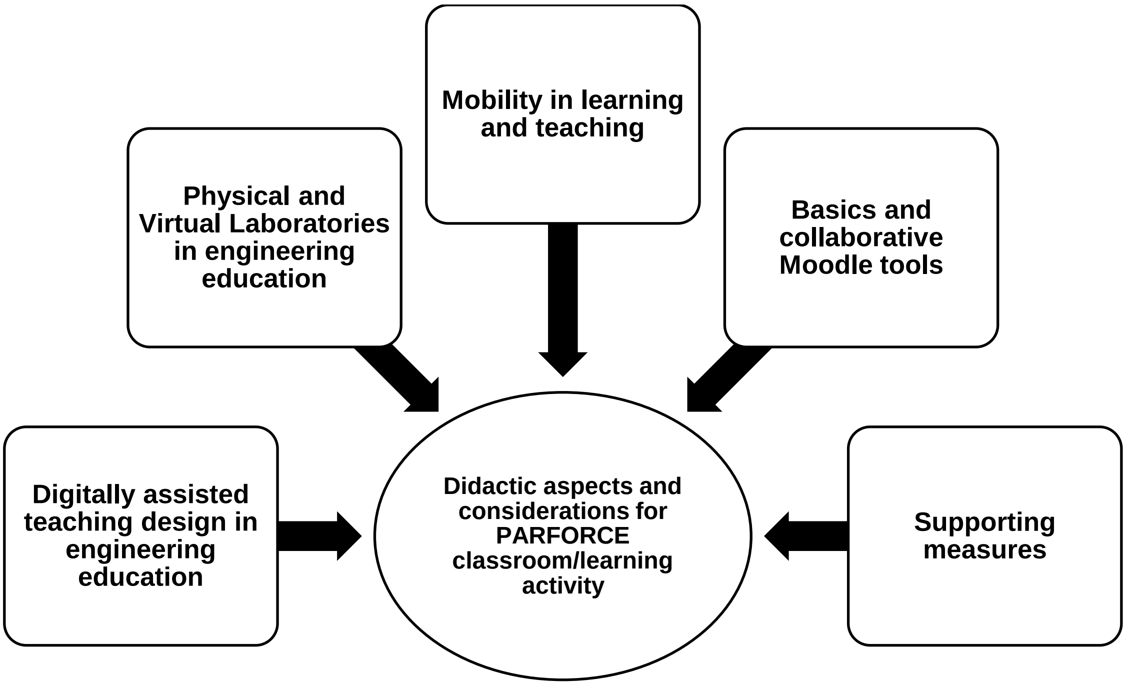


Figure 1.1: Considerations and didactic aspects for planning a virtual laboratory in civil engineering with the scope of PARFORCE Classroom.

The five aspects listed above are considered to be relevant to the purpose of the PARFORCE Project. Aspect 1 gives the basic didactic foundation to design (but are not limited to) teaching and learning activities. Aspect 2 classifies and describes laboratories in engineering education, learning objectives, and examples of innovative learning methods in relation to the laboratory activities, such as research-based learning. In this aspect, an innovative digital environment is also addressed to give basic information regarding the possibilities of a digital laboratory. Aspect 3 is discussed to engage the international and intercultural characteristics of the geographical scope within the PARFORCE learning activity. Aspect 4 presents a review of Moodle as a learning and collaborative tool with a description of its useful functions. Aspect 5 is presented to provide supporting measures in designing the didactical framework of the PARFORCE learning activity. For each aspect, the application of considered methods into the pilot course within the scope of this project is mentioned.

To make sure that associated literature resources to address the didactic aspects are reliable, the Centre for Teaching and Learning of Ruhr-University Bochum (ZfW-RUB, Zentrums für Wissenschaftsdidaktik) was invited to give didactic lectures as a two-day hybrid seminar for the PARFORCE Project Partners. The hybrid seminar (with online and present participants) was held from February 10th to 12th 2022 in Ruhr-Universität Bochum, Germany. The seminar also acted as a meeting where the participants were able to ask and discuss the didactic problem and classroom experience. Recommendations in the form of literature and presentations were distributed from the lecturer to the audience after the seminar.

The following six topics were presented by the lecturer(s) during the seminar:

- Basics for the design of teaching;
- Basics: Laboratories in engineering education;
- Considerations for the development of a repository (a didactic perspective);
- Teaching-Learning scenarios for PARFORCE: Inverted Classroom, Collaborative Teaching-Learning Methods, Research-Based Learning;
- Virtual Exchange.

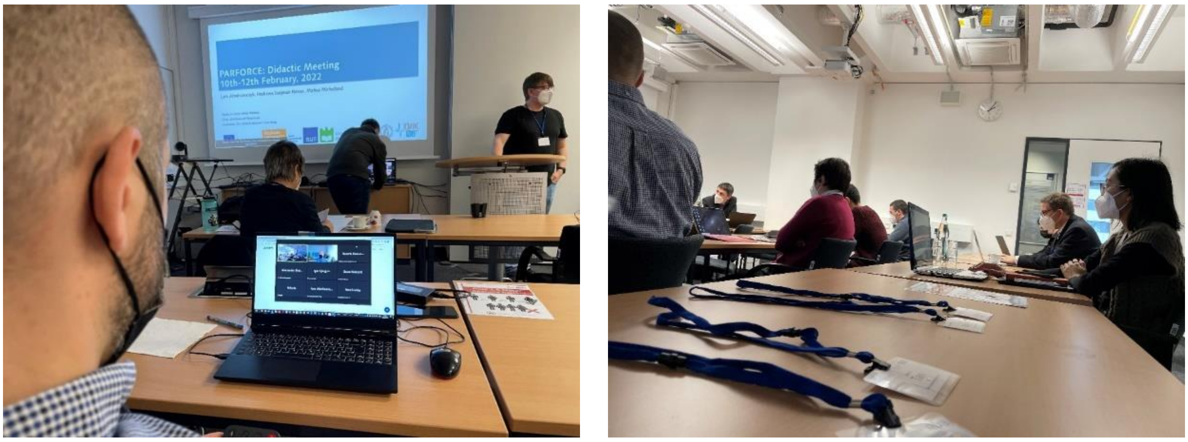


Figure 1.2: Didactic Meeting and Seminar in Bochum.

2. Digitally Assisted Teaching Design in Engineering Education

The main question for a teacher when designing a course is “What serves students best in their learning experience?”. The question is important because the object of a teaching strategy is the learning process of students. The following part will try to answer this question. Teaching is not easy. As teaching always implies learning, it is a difficult task. The main reason is that it is not possible to completely anticipate the learner’s side or to step into the role of the learner and see the learner’s needs. One way to deal with this problem is through learning design.

Learning design is thoughtful planning of teaching and learning and deals mainly with structure, methods, and learner autonomy. *Structure* means that there is a basic frame that gives orientation to the learner. *Methods* describe different ways to design the structure, between autonomy and guidance of the learner.

When designing teaching formats, especially in the case of virtual labs, the teacher should consider the following aspects to serve the student in the best way in his or her learning journey.

2.1. Didactical Situation and Process

Figure 2.1 illustrates a typical *didactical situation*, which traditionally involves two main parties: the teacher, often perceived as the primary source of knowledge, and the students, who are on their journey toward becoming experts in the subject matter. In classical/conventional educational settings, the teaching process tends to be one-sided. For instance, during a lecture, the teacher is primarily responsible for disseminating information and transmitting knowledge. The students, on the other hand, are expected to absorb this information, understand it, and process the content that is new to them. This model of teaching, while common, often results in a passive learning experience for the students.

To mitigate this, some lectures incorporate questions and small tasks to keep the students engaged and active. However, even with these additions, students are generally less active during a traditional lecture compared to when they are learning independently. This highlights the importance of integrating more interactive and participatory elements into the teaching process to foster a more dynamic and engaging learning environment.

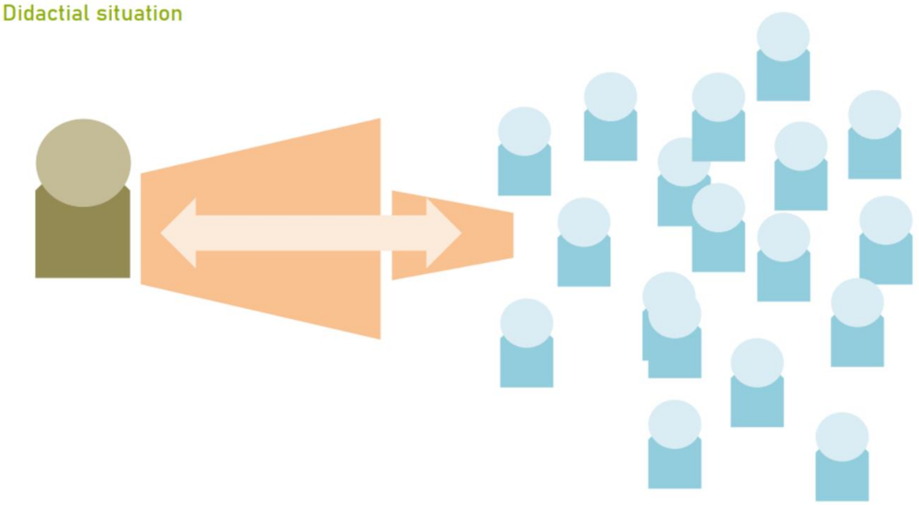


Figure 2.1: Didactical situation of teacher and learner in a classical lecture (Braungardt, 2022).

Modern didactics tries to break the passive role of the learner and wants to have a more *active learner*. Increased learner engagement leads to enhanced learning effectiveness, as it requires a deeper understanding and assimilation of the educational content. In this context, both the nature of the activity and the roles of the teacher and the learner play crucial roles. Modern views on the role of teaching see the teacher's role as a learning coach not prescribing the learning process but supporting it, the so-called *guide by the side* as shown in Figure 2.2.

Teachers perceive their role as guiding learners through a structured learning process, which encompasses a defined beginning and end. The culmination of this process involves learners attaining specific goals and competencies within a designated timeframe, enabling them to become proficient experts in their respective fields. To facilitate this, the learning process can be strategically designed, taking into account various didactical parameters that influence instructional outcomes. Depending on the state of these parameters, teachers may need to take proactive measures to ensure optimal learning experiences for their students. The learning process can be designed by taking into consideration several so-called didactical parameters. The parameters might require action by the teacher depending on the learner's progress.

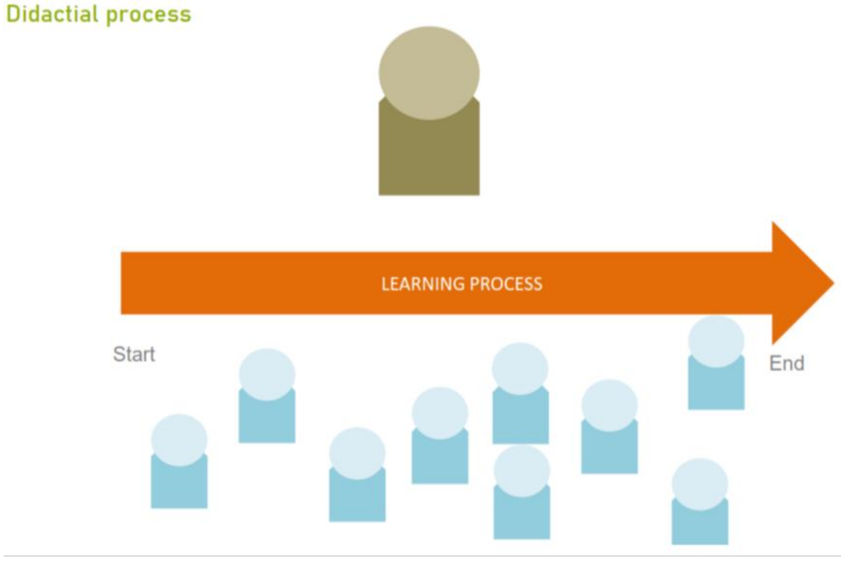


Figure 2.2: Learning process and the relation between teacher and learners (Braungardt, 2022).

2.2. Didactical Parameters

One important decision for the design of a university course is the *definition of goals*. There are goals on different levels. Relevant to the learning process can be the institutional goals. For instance, an institutional goal may be that students acquire very early research competencies. This goal can be reflected in the learning design. The teacher normally pursues subject-directed goals around the content and the methods of a field. But there might also be goals and skills outside the subject-related goals, for instance, computational or presentation skills that play a crucial role in personality/confidence development. Finally, the goals of the learner might not always be consistent with the teacher(s) or institutional goals. For instance, more important for a student than the acquisition of different levels of competency may be the passing of the course. Therefore, it is important to talk about goals so that the teacher and learner are aware of the respective objectives even if they might not be congruent in all aspects.

Very often referred to in the learning design is a taxonomy of *learning goals or learning objectives* (see Chapter 3.2). This taxonomy makes up different levels of cognitive and procedural skills. Memorizing and understanding are the basic levels. Only when the student understands and knows something, it is possible to apply knowledge and go further, for instance, by analyzing, evaluating, and creating content. This means there are higher-order learning goals that imply an in-depth understanding of the field of study. These can be used to design learning sequences and learning tasks. The taxonomy, however, does not need to be fulfilled in detail. Relevant is the insight that higher learning goals imply more intensive and broader learning activities. If they are not achieved, the knowledge acquired remains in a sort of still state. All learning activities should be designed with a reference to learning goals. This makes the learning activity relevant and transparent.

The role of the teacher and the learners needs to be considered. As discussed above, the more active the learner, the better the learning process. To achieve a suitable learning experience, the teacher needs to be clear about the audience of the course i.e., the target group. Such considerations may include:

- Homogeneous/heterogeneous group;
- Prior knowledge;
- Experience: learning and subject;
- Motivation;
- Gender;
- Age;
- Language;
- Cultural background;
- Impairments, e.g., eyes, ears, etc.

In general, not all characteristics of the *target group* that are important for the learning process are known beforehand. There are a lot of variables and characteristics that can influence the learning process. Each learner possesses unique characteristics, and the level of homogeneity within a group of learners can vary considerably. When significant differences exist among group members, designing a universally applicable learning process becomes challenging. In such cases, certain learners may struggle to keep up, experiencing difficulty in comprehending the requirements or understanding their tasks. While it is not feasible for the learning design to account for every learner variable, it is beneficial to be aware of them in order to implement suitable interventions.

One important variable is the degree of *prior knowledge* and *prior learning experiences*. Prior knowledge means learners can more easily process new information and incorporate it into their existing knowledge base. By implementing questionnaires or polls teachers can get to know the level of prior knowledge and adapt teaching strategies accordingly. Prior learning experiences can mean that learners, for instance, are used to learning on their own and acquiring new content with self-methods. This is usually relevant on the way from school to university learning but also when learners come from different institutional backgrounds. One consequence of the teaching strategy may be that stronger guidance of learning activities is necessary for certain students.

Motivation can be found in various forms and at various degrees in learners. Some may be very ambitious while others only give minimum effort to successfully finish a course. This is of course related to personal goals and values that students connect to a course or a learning activity. Usually, there is a mixture of intrinsic and extrinsic motivation, which means the students are driven by their interests or by external rewards. Depending on the motivational state, several strategies can be applied, for instance, setting up challenging tasks or rewards.

Other variables such as gender, age, language, and cultural background refer to the *socio-economic status* of students which cannot be always addressed directly but at the least form determinants of learning and communication behavior. This may play a role in learning tasks that are designed for collaboration but also in general when participation is required. In this respect, a potential teaching strategy could be to increase the level of participation to a greater degree than usual.

Emphasizing the importance of *accessibility* is essential, particularly when considering learners with hearing or visual impairments. While these needs may initially be perceived as special requirements, prioritizing accessibility benefits all learners by enhancing the usability of the course (referring mainly to the online part of a course). In general ways of considering learner variables is to set up questionnaires with anonymous answers at the beginning of a course to get to know the knowledge level and interests of students. Also, direct communication about interests and goals can provide a general idea about the learners.

It is important to communicate the *conditions and structure of the course* early during the learning journey. There is a range of parameters or conditions that are influential but cannot be changed from the teacher's perspective. They are also to be considered and moderated in the learning design. In preparation for the upcoming course, the teacher should address the following aspects during discussions with the students:

- Topic and content;
- Level (prerequisites);
- Credits, workload;
- Duration, time;
- Assessment criteria;
- Group size(s);
- Type of course;
- Obligatory/voluntary.

The selection of *topics or content* for a course is typically dictated by the curriculum, where the quantity of content may be predetermined. Both the quantity and complexity of the content can significantly impact the course design and have implications for the learners. In certain cases, an advanced course can ignite motivation in certain students, while simultaneously diminishing the motivation of others. Often, an overwhelming amount of learning content can lead to learner overload, subsequently diminishing motivation. To address this, breaking down the learning content into smaller, manageable parts can prove beneficial.

The *level of knowledge* is very often set. Courses are offered for a certain level of knowledge and learning activities should be designed accordingly. A problem could be that learners are not aware of the level of knowledge they are supposed to have (i.e., prerequisites). One possible solution to this issue would involve offering self-assessment tests.

Credits and workload form also part of fixed conditions dictating the level of teaching autonomy. With more credits, there is room for more learning activities. Nevertheless, neglecting the workload can result in frustration when the course workload does not align with the allocated credits. It is crucial to ensure transparency in learning tasks and avoid any hidden tasks.

Every course also has a fixed *duration* and a distribution of time slots. This usually refers to synchronous sessions (i.e., schedule). Based on the learning design, the combination of synchronous sessions in combination with asynchronous activities need to be planned and discussed.

The type of *assessment* should be determined beforehand i.e., written/oral exams, assignments, and(or) mandatory tasks. This choice of assessment significantly influences the learner's engagement and activities. Disregarding this consideration may result in the learning activities being perceived as unsuitable. Conversely, if the focus is excessively placed on exam-oriented learning, there is a risk of inadequately achieving all the learning goals.

The *group size* is also important. Larger groups allow fewer opportunities for active learning and possibilities for participation. This has to be carefully designed, especially for large groups participatory technology (voting tools) can be used.

University courses usually are offered in fixed *course types* like seminars or lectures. The latter induces a greater amount of instruction with fewer chances for active learning and participation.

According to the study plan some courses are offered as *obligatory*, some as *voluntary*. Students tend to exhibit higher motivation when they have the freedom to choose their courses. These parameters mentioned above are influential factors in learning design, acting as facilitators or barriers by enabling specific instructional approaches. Some parameters may hold greater significance than others. Therefore, the learning design should consider these factors based on the specific situation at hand.

The *course structure* is the basic object of learning design. A course is divided or segmented into several units or lessons which can be structured along various criteria, for instance along the taxonomy of learning goals, from easy to complex, or simply according to the logic of contents. A general example is shown in Figure 2.3. An important design decision is the question if the learner must follow a strict learning path or if the learner can jump between different units. Usually, advanced learners do not necessarily need to follow a specific prescribed path but can follow a self-devised strategy.

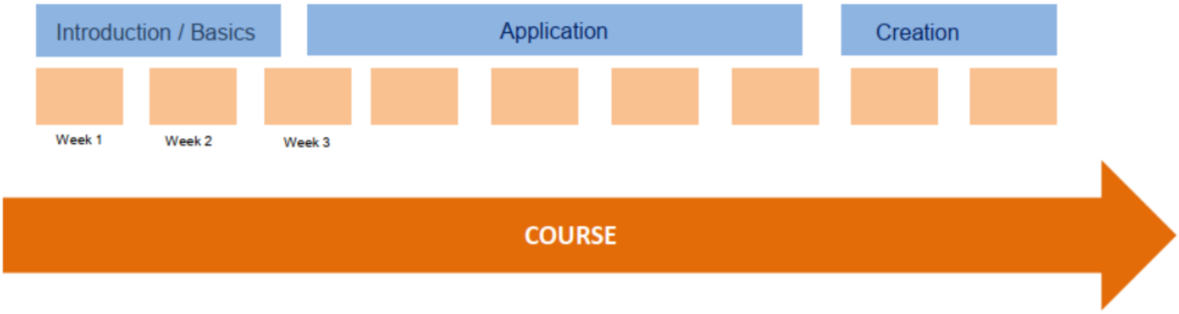


Figure 2.3: Course structure during a semester (Braungardt, 2022).

With digital learning technologies, there are also possibilities to design a course with *synchronous and asynchronous* phases. As shown in Figure 2.4, synchronous phases can be local but also online with web conferencing technology. Synchronous phases are especially suited for intensive communication and dialogue. Asynchronous phases can be specifically tailored to support individual learning and self-study scenarios, where communication and interaction can take place asynchronously through messenger platforms or online forums.

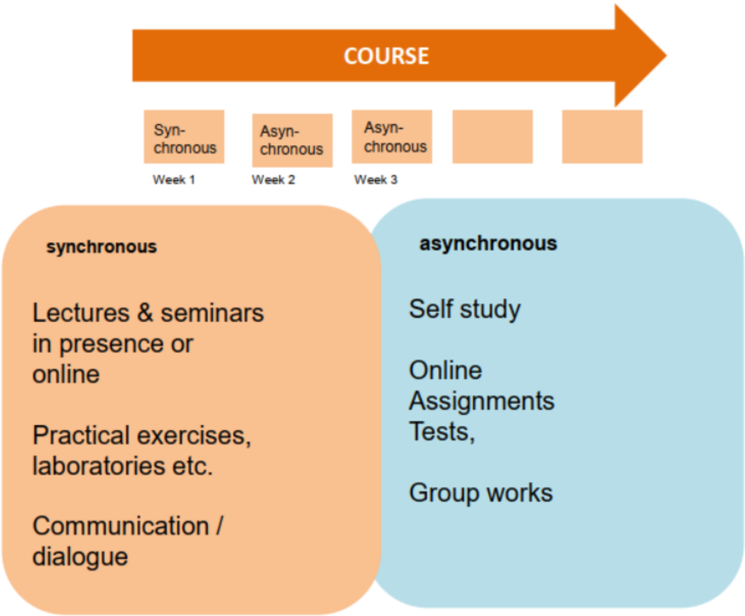


Figure 2.4: Implementation of synchronous and asynchronous phases (Braungardt, 2022).

Each unit of a course can be effectively designed by incorporating activities from the domains of content, assessment, and collaboration. Ideally, the provision of a content element is combined with a *learning task*, done individually or collaboratively. Distinct domains provide opportunities for employing diverse approaches and methodologies. Especially digital learning tools can be implemented and used to provide variety and even increase motivation alongside specific methods like problem, collaborative, or research-oriented learning. In each domain, there are various forms of representation available to cater to diverse learning needs and preferences.

Table 1. Multiple forms of representation exist within each domain.

Content	Assessment	Collaboration
Textbooks	Questions	Group assignments, group projects
Lecture notes	Problems	Group assignments should be complex so that an individual cannot do it alone
Scientific literature	Case studies	Group assignments are good from a didactic point of view as it activates different competences
Videos		

2.3. Learning Models

The details of the teaching design follow the chosen *learning model*. Three *learning models* are suggested here, which can be used as a pattern to construct a course as shown in Figure 2.5 and Figure 2.6. The focus of the instruction-based learning model is the delivery of basic knowledge. It is directed towards beginners and works with guided and prescribed activities. Contrary, the explorative learning model can be seen as the opposite of instruction-based learning. Explorative learning requires more initiative by the learners. It is highly self-directed and makes use of higher learning goals following the taxonomy of Bloom (see Chapter 3.2). The self-study learning model can be used to design learning phases without synchronous sessions. It requires self-regulation as an individual learning strategy and can be used to learn basics but also to go deeper into a topic. All three models can be combined in a single course. The teacher should decide which learning model or which combination of learning models is best suited for the course. The type of used learning model depends on the subject and general field of learning and target group. For instance, self-study might be hardly achievable in a few courses.

Figure 2.5: Three learning models for implementation in a university class (Braungardt, 2022).

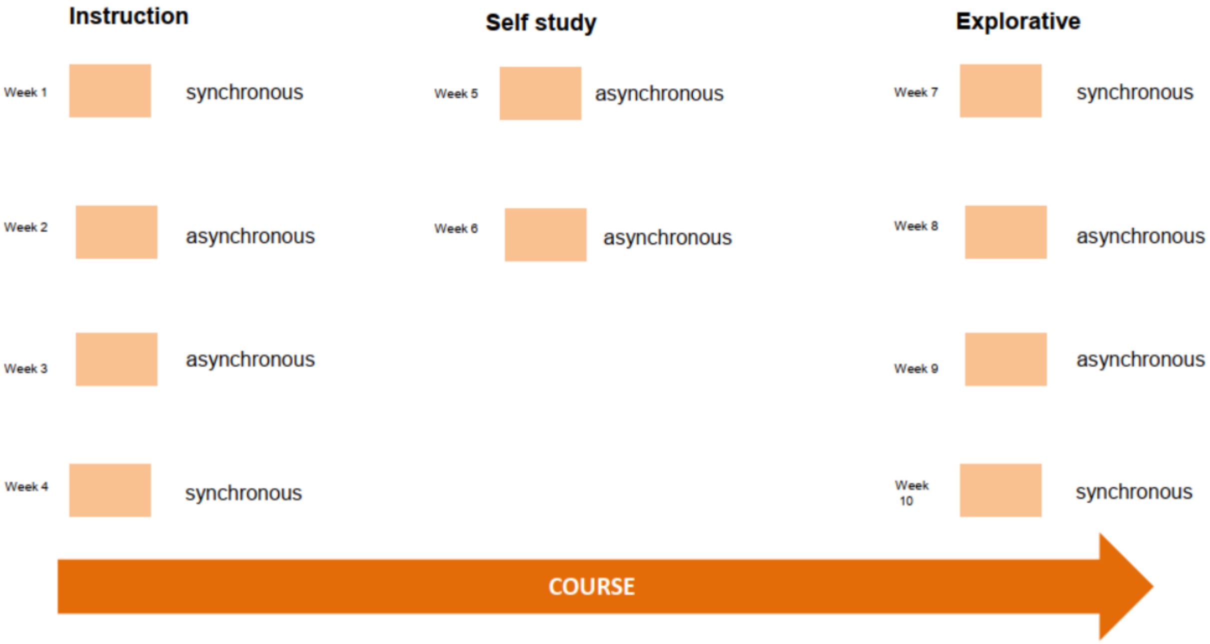


Figure 2.6: Course design implementing three learning models, instruction, self-study, and exploration (Braungardt, 2022).

2.4. Evaluation of Teaching and Learning/Feedback

To measure or get an insight into the success of the learning design several methods for *evaluation or feedback* can be used. It can be differentiated between formative and summative evaluation. Evaluation also means that students give feedback on the learning design of the course. Formative means proceeding with different types of questionnaires during the course to have the chance to adapt the learning design by, e.g., polls, learning journals, and dialogue. For instance, if the pace of the course is too fast, there is the possibility to slow down and to give the possibility to repeat certain parts. The summative form of evaluation (questionnaires, statistics) is conducted at the end of the course and is ideally related to the goals of the course. For instance, a question could be if the learning activities have contributed to the goal acquisition.

Chapters 2.1, 2.2, 2.3, and 2.4 are based on (Braungardt, 2022).

2.5. Inverted Classroom Method

Inverted Classroom Method (ICM) refers to a teaching-learning concept based on the idea of "flipping" the basic activities of the classical lecture. In the traditional lecture format, the learning input takes place through the lecture by the teacher in front of a group of students in the lecture hall, whereas the in-depth process and discussion of the content usually take place at home in individual work.

In ICM, on the other hand, the learning content is acquired through multimedia online material for individual work. Individual work (out-of-class) is proposed to subsequent the classroom session (in-class) as a joint in-depth and interactive discussion of what has been learned. Figure 2.7 shows the scheme of a conventional and an inverted classroom respectively.

The inverted classroom (ICM) is not to be understood as a single method, but rather as a guiding idea for (inter-)active university teaching, which can be designed in different ways depending on the course. ICM can be understood as a special form of blended learning, i.e., the interlocking of computer-supported learning and classical teaching. If the teacher wishes to engage more in conversation with the students, dive deeper into a particular topic, or work in a more application-oriented way, the inverted classroom could be very useful to be implemented.

(a) **(b)**

Figure 2.7: Schematic of conventional **(a)** and inverted classroom **(b)** (ZfW-RUB, Inverted Classroom).

2.5.1. Objectives and Purposes of ICM

The overarching goal of ICM is to create more space and time for a shared approach to supplement face-to-face teaching by outsourcing basic learning activities to the online phase. In contrast to the conventional lecture format, ICM allows the teacher to make more targeted use of the cooperative learning opportunity in the lecture hall and to shift the focus away from a more teaching and instruction-oriented approach to a learning and interaction-oriented one. Accordingly, in the in-class phase, it is important to initiate core interactions: Through sharing, discussion, and bringing perspectives together, which enables the sharing of questions and ideas within students, the teacher enables the development and reflection of the learning content in a way that cannot be achieved in individual work. Implicitly, the ICM model thus assigns a high relevance to cooperative face-to-face learning.

The out-of-class phase, however, is not only a means to an end for the in-class phase, but it holds the potential for didactic added value. The use of digital elements allows students to acquire the necessary basics individually, flexibly in terms of time that is adjustable to each individual. For example, individual learning with shared online videos opens the possibility of learning content at one's own pace, depending on personal pace, depending on one's own prior knowledge. Contents that have not yet been adequately understood can be watched again. Accordingly, the contents that are already familiar to the students can be skipped over. Questions integrated into the videos (and immediate feedback if necessary) can support students in checking their learning status and process. Based on individual response behavior, innovative e-learning tools allow students to navigate to a specific point in the video (e.g., clarification of terms) or provide them with further information. Desired effects in the out-of-class phase from the side of the students are thus the flexibilization and individualization of the learning process as well as the development of increased awareness of one's learning progress. In this way, ICM promotes the self-direction skills that are increasingly relevant in today's working and living environment. It also trains the students in the use of digital educational resources. For teachers, too, "turning around" their courses has the advantage of being able to accompany the students in the learning process more closely, identify difficulties more easily and develop their teaching in a meaningful way.

2.5.2. Procedure and Structure

A proven (but not indispensable) means of familiarizing students with the learning contents for the out-of-class phase of an inverted classroom are short instructional videos. Videos are suitable, for example, for the presentation of processes (e.g., work procedures), for illustrating certain procedures and systems (e.g., an operating theatre in the field of medicine), or for catchy learning materials. It is up to each teacher to decide whether to produce their video in the form of a lecture recording, a screen recording with sound, or a more elaborate green screen recording, or whether to use an available video created by others. Since about eleven percent of students are affected by a disability, e.g., a hearing impairment, it is worth checking whether you can add subtitles to videos, for example, or increase accessibility in some other way.

To promote active engagement with the content in the self-learning phase, it is recommended that teachers do not provide the video as a stand-alone learning medium, but enrich it with further links, text, images, and(or) audio files as well as accompanying tasks. Questions embedded in the video or separate worksheets can help learners to reflect on what they have seen and read and review their learning process. For example, H5P features can be used. They also provide a good starting point for clarification of comprehension problems of the digital content and further engagement with the content in the in-class session. In-class sessions, in which what has been learned online is discussed and/or applied and/or deepened, primarily in cooperative work, and/or deepened in cooperative work.

Since the "flipping of teaching" must always be fitted into the didactic and structural framework of each course, inverted classroom scenarios are diverse in their design(s). In general, with an individually designed ICM teaching method, the teacher should always aim to create a profitable and close link between online and face-to-face teaching. This connection is a key element in ICM. As a self-directed learning method, the course participants acquire knowledge with the help of the content presented in the out-of-class phase and thus the necessary tools for the in-depth learning activities in the in-class phase.

2.5.3. Didactic Design and Planning

The concrete design of an inverted classroom depends on various factors such as the respective teaching-learning objectives of the course, the prior knowledge and learning needs of the students, the preferences and experience of the teacher, and finally, the curricular and structural framework conditions (e.g., number of participants, examination regulations, technical and spatial resources).

Decisions about which online tools and methods are to be used, how learning units are to be structured in a meaningful way, and which individual and/or cooperative tasks are to be set for both the digital and the analog setting.

The following questions can guide a teacher during the didactic design and planning of an inverted classroom:

- Clarify goals
    - What do I want for learning and teaching in my lessons?
    - (How) can an Inverted Classroom contribute to improving my teaching?
    - What learning objectives do I want/need to pursue in my course?
    - What competences do I want the learners to acquire?
- Identify the target group
    - Who are the learners (first-year students, previous knowledge, number of participants)?
    - What special needs do they bring with them?
- Check conditions
    - What do I want to achieve in the attendance phase?
    - Which methods are suitable for my in-class course to achieve the learning objectives?
    - What are the spatial conditions (technical infrastructure, flexibility, e.g. in seating arrangements)?
- Encouraging interaction
    - How do I activate my students both in-class and online so that they don't just let themselves be "sprinkled"?
    - How can I also promote online interaction?
- Setting the scene
    - Do I turn my entire course around?
    - Do I take out just one session and change it on a trial basis?
- Selecting material
    - Which online materials do I use? What are my requirements?
    - Do I use Open Educational Resources (OER)?
    - Do I make my teaching videos and other materials and if so, how do I do it?
    - How do I ensure the accessibility of my presentations or videos?

- Reflecting on my role and evaluation
  - What is my (new) role as a teacher? And how do I fit into it?
  - How can I meaningfully accompany and evaluate the students' learning process and my course?

2.5.4. In-Class Session

The in-class session, whose further development is the focus of interest in the ICM, should be the starting point for planning the concrete use of methods. Which methods you use as a teacher for the out-of-class phase ultimately results from the consideration of how your learners are to be adequately prepared for the in-class phase.

For example, the three core aspects of design on which the in-class phase typically focuses are Activity, Communication, and Deepening/Application. These aspects can be realized in different ways. One challenging task for the teacher is to structure and moderate the interactions appropriately to advance them. and moderate the interactions accordingly to drive them forward and make them beneficial to the learning. Figure 2.8 shows an exemplary collection of some ideas for the design of the in-class phase.

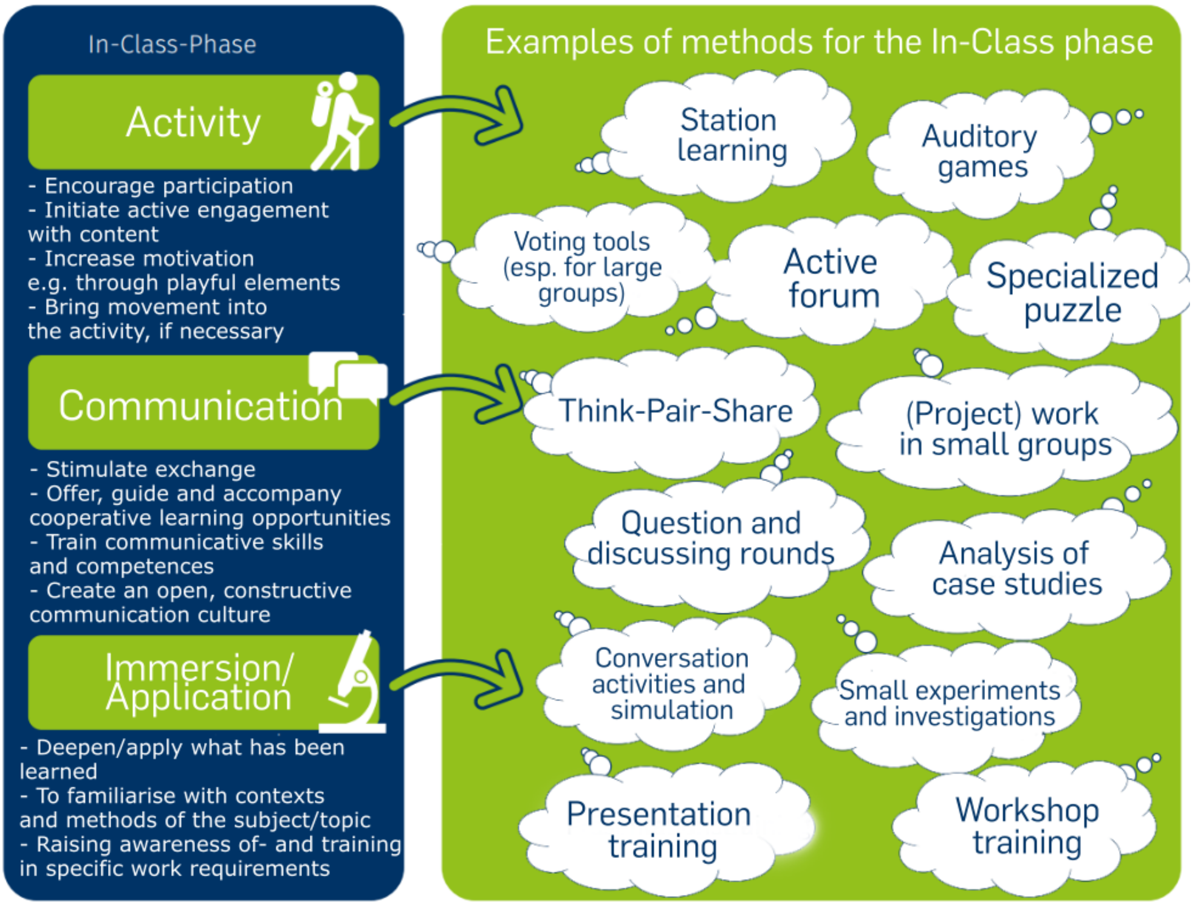


Figure 2.8: Exemplary core aspects and method examples for designing the in-class phase (ZfW-RUB, Inverted Classroom).

2.5.5. Out-of-Class Session

The out-of-class phase is to be designed in such a way that the learners are equipped with the necessary "tools" for profitable participation in the in-class phase. Videos can, but do not necessarily have to be used to convey knowledge. With the help of a learning management system such as Moodle, a wide variety of materials can be structured and supplemented with additional features (e.g., gamification elements, individual tests gamification elements, individual tests, or cooperative tasks) to stimulate active learning behavior. The following example of tools and tips for the teacher to develop a more effective and interactive out-of-class phase are listed below.

- eLP (Electronic Course Planner - *Der Elektronische Lehrveranstaltungsplaner*) as a supporting tool for planning an inverted classroom.

  The freely accessible, online-based course planner eLP of the University of Wuppertal is not specifically designed for the organization of inverted classroom scenarios, but it also offers valuable support for "inverted teaching" to formulate learning objectives along suitable taxonomies, to specify the sequence and coordination of online and classroom phases and to record the need for materials and technology.

- H5P (HTML5 Package) as a versatile tool for activation in the out-of-class phase

  For education, H5P is an open-source JavaScript-based program framework that enables educators to create interactive content in web-based media, e.g. Moodle. This enables Moodle to offer numerous possibilities to make existing or newly produced learning material available digitally and to prepare it in such a way that learners are encouraged to actively work on it. For example, the plug-in H5P, which is implemented as standard in Moodle at the RUB, allows locally stored videos as well as videos available on YouTube to be provided with intermediate reflection tasks in no time at all. In addition, the tool offers various other possibilities to advance the individual learning process.

- Voting Tools

  Especially in events with a large number of participants, voting tools offer the possibility of activating learners and promoting interaction if they are combined with cooperative forms of work (e.g., prior discussion of the question among participants in pairs). Some examples of voting tools such as:

  - ArsNova as an example of an online-based voting tool: an innovative Audience Response System is ARSnova (Particify, 2022) is a publicly available and free-of-charge voting and feedback service for educational institutions. To use ARSnova as a lecturer or student, simply open the browser on your smartphone, tablet, or laptop and enter the following address: arsnova.eu. This gives a simplicity aspect where the users do not need to download a phone app from an app store. ARSnova also provides a feedback channel for lecturers so that students can anonymously ask questions during the lecture (Technische-Hochschule-Mittelhessen, 2022).

  - Plickers as an example of an almost analog voting tool (e.g., in case of insufficient internet connection): an assessment tool application made by a teacher who was looking for a quick and simple way to check student understanding. This assessment tool allows teachers to collect on-the-spot formative assessment data without the need to have students use devices or paper and pencil (University-of-Massachusetts-Amherst, 2022).

Chapter 2.5 is a translation and adaption from "Inverted Classroom" by ZfW-RUB, licensed under CC BY-NC-SA 4.0 (ZfW-RUB, Inverted Classroom).

2.6. Teaching and learning methods in the pilot course

The methods of teaching and learning that have been discussed will be taken into account in the organization of the pilot course. In view of the hybrid nature of the course, the international and different cultural backgrounds, and the different locations of the participants, appropriate teaching methods should be introduced. The diversity of the students' academical backgrounds (major) should also put in mind. Students may have different aims and interests in participating the pilot course. For example, students may have lower motivations if the pilot course is not considered as a compulsory subject in their Master's programme. On the other hand, a student may be highly motivated if a certain attachment is formed during the pilot course, e.g. high interest in the course topic, the will of networking and gaining experience. In this sense, the following teaching and learning methods are introduced in the pilot course

- Out-of-class session and collaborative task through semester project;
- In-class session through consecutive online lectures, built to give background information on the given project task;
- The use of online quiz;
- Specialised lecture contents that is believed to have not yet been provided in the other class of the student's programme (e.g. measurements from various specific laboratories).

3. Physical and Virtual Laboratories in Engineering Education

3.1. Classification of Laboratories

The implementation of laboratories in engineering education can lead to substantial learning success for students that can be hardly acquired in other classical learning environments and didactic situations. To achieve this learning success, laboratories should be developed within a course or curriculum with a focus on the potential added value of using laboratories for the learner and which learning objectives can be realized within the laboratory.

As summarized by (Terkowsky et al., 2020), a laboratory is understood as a scientific or technological environment in which scientific or technological research, development experiments, tests, or analyses are conducted. In the context of engineering, technical laboratories are used to build, develop, and test machinery, processes, and products. Laboratories in engineering education can be utilized for empirical research to observe, measure, experiment, test, and analyze. (Terkowsky et al., 2020) list twelve different laboratories that can be utilized in scientific or engineering education:

- Mini-Labs, limited to a brief time frame;
- Classical beginners teaching-learn-laboratory;
- Development- or construction laboratory to solve clear problems utilizing products, processes, or constructions;
- Research laboratory, with open questions to gather new insight;
- Integrated laboratory within other teaching environments, where the advantages of laboratories are utilized to enhance understanding;
- Practically oriented laboratory, to prepare the student for working as an engineer;
- Teaching-training factory, where products are to be created by the learner, demands a high level of self-organization;
- Game-based learning laboratory, where motivating effects from games are utilized to improve the learning experience;
- Fablabs and Makerspaces are free to use for students, requiring the student’s initiative;

- Walk-in labs, with a low threshold to be utilized by students. Walk-in labs can be combined with other ideas of laboratories resulting in a variety of possible achievable learning objectives.

(Zutin et al., 2010) distinguishes between a variety of different laboratories as shown in Figure 3.1. Local laboratories are classical laboratories that are frequently utilized in engineering education. These laboratories require the physical attendance of the student in the laboratory. Contrary, online laboratories do not require the presence of the learner but can offer the learner an experimental experience that is accessible from anywhere so that experimentation from within the learner's home is possible and independent of the distance to the institution. Here, a distinction is made between a remote laboratory and a virtual laboratory. The former requires physical hardware equipment similar to the classical local laboratory, whereas the latter is solely created in a virtual environment of software simulations. (Terkowsky et al., 2020) introduces the term cross-reality laboratory to describe any combination of classical, physical laboratories with virtual realities.

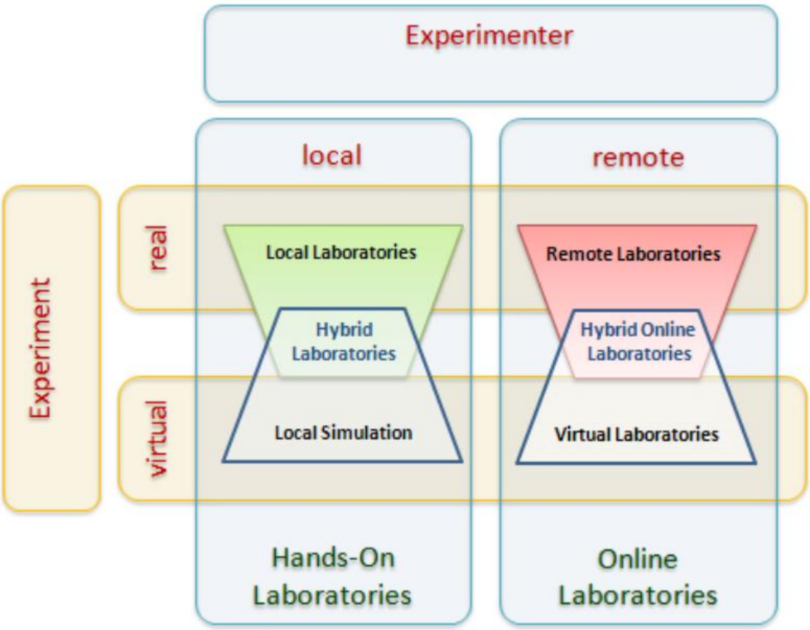


Figure 3.1: Classification of laboratories, copied from (Zutin et al., 2010).

Online laboratories offer a significant advantage by providing learners with the flexibility to access them from any location and at any time, effectively overcoming the limitations of traditional laboratories. (Zutin et al., 2010) highlight that the utilization of expensive and specialized equipment, which often leads to inefficiencies in traditional laboratories, can be effectively addressed by offering online laboratory experiences to students. Furthermore, online laboratories allow for increased scalability and accessibility, as they can accommodate a larger number of students without the constraints of physical space or equipment availability. This not only promotes inclusivity but also encourages active participation and exploration in laboratory activities.

Table 3.1 delineates the roles of students and teachers in relation to different types of laboratory activities. It provides a comprehensive overview of the responsibilities and engagements of both students and teachers in facilitating and guiding laboratory-based learning experiences.

Table 3.1: Roles of student and teacher in association with laboratory activity type (Sunal, Wright, & Sundberg, 2008)

Laboratory Activity Type	Role of Student	Role of Teacher
Confirmation	Attends to what the teacher is doing and saying, performs activity as instructed for results already known	Provides question, procedure, materials, expected results, and determines the appropriateness of answer
Structured inquiry	Investigates, constructs answers, and determines appropriateness to the question	Provides questions, procedures, and materials to carry out an investigation and facilitates students in their role
Guided inquiry	Plans investigation, performs investigation, constructs answers, and determines the appropriateness of the question	Provides questions and materials to carry out an investigation and facilitates students in their role
Open inquiry	Determines question, plans investigation, performs investigation, constructs answers, and determines appropriateness to the question	Facilitates students in their role

3.2. Learning Objectives

> *If you don't know where you want to go, you won't know which road to take and you won't know if you have arrived - Truism found in (Feisel & Rosa, 2005)*

Learning objectives are the learning benefits for the learner that finishes a course successfully by participating in the various course activities that are stated in the course description (Biggs J., 2011). The student's achievement of reaching the defined learning objectives is controlled at the end of the course by the teacher. Learning objectives are the starting point when planning an engineering teaching environment. Learning objectives provide the goal and the outcome of skills and competences that a teacher wants to deliver to the students. As the goal is clearly formulated, the path to reach these objectives during the teaching activity becomes more comprehensible to the teacher. Learning objectives should be set, discussed, and aligned with the students' needs and the goals of the institution, the teacher, and the students. These specific goals might vary significantly between the different parties but also within parties. For instance, some students might just want to pass the class, whereas other students want to learn more even beyond the basic topics discussed.

From the student's point of view, learning objectives clearly state the added value they receive when finishing the class successfully. Hence, learning objectives should be stated explicitly at the beginning of the teaching activity. Often, learning objectives are described in a list starting from objectives that are rather simple to achieve to hard-to-achieve objectives. To formulate teaching objectives in the framework of teaching at the university level, bloom's taxonomy and its revision (Anderson, 2009) and the SOLO (Structure of the Observed Learning Outcome) Taxonomy (Biggs, 1999) can aid the teacher (shown in the right of Figure 3.2). These taxonomies offer hierarchies for different learning objectives.

The more utilized Taxonomy by Bloom (Terkowsky et al., 2020) is shown in Figure 3.2 on the left. At the bottom of the triangle, the simplest cognitive learning objective is described. At this lower level, the student gains and remembers knowledge. To define and describe the different stages of learning objectives, Bloom's hierarchy proposes a variety of different verbs. The verbs can be seen as key-action words to actively describe the task statements. For instance, for the first stage where "remembering" is the objective, verbs such as "define", "identify", "list", "name", and "label" can be utilized. The higher a learning objective is positioned in the triangle, the more intricate it is for a student to achieve. The different levels that require increased cognitive abilities are "understanding", "applying", "analyzing", "evaluating", and finally "creating". As stated by (Terkowsky et al., 2020), both taxonomies (Bloom's and SOLO) are not specifically formulated regarding learning in laboratories, and learning outcomes that are conceptualized with a focus on work in the laboratory are absent. Many of the tasks that are solved by students in the laboratory would be included in Bloom's Taxonomy in the category of "applying" (Terkowsky et al., 2020).

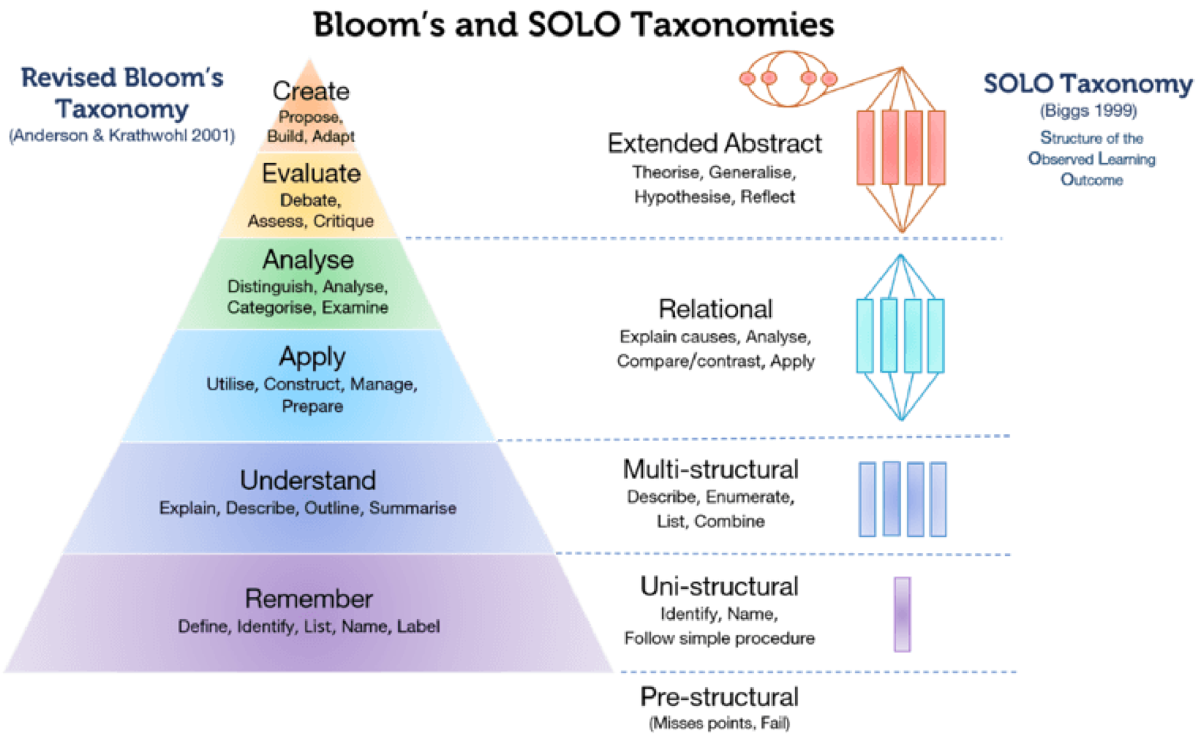


Figure 3.2: Bloom's revised Terminology and the SOLO Taxonomy (Gulzar, 2021).

As providing engineering laboratories requires suitable facilities, equipment, and staff, they are frequently more costly than conventional teaching environments. When such laboratories are made available as remote or virtual laboratories, monetary costs, time for didactic planning, and requirements for technical equipment and infrastructure increase. Hence, the utilization of physical and virtual laboratories in engineering education curricula requires substantiation of how the students' work in laboratories can supplement learning objectives from classical teaching situations. Hence, learning objectives should be formulated to underline the importance and the possibilities of laboratories for engineering education.

(Feisel & Rosa, 2005) formulated 13 learning objectives that can be assigned to the learner's cognitive, affective, and psychomotor domains as shown in Figure 3.3.

- Objective 1: Instrumentation. Apply appropriate sensors, instrumentation, and/or software tools to make measurements of physical quantities.
- Objective 2: Models. Identify the strengths and limitations of theoretical models as predictors of real-world behaviors. This may include evaluating whether a theory adequately describes a physical event and establishing or validating a relationship between measured data and underlying physical principles.
- Objective 3: Experiment. Devise an experimental approach, specify appropriate equipment and procedures, implement these procedures, and interpret the resulting data to characterize an engineering material, component, or system.
- Objective 4: Data Analysis. Demonstrate the ability to collect, analyze, and interpret data, and to form and support conclusions. Make the order of magnitude judgments and use measurement unit systems and conversions.
- Objective 5: Design. Design, build, or assemble a part, product, or system, including using specific methodologies, equipment, or materials; meeting client requirements; developing system specifications from requirements; and testing and debugging a prototype, system, or process using appropriate tools to satisfy requirements.
- Objective 6: Learn from Failure. Identify unsuccessful outcomes due to faulty equipment, parts, code, construction, process, or design, and then re-engineer effective solutions.
- Objective 7: Creativity. Demonstrate appropriate levels of independent thought, creativity, and capability in real-world problem-solving.
- Objective 8: Psychomotor. Demonstrate competence in the selection, modification, and operation of appropriate engineering tools and resources.
- Objective 9: Safety. Identify health, safety, and environmental issues related to technological processes and activities, and deal with them responsibly.
- Objective 10: Communication. Communicate effectively about laboratory work with a specific audience, both orally and in writing, at levels ranging from executive summaries to comprehensive technical reports.
- Objective 11: Teamwork. Work effectively in teams, including structuring individual and joint accountability; assign roles, responsibilities, and tasks; monitor progress; meet deadlines; and integrate individual contributions into a final deliverable.
- Objective 12: Ethics in the Laboratory. Behave with the highest ethical standards, including reporting information objectively and interacting with integrity.
- Objective 13: Sensory Awareness. Use the human senses to gather information and to make sound engineering judgments in formulating conclusions about real-world problems.

To highlight the importance of laboratories, the learning objectives should be formulated in such a way that not only knowledge and skills related to the scientific or technical field are acquired, but the development of relevant pre-vocational competencies relevant for future engineering jobs is focused. Laboratories can offer the teacher the opportunity to provide students with a learning environment in which the learners can creatively solve formulated engineering challenges that are aimed to facilitate competencies required by engineers in the digital age. These objectives can be defined in such a way that they require, besides other characteristics, individual responsibility, self-control, self-organization, independent work, and collaborative work (Terkowsky et al., 2020).

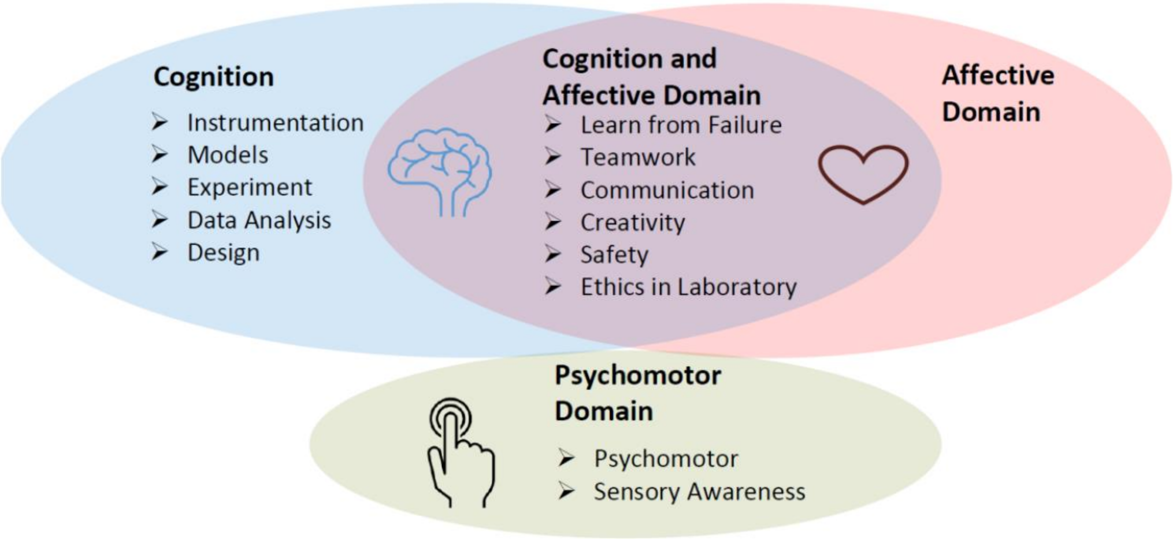


Figure 3.3: Related domains regarding the 13 learning objectives for laboratories. Figure from (Berbuir, 2022).

Despite the great potential of engineering laboratories to activate and develop competencies that go beyond conventional knowledge and skills that are achievable through classical teaching environments, engineering laboratories often fail to offer added learning objectives (Terkowsky et al., 2020). In many laboratories tasks and topic descriptions that offer a clear description of the problem description, and a well-defined solution strategy are handed out to the students. This is of course in stark contrast to many challenges in the professional life of an engineer where neither problem nor solution are explicitly known beforehand. This strongly guided approach also contrasts the learning objectives that aim to develop self-organized and self-controlled engineers.

To address this challenge, Terkowsky et al. (2020) propose an alternative approach by allowing students to complete a laboratory assignment through the creation of a journal paper, rather than the traditional format of a final lab report. This enables students to demonstrate their understanding and application of concepts in a more comprehensive and scholarly manner. Moreover, Terkowsky et al. (2020) emphasize the importance of students presenting both partial and final results to foster the development of competencies. However, they acknowledge that achieving the goal of activating competencies beyond basic knowledge requires careful didactic planning that may surpass the limitations of a standard university class. In cases where learning laboratories cannot fully reach the highest levels of Bloom's hierarchy, the curriculum can incorporate additional teaching methods and initiatives to effectively activate these higher-order competencies.

3.3. Realization of Online Laboratories in Engineering Education

At the beginning of 2010, the Rectorate of Ruhr-Universität Bochum promoted three projects in the scope of the “Research-Based Learning” internal program (refer to Chapter 3.5 for more details on Research-Based Learning). One of the projects, ViChemLab, presents a real technical test facility in environmental and process engineering in a virtual environment using a web application.

The ViChemLab "Virtual Chemical Laboratory" is a web-based application that simulates a real technical test facility in environmental and process engineering. Essential influencing parameters of the plant operation, such as gas and liquid volume flows, can be varied according to the real plant operation. Therefore, the test results, such as the pressure loss, can be produced virtually. The students independently carry out experiment procedures from their home PC and evaluate them according to scientific methods and requirements.

Degree programs such as mechanical engineering strive to prepare students for the strongly practical orientation of their later profession, in addition to providing a scientific background. The tasks of typical professions that graduates later pursue include the planning and execution of experiments in the laboratory and on equipment close to the industrial scale. Therefore, the study plan provides for some so-called specialized laboratories, in which practical experience in scientific experimental facilities and scientific procedures.

The first concrete experimental facility that has been mapped for the ViChemLab is an absorption column. Essentially, this facility consists of an upright hollow cylinder in which a gas and a liquid are brought into contact. A typical application of such plants is the separation of certain components, e.g., pollutants in exhaust gases, from a gas stream. The process is therefore also referred to as "gas scrubbing". These processes, such as those which are usually carried out at a real plant, are designed to last at least a few hours, sometimes a whole day.

This means that experiment supervisors and students have plenty of time for discussion and questions. The measurement procedures can be designed extensively or, if necessary, reproduced. However, due to this comprehensiveness, the number of such specialized laboratories provided in the curriculum is limited. The idea of the ViChemLab is motivated by the fact that specialized laboratories are highly valued by teachers and students as an intensive learning experience. The presence of these practical experimental courses in the study program is desired. The ViChemLab lends itself here to supplement specialized laboratories with virtual, but realistic experiments and to make the students' learning experiences with experiment to be more comprehensive.

Analogous to the preparation for a physical laboratory experiment, an experiment script is available, which includes an introduction, a detailed description of the experiment, and the thematic classification of the subjects. Furthermore, instructions are given on how to use the ViChemLab application (login, internet address, operation of the environment) and on how to conduct the experiment.

The independent experiment planning from the part of the students will be part of the performance. This usually includes planning the series of measurements. For example, preliminary considerations on which gas flows and which liquid flows have to be measured in order to fulfill the task of the specialized laboratory. After the experiments, the students apply the knowledge they have acquired in the teaching events by studying the experimental script to evaluate the measurement results and formulate statements about the evaluation of the results. This is because measurement errors and fluctuations can also occur in the virtual experiment in order to reproduce the system realistically.

According to scientific procedure, appropriate documentation, and presentation of both the experimental procedure and the results are presented in a report by the students, e.g., in the form of a protocol, possibly with an oral presentation. This is part of the complete scope of the learning experience.

The students prepare themselves for the execution of the experiment on the virtual test facility utilizing the provided experiment script. Through the preparation, the students will gain the ability to plan a systematic experiment independently. The experiments are then designed with systematic variations of the essential operating parameters of the experimental plant (pressure, temperature, mass flows, etc.). The phenomena announced in the experiment script are observed in the sense of learning. The students should recognize measurement errors and outliers that may be foreseen by the teacher in the application based on their prior knowledge and correct them by taking new measurements if necessary. The process of this virtual experiment must at least be supervised by competent teachers, whereby there are also high requirements regarding the programming and animation of the application. The impersonal preparation for the experiment employing the experiment script must be extensive and complete so that the execution of the experiment and the subsequent evaluation can be carried out independently and without the presence of a supervisor. Instructions and tasks must be formulated clearly and understandably.

Post-processing of the completed experiment will be the final step of this virtual laboratory. This usually includes documentation of both the preparation and the execution of the experiments. The evaluation methodology and derived results should also be presented. This can take the form of a report to be written or an oral presentation or a combination of the two. The learning objectives are the independent preparation, planning of the series of measurements, carrying out the experiments, evaluation, and knowledge-based assessment of the results.

Chapter 3.3 is a translation and adaptation from “Forschendes Lernen” by ZfW-RUB, licensed under CC BY-NC-SA 4.0 (ZfW-RUB, Forschendes Lernen).

3.4. Augmented Reality and Virtual Reality as Learning Environments

As a subset of computer-generated learning objects, virtual, augmented, and mixed reality (VAMR) applications have been widely implemented in various educational fields (Matišák, Rábek, & Žáková, 2020). For instance, various applications have been employed in healthcare and medical education, and have proven as effective tools for interactive and immersive training (Gerup, Soerensen, & Dieckmann, 2020). In diverse research fields, such as aviation, robotics, and industrial engineering, comparable research efforts on VAMR applications have been conducted to evaluate the efficiency and quality of immersive experiences, both in training and in practice (Bartik, et al., 2019). Also, a wide range of VAMR applications has been implemented in the architecture, engineering, and construction (AEC) industry (Cheng, Chen, & Chen, 2020; Tayeh & Issa, 2020). During the last decade, several implementations of VAMR applications for AEC education and training have been conducted and reported (Wang et al., 2018). For example, Turkan et al. (2017) have developed an augmented reality application for teaching structural analysis concepts using holographic 3D models, and Mirboland, et al. (2022) have designed a mixed reality application for interactive experiments in structural engineering.

As a notable research effort, Yepes, et al. (2020) have reviewed existing guidelines for designing educational multimedia environments and have derived categories of design principles suitable for transformation to mixed reality learning environments. To this end, Krischler et al. (2021) have implemented learning scenarios from the field of structural mechanics and have examined motivational and cognitive parameters by user studies and elements of success control. Later, the authors studied the learning behavior and corresponding control variables in an experimental setting for the target group of civil engineering students (Tasliarmut, et al., 2022).

Within the framework of the PARFORCE project, learning objects with specific features are to be used for delivering virtual laboratories and remote experiments. For this purpose, VAMR applications may be regarded as suitable learning objects due to the following characteristics (UKEssays, 2018):

- Complexity: A VAMR application is a computer-generated learning object or entity, which requires prior computer-aided design (CAD) knowledge and implementation. Although it may sound complex, the development efforts are highly dependent on learning objectives, hence, on suitable data formats and design scenarios. VAMR applications vary from simple augmented information boxed to full virtual environments. A mixed or extended reality application, which overlays virtual objects in the real environment is believed to have the highest design effort. However, successful implementations of such applications have been reported in engineering fields.

- Accessibility: VAMR applications can be used on various devices in the form of closed- or open-access learning objects. Based on the object complexity, VAMR applications can be delivered to students using various hardware, e.g. virtual and augmented reality headsets, smartphones, tablets, and laboratory computers. Also, web-based or offline standalone versions of the VAMR application may be employed within eLearning platforms. Furthermore, a VAMR application can be designed as an interoperable entity, i.e. one version may be designed to be used on multiple platforms.

- Interaction: CAD learning objects may be easily modified and extended with respect to intended learning objectives. Therefore, the educator has opportunities to revise and reuse the learning object. Above that, the VAMR application offers modification opportunities not only to educators but more essentially, to students. Therefore, similar to conventional laboratory experiments and collaborative course activities, VAMR applications allow students to interact with the learning object and alter the outcomes of a learning object, which may become useful for eLearning task assignments or project (result) submissions.

Various data formats may be included in VAMR applications. For instance, a virtual room can be built upon 360° footage of an existing laboratory or may be constructed based on 3D point clouds scanned from real space. For the use cases envisioned within the PARFORCE project, pre-recorded 360° footage from experiments is considered a suitable data format for constructing virtual laboratories and remote-access learning objects.

3.5. Research-Based Learning and Teaching in Laboratories

Research-based learning (RBL) enables students to learn in a research format. Students are enabled to subjectively explore new things and thus at the same time to become familiar with scientific working processes as well as to acquire sustainable knowledge and skills. Through RBL, students can develop skills that go beyond subject knowledge and methodological knowledge - above all independence, but also the emotional and social sides of learning. These skills are necessary to be able to work on tasks competently and systematically later in their careers. The principle of research-based learning aims at scientific action competence and emphasizes and links the theoretical and practical sides of the scientific knowledge process.

Research-based learning is about experiencing the significance of theoretical knowledge in the encounter with scientific research processes, learning how to deal with it, and participating in the creation and further development of this knowledge. The result of research-based learning is not "inert knowledge" but "skills" that can be used in new situations. Research-based learning is distinguished from other forms of learning by the fact that the students learn the process of a research project, which is aimed at gaining insights that are also of interest to the third parties, in its essential phases - from the development of the questions and hypotheses, the choice and implementation of methods, and the testing and presentation of results in independent work or active collaboration (Huber, 2009).

From this, only the provision "aimed at gaining knowledge that is also of interest to third parties" should be emphasized again here. When the critics of the concept ask if it is to deserve the name research, which must also produce results that are "new" in the universal framework or "change the discipline", they are claiming that student work will rarely be fulfilled. However, in the Author's (ZfW-RUB, Forschendes Lernen) opinion, this also calls into question what teachers and staff do as research in everyday academic life. The Federal Assistants' Conference has tried to emphasize the common core of research and research-based learning, not the novelty of the result, but the process of constantly questioning every available statement and the methodical-systematic effort to overhaul it. Consequently, their results should also be of interest to third parties, be it to the "scientific community" at a conference, a department in a public university, or other similar forms.

In any case, the result should not only be the learning gain or the learning performance for the learner. This is precisely what distinguishes research-based learning from other concepts of higher education didactics; it has something of each of the didactic approaches, but also sets a specific accent in each of the cases. Research-based learning emphasizes not just the acquisition of knowledge, but also the development of critical thinking, problem-solving skills, and the ability to apply theoretical concepts to real-world situations.

3.5.1. Phases of Research-Based Learning

As already indicated, an essential means of dealing with or reducing the known difficulties of research-based learning is the careful planning and design of the phases. The following phases may be considered (Hellmer, 2009):

- Introduction: for example, in the form of information about the event in which the basic didactic concept is explained. Such as the research methodological preparation for the students, or at least a very detailed and clear announcement of the activity.
- Finding a question or specification of a problem: usually within an already given or known overall topic and project. However, it can also be a separate section in which the students have time to find and formulate their questions or approaches.
- Information gathering on the subject matter of the project topic. The time and duration of this phase vary greatly, and so does the form: teaching of necessary prior knowledge by teachers (e.g., in the form of lectures), elaboration by the students themselves, and exchange among the students (e.g., through an online platform).
- Acquisition of methodological knowledge for dealing with the research question: in many projects, it can be systematically integrated into the conception of the course as a separate phase, otherwise it can be assumed or organized alongside.
- Development of a research design: a central moment in the projects, largely placed in the hands of the students.
- Carrying out a research activity: this phase can take place outside the lecture. This phase may take place outside the lecture period and in places other than the university itself (internships, excursions, field studies, group projects).
- Elaboration of the results. It may be integrated into the time structure of the course or be carried out after the course (e.g., in the form of seminar papers, theses, or articles).
- Communication of the results: Report, documentation, presentation, or publication within the event, at forums of the department, the university or at conferences, or in the scope of the class.
- Reflection on the procedure, the work and group process, and the status and relevance of the results.

3.5.2. Fostering Research-Based Learning in Everyday Teaching

It can be also understood that in RBL several cognitive and emotional levels as well as the level of action are required or promoted. On the cognitive level, in addition to mastering the basic knowledge of a subject area such as the special techniques and basic scientific procedures, the development of the skills for problem identification and idea generation is promoted. At the emotional level, factors that focus on the learner's attitude and motivation will be considered. Finally, at the action level of RBL, it is necessary to enable the learner to make practical applications for problem-solving and to learn a concrete action that has to be taken. Based on this concept and the characteristic of research-oriented learning, implementation of RBL to everyday learning, such as regular classes or projects in a regular class can develop the self-driven motivation of the student to the learning contents. Above all, learning the cognitive techniques and skills mentioned at the beginning, which are necessary for problem identification and brainstorming pose a particular challenge.

Here, divergent and convergent thinking should be considered. Convergent thinking primarily represents conventional thought processes and familiarity with facts. It is a matter of efficiently applying what has already been learned to the problems according to given rules of logic and rationality to find the best possible solution. In this assumption, there is always only one "right" answer, and the task is, in principle, to find it. Divergent thinking, on the other hand, does not run along strictly and allows for individual directions of thought to develop, which in turn allow several possible solutions that are not already a priori "right" or "wrong", but represent different ways of dealing with the situation. Both ways of thinking are of great importance for explorative learning. However, for (e.g., pressure to conform), there is often the danger that convergent thinking is promoted one-sidedly and with higher priority.

From the perspective of the laboratory and specifically, virtual laboratory, the term Research-based Teaching (RBT) can be considered in the design of the activity. (Healey & Jenkins, 2008) introduced a model for systematizing RBT, as shown in Figure 3.4. It must be noted that the differences in terms between RBT and RBL do not consequently disintegrate the two concepts, instead, the two closely coexist. The figure below shows the RBT models by Healey and Jenkins based on the level of student participation and the research contents.

The intrinsic connection between research and laboratories becomes evident when considering the instrumental role of laboratories in conducting research. Notably, (Pena, 2019) exemplifies this synergy by characterizing the test station for a wind turbine in Østerild, Denmark, as a "natural laboratory." In this context, the research revolves around investigating the atmospheric wind profile and turbulence profile by leveraging wind speed measurements obtained from real-world lightning masts. Such examples highlight the inherent interdependence between laboratories and research, making it challenging to discern the absence of research within laboratory activities. This symbiotic relationship reinforces the vital role laboratories play in facilitating innovative research and fostering scientific advancements.

To describe concisely research features in the laboratory, a classification of learning inquiries in the laboratory quoted directly from (Terkowsky, May, & Frye, 2020) is summarized below. The following learning inquiries can also be used as a suggestion for a system of activities in the laboratory.

- *Demonstration inquiry*: The experiments including data evaluation and interpretation are carried out in the lecture by the teaching staff.
- Confirmation inquiry. Describes the guided comprehension of previously introduced engineering concepts. The task for the students is to verify them along defined steps.
- *Structured inquiry*: Teachers present a task with an unknown outcome for the students. Work steps and procedures are structured utilizing appropriate learning activities and materials.

- *Guided inquiry*: The teaching staff only provides a question and supports the learners in determining and carrying out all work steps and procedures.
- *Open inquiry*: Students determine their research question. The teaching staff advise and support them in their decisions and the implementation of the research.
- *Scientific inquiry*: Students carry out independent research and are responsible for the procedure and content of the work.

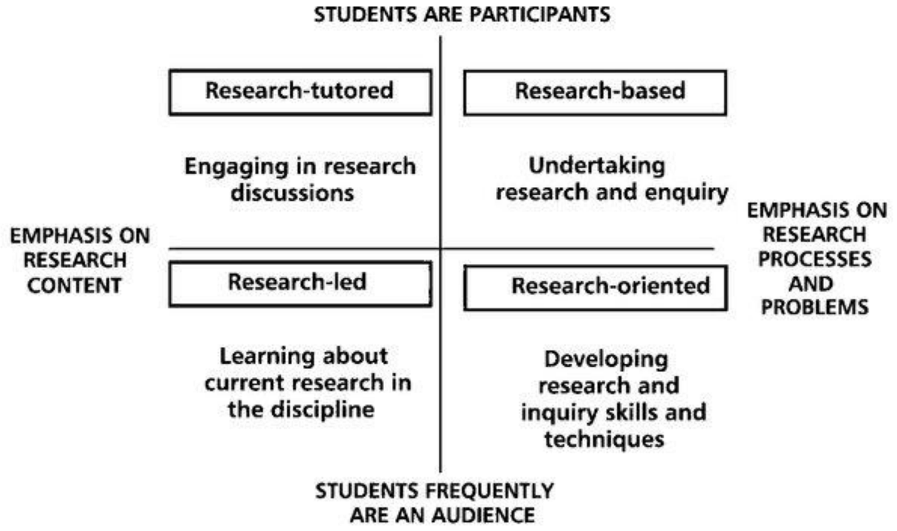


Figure 3.4: Model for systemizing Research-based Teaching (Healey & Jenkins, 2008).

3.5.3. Practical Tips for Research-Based Learning in Regular Teaching

The following practical tips are suggested to implement RBL in regular teaching:

1. Start "small" to base a solid subject knowledge, create space and opportunities for divergent thinking and encourage your students to try new ideas and approaches, such as:
   - Avoid "imposing" prefabricated solutions;
   - Show that you are flexible, versatile, and interested in new ideas, and emphasize this attitude to your students;
   - Be open to unusual ideas and allow for the "possibility of failure" in which it does not define a priori a "right" or "wrong";
   - Provide regular and timely feedback;
   - Give praise and recognition for original ideas and approaches. Also, praise the venture of "less successful" new approaches;
   - Offer constructive criticism so that learning (from "mistakes") can take place;
   - Offer time and material as an incentive for new ideas and approaches.

2. "Refine" your everyday teaching by encouraging and enabling viewing from different perspectives:
   - Include different "analytical glasses" or approaches from different disciplines in your everyday teaching, e.g.,:
     i. Look at a problem from a new (holistic) perspective and explore alternative and novel ways of doing things;
     ii. Discover discrepancies, inconsistencies, and contradictions;
     iii. Recognize analogies and combine thinking strategies;
     iv. Develop skill and intuition in searching for information;
     v. Break habits of thought to encourage intuitive thinking.

3. Deeper integration into your everyday teaching by embedding the two points above into a situated (multimedia) context, for example:
    - Create practical application possibilities through authentic and realistic problem situations in order to learn concrete courses of action (e.g., processing business episodes);
    - Offer your students suitable support in this respect, for example in the form of multimedia platforms, on which the organization of knowledge (e.g., in the form of a wiki), but above all also a joint exchange between you and the learners. In such a platform, the interaction between the learners themselves (and with the teachers) can also actively take place (e.g., in the form of an open discussion forum).

3.5.4. Research-Based Learning Activity in the Laboratory: Example

(Nestorović, 2018) conducted a project to gain motivation for the students in the subject of mechanical dynamics through experimental investigations which are done and explored by students independently. In this project, the one-time block course was offered to 100 students to conduct an independent mechanical dynamics experiment, evaluation, and documentation. Three different students are invited to participate: Bachelor students (Early-phase), Bachelor students in the final phase, and Master students.

The main objective of the project is firstly to prepare and motivate the students regarding the discipline and topic in the area of dynamics of the system through research-based courses, in the hope to increase their success in their studies. This project is also aimed to help the students to recognize their research-oriented thinking and use them for a problem-solving case. The following learning objectives for the students are formulated for this project:

- To introduce the problems in the relevant topic of discipline, such as vibration analysis and measurement, and machine diagnosis.
- To demonstrate the experimental process of the related topics.
- To evaluate and document the measurement data.
- To use the experiment-relevant software to support the evaluation.
- To independently write a script for data evaluation.

The block course and teaching process is chronologically structured by first demonstrating an experiment. After that, assignments are designed which are tailored to the student’s level of studies. For example, the students with higher semesters would need to obtain an independent discovery and conduct a problem-solving.

Chapter 3.5 is a translation and adaptation from “Forschendes Lernen” by ZfW-RUB, licensed under CC BY-NC-SA 4.0 (ZfW-RUB, Forschendes Lernen), with additional information from the presentation (Schmohr, 2022).

3.6. Introduction of Virtual Laboratories in the Pilot Course

Three means of introducing research-based learning and laboratories were identified in the pilot course:

- A semester group project assignment, which required students to conduct a literature review and analysis according to current practices and standards.
- Introduction of different civil engineering laboratories through virtual laboratories and physical excursions.
- Self-use of virtual laboratories.

The project assignment is not only designed to simply assess the pilot course. It is also designed to implement research-based learning through literature review, analysis, and group work. This means that students have to carry out calculations and analyses without the explicit support of the lecturer. The project assignment also requires students to produce documentation in the form of a report and presentation, which requires students to be able to present their results scientifically.

The special knowledge covered in the pilot course is an introduction to experimental testing in wind, fire, and earthquake engineering. The contents are introduced through lecture sessions and the use of the virtual laboratory. This allows participants to learn the basic measurement methods in the relevant laboratories without the need for a physical visit. Three virtual laboratories have been built and linked to the teaching activities of the pilot course: Boundary Layer Wind Tunnel Virtual Laboratory, Fire Resistance Test Virtual Laboratory, and Quasi-static Test Virtual Laboratory. For further reading on the virtual laboratories built, the reader is referred to the Intellectual Output 3 report. Initially, the laboratories are introduced through online lectures where experimental objectives, measurement techniques, and current research projects are elaborated to provide basic knowledge and motivation to the students. Between the lectures, virtual laboratory sessions take place. A tutor guides the students through the virtual laboratories and emphasizes the important points that can be learned from using the laboratories. Not only can students visit the virtual labs during lectures, but the virtual lab desktop program is also made available to students. This allows students to download the program and experience the virtual lab from home on demand. Short quizzes are introduced in the course where the solution can be found by opening the virtual lab and searching for the answer.

The reader is referred to the PARFORCE website for the published resources: https://www.uni-weimar.de/de/bauingenieurwesen/international/strategische-partnerschaften-erasmus/

4. Mobility Approaches for Learning and Teaching in an International Environment

When international and intercultural environments are involved in the learning process, many aspects need to be taken into account in order to have a successful learning process. In an intercultural learning process, it is demanded to have a responsive attitude towards diversity and intercultural learners and learning conditions. (Otten, 2003) describes intercultural learning to include the acquisition of knowledge about one’s own and about other cultures. The aim of intercultural learning is to stimulate an open attitude towards intercultural settings. Effective interaction and collaboration with people of different backgrounds is also an important objective in the intercultural learning process, which can be set as a social objective when planning the intercultural classroom. The UNIC Handbook on Physical and Virtual Mobility (Tan, Salden, & Schiffmann, 2021) defines the three approaches that have to be taken into account when dealing with an intercultural learning activity.

- Assimilation: learners make an effort to fit into the diverse system of the intercultural classroom.
- Adaptation: the host system of the intercultural classroom needs to take the learners' needs into account. Appropriate measures from the host system may be required to react to the diverse environment.
- Negotiation: learners and teachers, as well as learners to learners, need to discover and discuss alternatives when collaborating in the scope of completing the given task. Negotiation can be used as a tool to share different perspectives from learners with different backgrounds.

4.1. Mobility Classification and Examples

In their recent publication, (Tan, Salden, & Schiffmann, 2021) delve into an insightful exploration of mobility classification, specifically focusing on four distinct types i.e., physical mobility, virtual mobility, virtual exchange, and blended mobility. By examining these four types of mobility classification, the authors shed light on the diverse ways in which individuals can engage in educational and professional experiences across different modalities. Their comprehensive analysis offers valuable insights into the evolving landscape of mobility in today's interconnected world.

1. Physical Mobility

Physical mobility or physical student mobility has been a focus point in the internationalization of education, that is, sending domestic students abroad to study at foreign universities where they can acquire recognized credits. Physical mobility requires large finances, and this leads to a low rate of student mobility. Only a minority of students can experience physical mobility, in comparison to other mobility types. This might be due to, for example, travel costs or giving up one's employment in the home country). However, physical mobility is still important in such a way it gives the students a direct international and intercultural experience.

2. Virtual Mobility

Virtual mobility is any form of international mobility facilitated by digital communication tools. An advantage of virtual mobility is that its availability and accessibility can be shared with most students, as long as digital communication is established. This lets virtual mobility and intercultural discussion to be accessed by more people. However, several challenges that can occur in virtual mobility such as lack of social contact, can create low communication and interaction within the classroom. Deeper relationships between the intercultural students may also not be established, due to limited and unphysical interaction.

3. Virtual Exchange

Virtual exchange is defined as a special form of virtual mobility. In virtual exchange, virtual mobility is characterized by establishing intensive interaction between teachers and students from at least two different countries. The virtual exchange focuses on uniting students from different universities to virtually collaborate to work on a task or in the scope of academic exchange. For example, students from two or more different countries can be formed as a group and a task was given. Collaboration with intercultural students is needed to solve the task. Intensive tutoring and discussion from the teachers are also present during the period of virtual exchange. An example of virtual exchange in the scope of academic exchange can include (but not limited to), the regular courses from two or more different teachers from different countries are given, but the course is also at the same time linked to each other by the use of digital tools.

4. Blended Mobility

Blended mobility can be defined as a mix of virtual and physical settings of mobility. Usually (but not always), physical mobility is shorter or the same period as virtual mobility. In this concept, virtual settings can be provided for both preparation and follow-up of the physical setting of the activity. The following model of the blended mobility concept is discussed in (Tan, Salden, & Schiffmann, 2021). First, a preparation activity is established. This can be done through virtual settings, as preparation for the physical setting. For example, by preparing the students virtually for a task that will be conducted in a physical format. After the physical setting is conducted, an additional virtual setting is organized to follow up the physical activity. Feedback and questionnaires can be used for the students and discussed in a virtual format altogether.

4.1.1. Examples and Supportive Measures for Mobility

For each of the four types of mobility classification discussed above, the following stories from the field are taken to illustrate the supporting measures which can support collaborative teaching and learning activity.

- In the context of Physical Mobility: to organize a workshop for teachers on the design and assessment of group work, especially for diverse groups of students, to increase the number of courses with group work. This measure is implemented at Koç

University, Istanbul to give more group cases for the students of the university and to get them used to working together in groups. Peer support to help international mobility students when arriving at the exchange university and to allow them to meet new people, a buddy program by the home university can be organized. An example of this is implemented at the University of Liège, where the buddy program allows foreign students to understand local traditions to experience a part of the Belgian culture.

- In the context of Virtual Mobility: a hybrid lecture from different universities or institutions to support the professional or educational learning process. A special hybrid lecture can be conducted where the guest lecture is from a different university and the audience can also be composed from different universities or a combination of the university partners. This will create an interaction between two different learners' backgrounds. As an example, a hybrid lecture was conducted between the Social and Human Sciences Faculty of the University Deusto in Spain and the university in South Korea, in which 102 students participated, the majority of whom (70 students) followed the lecture online and 32 students followed the lecture in person. The time difference was taken into account so that the lecture took place at a mutually convenient time. In addition, all participants were provided with a pre-communication session to enhance interaction between the lecturer and the students, as well as between the students themselves.

  The use of inverted classroom and digital tools. Based on the story from UNIC Spring School at the University of Oulu, teachers felt that an inverted classroom approach worked well in the courses. Moreover, group work and real business cases helped to increase engagement in the completion of the course. In this way, the teachers supported the students through the online platform (Moodle) and encouraged them to support each other and provide answers through discussion channels.

For the context of virtual exchange and blended mobility, the example of these mobilities will be presented instead of supporting measures. Both virtual exchange and blended mobility consist of a unique form of mobility, by focusing on an intense collaborative task. Both these mobilities also join and develop the techniques used in physical and virtual mobility. Therefore, an example of Virtual Exchange and Blended Mobility is presented to give further inspiration on how it's done.

- Example of Virtual Exchange

  Based on the stories of a virtual exchange between Ruhr University Bochum and the University of Leon in Spain, the activities are structured in the following way. The professors of both universities agreed to have the students work together virtually for 8 weeks during the semester. After a period of getting to know each other, they plan to have their students work on a common task in small, internationally mixed groups for 6 weeks. The students are to develop a set of online teaching methods for teaching English and discuss their results with professional English teachers at secondary schools in their respective countries. In this way, they can exchange their ideas and receive feedback directly from practitioners. Additionally, cultural similarities and differences in English teaching can become clear. In this opportunity, the students also create material that they can try out in their future teaching and share with practitioners.

- Example of Blended Mobility

  One example of a massive, blended mobility project is the international curriculum-development project "Advancing Digitally Renewed Interactions in Art Teaching'(ADRIART)" which is built and implemented within four universities from

Croatia, Austria, Italy, and Slovenia (Purg, Sirok, & Brasil, 2018). Quoted and adapted from (Purg, Sirok, & Brasil, 2018), "the entire two-year implementation cycle of the international two-year Master's program "Media Arts and Practices" (MAP) is characterized by short intensive workshops focusing on the site-specific approach and strongly supported by e-learning methods. It consists of "mobilities", which is a highly intensive learning and events preceded by 4-6 weeks of online collaboration. Online collaboration refers to a joint research and project conception of the given task. In this example, 'mobility' refers to a multi-day intensive learning event at a specific site, embedded with a blended learning concept that takes place away from the home (residential) school premises. Approximately 2–4 weeks after the academic mobility event, the student works were completely finalized for archiving. Then, the project collaboration was reported on, and the academic experience was reflected on–all in the online learning intranet that also enabled assessment feedback and grading. The mobilities of ADRIART lasted from 8 to 12 days, were attended by 12–18 student participants, and involved 4–6 mentors."

4.2. Implementing Blended Mobility in the Pilot Course: Challenges and Experience

Further differences from intercultural learners can give a few challenges in the learning process, regarding the roles of the learners and the rules of the classroom. With respect to this aspect, the following settings are recommended for the teachers or tutors (Tan, Salden, & Schiffmann, 2021):

1. Formulate the challenges that may occur for the students when participating in the intercultural course;
2. It is recommended to integrate the cultural aspect and the learner's background into the assigned task. In this way, the underestimation of the assignment by the learners can be avoided. By integrating the learners' background into the task, the learners may feel affiliated with the learning activity;
3. The expectations and opinions of students need to be made explicit. This is due to the learners with different backgrounds may have a different understanding of a task or learning methods. In this situation, the role of teacher and students has to be set clearly for every classroom participant. For example, this can be further amplified by setting clear learning objectives and activities. Clear verbal and written communication is recommended to always be maintained;
4. To explain the diversity itself and to communicate the teaching and learning culture. The diverse environment within the intercultural classroom may not be realized by the learners and teachers at first sight. By communicating diversity to the learners of the classroom, the expectation and assimilation can be greatly improved. This can be done by setting a clear teaching and learning culture in the classroom;
5. To have clear communication regarding deadlines and assignments.

(Gay, 2018) and (Muñiz, 2019) defines an important factor of integrating international perspective into teaching and interculturally responsive teaching lies in the selection of topics and materials. Although the scope of learning content is limited to the discipline of the studies, an international perspective can always be considered when selecting and creating learning materials. The following actions can be taken to give international aspects to the learning materials:

- Check (and use, if possible) the international journals and internationally comparative perspectives of the teaching topic;

- Avoid critically discussing stereotypical illustrations or examples from teaching materials;
- Establish, if possible, at least one session to discuss the international perspective from your teaching material with the learners;
- Invite guest lecturers from another country. For example, in a transnational classroom, each project partner from each country can send one lecturer as a representative. This can stimulate the international atmosphere in the classroom.

Communication and interaction are fundamental elements of an international learning environment. When both learners and teachers were set in a new and diverse setting of the classroom, in some ways, inactive communication can often occur. Just like in a normal classroom, active communication has to be even more believed as a necessary element when a learning activity is performed.

Teachers and tutors have to be mindful of the importance of active interaction before and when designing the activities. In an intercultural learning environment, active interaction in the classroom can help learners who are not coming from the majority group. Different perspectives and new insights are also exchanged through established interaction. Interaction can be designed by developing a certain learning objective that requires the learners to interact with each other. The following recommendation from (Tan, Salden, & Schiffmann, 2021) can be used to establish interactions between the learners:

- Create a task for the learners that will require interaction, however small it may be;
- Encourage learners to ask questions. First, the teacher can ask an open question themselves and let the learners attempt to answer. Opinion polls and votes can be also used to promote an active learning environment;
- Organize small group work with the learners. For example, forming groups among learners in a task that requires brainstorming will encourage contact and communication among the learners;
- Encourage the learners to share personal stories regarding their background (e.g., background studies), by giving questions about personal experiences in the scope of assignment topics;
- Allow the learners to ask and discuss with the teachers. Teachers should be open to contact and engage in the learner's discussion when needed (e.g., actively checking and responding in the forum).

A pilot course in line with the PARFORCE project task is organized for a group of Master’s students, combining regular online sessions with an intensive physical meeting at the end of the semester. In this way, the mobility in learning and teaching is all-round. The course consists of a series of lecture sessions that take place virtually, with a parallel project task that lasts throughout the semester. At the end of the semester, a physical week program will be the culmination of the previous sessions in an intensive face-to-face event. In the physical week, the students are given a strategic lecture with exercises. As one of the vital points, the project task requires the student to work throughout the semester, as its evaluation process will be carried out in the last days of the physical workshop.

In the pilot course, the situation of blended mobility with an international environment also poses specific challenges. The challenges are not only due to cultural differences but also to the different backgrounds of the home institutions. The students came from four different institutional countries: Croatia, Germany, North Macedonia, and Portugal. In addition, some of the participating students came from different home countries. In order to achieve multinational collaborations, the groups should be composed of people from different countries. The development of the assignment will be carried out with the help of consecutive lectures in construction, which will standardize the basic knowledge of all students. At the beginning of the course, a virtual ice-breaking session is held to promote interaction among the participants. The students are divided into groups according to the project work team and are brought into a breakout room in the online communication platform. A special tool called "Meetup Town" is used to increase interactivity. In this session, students can exchange contacts for further communication during the pilot course.

In order to meet the challenge of cooperation between the students and to increase the harmony within the groups, the task is designed in such a way that it uses the different materials elaborated earlier in the training and requires different documentation of the subtasks. For example, to answer the given task, an analysis is required that has to be elaborated in both a report and a presentation. In this way, contributions from each member of the group are needed to complete the subtasks. Collaboration should start automatically and grow within the group.

It is worth noting how the implementation of an intensive workshop week can support the challenge of collaboration and interaction between the project task team and the course participants. The one-week workshop includes not only a series of lectures and a final presentation of the project but also excursions. The workshop is designed in such a way that the students also experience a journey together, visiting excursion sites and two different cities, Weimar and Bochum. Students are also given free time to develop a natural friendship and teamwork outside of the formal sessions.

Chapters 4.1 and ***Error! Reference source not found.*** *are adaptations from Handbook on Physical and Virtual Mobility licensed under CC BY-SA 4.0* (Tan, Salden, & Schiffmann, 2021).

4.3. Experiences from Advanced Training Course

The advanced training courses in Applied and Computational Mathematics in Engineering Application aims to complement the mathematical education of PhD students during their regular studies by modern and actual methods and techniques, such as Bayesian statistics or machine and deep learning as well as broaden their view on possible applications in an international environment.

The focus of these courses is on acquiring competencies such as:

- to choose and implement correct regularization algorithms for a given inverse problem;
- to pre-process and analyze experimental data;
- to evaluate the quality of numerical methods/ algorithms for a given mathematical model;
- to analyze errors and their propagation in mathematical models;
- to implement and train a machine learning algorithm;
- to setup and properly work with virtual reality experiments;
- Students will be able to work in an international environment and practice their management, presentation, and language skills.

The courses are given following the blended learning approach with an online part and a presential part at the University of Aveiro. As such they have both a heterogeneous collection of students with different cultural and socio-economic backgrounds as well as a broad area of topics. This makes it the ideal testing ground for different didactical approaches and techniques. Using blended learning the hybrid courses start with the online part while the presential part follows afterwards. Although it goes against conventional wisdom where an initial presential part is used to familiarize the students with each other and create a group identity which is later explored in the online part. Here the theoretical part is given first which students follow on a more individual level while the presential part focuses on the practical work where direct contact between the students is more important. A rotation-based blended learning approach based on interchanging online and presential sessions might prove even more advantageous but is being constrained by the distances between the universities which makes such interchanging economically unfeasible.

Since the target audience has a high level of prior-learning experience a more individual and group-based approach should always be preferred. While in principle the online part consists of an instructor-driven learning environment the presential part focuses mainly on research-based learning paradigms. Although in practice it also depends largely on the topic. In the online part, classic topics like exposition to the mathematical basics of a given subject have been shown to achieve better learning results in an instructor-driven learning environment using a classic lecture format. These are recorded and available for consultation at any time. Additional educational videos are provided by the teachers. More modern topics like the implementation of algorithms and methods are better handled in learner-driven environments like inverted classrooms as well as using group and individual project work. Hereby, modern online tools like breakout rooms and remote access to the learner's work environment allow for closer interaction and result in a faster learning rate as well as higher motivation.

In the presential part, research-based learning is to be preferred with group assignments, ideally with connections to the student's research topics. Often this is not possible due to the heterogeneous nature of the participants of the advanced training course which leads to more standard assignments in relation to problems and data sets and group project work. Close contact between the students is essential to the success of this approach. Hereby, the special situation of this part of the advanced training course as an intensive course at the University in Aveiro allows for additional contact between the students outside the classroom which increases interaction and creation of group identity between the students thereby improving both the motivation of the learners as well as the atmosphere of both in-class as well as out-of-class learning environments. The international environment allowed the students to have additional learning experiences in professional network development and working in multidisciplinary teams.

An observation of the courses is that the lack of initial social contact between the learners is to be preferred to the lack of direct contact during the later project work. Feedback for both parts is given by questionnaires as well as direct interaction with the teacher. The questionnaires are chosen to allow both a SWOT (Strength/Weakness/ Opportunities/Threats) analysis and a statistical analysis as well as automatic evaluation using machine learning algorithms. Among other things, these evaluations showed the importance of clearly defined learning outcomes as well as the use of interactive formats in the online part.

5. Collaborative Moodle Tools and Training Units

To conduct any form of online teaching, Learning Management System (LMS) is often used. The most used LMS is Modular Object-Oriented Dynamic Learning Environment (Moodle). Statistics show that there are 331 million Moodle users in 242 countries. The advantages of Moodle are the flexibility of the platform, open-source, and free. It is a powerful tool that enables learning in different ways (Gamage, Ayres, & Behrend, 2022).

The development of Moodle is based on social constructionist pedagogy; in such a way, the student becomes an active participant in the learning process. Moodle contains many tools that can help us in fulfilling both teaching and learning goals. It can be used in synchronous (e.g., used in live video conferences such as BigBlueButton) and asynchronous (video lections) modes. By carefully choosing activities and resources using Moodle, 21st-century core skills can be developed: technical, information management, communication, collaboration, creativity, critical thinking, and problem-solving (Laar et al., 2017). For example, learning objectives 10 (communication) and 11 (teamwork) formulated by (Feisel & Rosa, 2005) can be fulfilled with communication (e.g., forums) and collaboration (e.g., wiki, glossary) activities (see Chapter 3.2).

Moodle supports different types of evaluation, formative and summative, or self-evaluation and peer evaluation (as one of the possible collaborative activities). The most used activities in Moodle are "quizzes" and "workshops", both are used for evaluation; and videos that are easily integrated into Moodle (Gamage, Ayres, & Behrend, 2022).

5.1. Implementing Moodle Tools in Virtual Laboratory Classes

5.1.1. Communication and Collaboration Activities

- Forum: in addition to being a place to find relevant information, a forum can also serve as a place to asynchronously discuss a given topic. The question-and-answer type of forum enables the mentor to condition the student's insight into the discussion by sending at least one message to the particularly interesting forum. In this way, students' opinions are formed independently of the opinions of other discussion participants. In addition to vertical communication (teacher-student), it is possible to create a forum for horizontal communication (student-student), which can be used for their mutual conversation regarding the creation of a joint project. Furthermore, the forum can also be used for an introduction.

- Wiki: this activity enables the collaborative creation of shared content, where the teacher can see any version of the created content at any time and to see exactly which student is the author of which part of the content. An interesting example of using a wiki is creating a database of links on a given topic.
- Glossary: this activity allows students to jointly create (and supplement) a base of concepts (with explanations), or definitions related to the studied content. A useful example of using a glossary is creating a base of measurement units.

5.1.2. Evaluation Activities

- Quiz: the quizzes are the most used activity to assess knowledge. It is a suitable and very useful activity for creating short quizzes for formative evaluation during the course, but also for summative evaluation at the end (or during the semester for continuous evaluation) of the educational process. The quizzes contain different types of questions that enable, with the creativity of the teacher, to check all levels of knowledge according to Bloom's taxonomy (Figure 5.1). Numerous settings in the quiz provide different possibilities both in the admission to the test and in the feedback to the students. The question database is stored separately from the quiz, and it can be reused in different quizzes. A very useful option is the classification of questions into categories and subcategories. In this way we can ensure that in the generated quiz, each student will receive different questions, but from each area of a certain number of questions.

Drag-and-Drop-Zones

Assign the labels to the objects shown in the picture.

Note: Make sure that the circle lies on the object, the text itself may also lie outside.

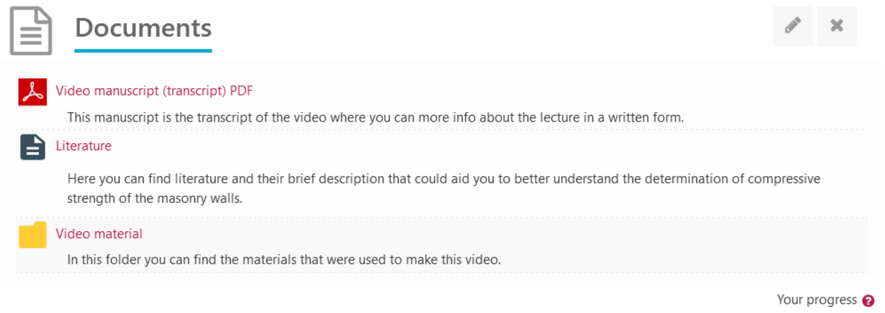
Figure 5.1: Drag and drop into the image question type in the quiz (PARFORCE, 2021).

- Workshop: this activity is used primarily for peer assessment. The workshop is conducted in several stages. The final stage is not the submission of one's research project work but the evaluation of peer's work. For example, the task can be the creation of a mind map (using some other digital tool or on paper and submitting such work in .jpeg or .pdf format) on a specific topic. In addition to the instructions on creating the project, it is recommended to give the students the rubrics (set of criteria) in advance, which is what the workshop enables us to do. Rubrics are useful not only as instructions for grading but also as guidelines or checklists for creating project work.
- Assignment: it is an activity in which the student submits the work to the teacher for evaluation. The work can be written online or uploaded as a document. In addition to the grade itself, the teacher is enabled to give more extensive feedback. For example,

if the document is submitted in .pdf format, the teacher can add comments in the document itself and return such corrected work to the student.

5.1.3. Providing Learning Materials

- Resources: documents with different extensions can be loaded in Moodle (Figure 5.2). Different files you can organize into folders. Also, it can be integrated with external links. Multi-page resources can be arranged in book format.
- Video with H5P: an additional, very useful plug-in is H5P, which can be successfully integrated into a video. Using this tool, the video can become interactive. By inserting questions into the video, the student becomes a more active participant, not just a passive viewer/listener (Figure 5.2). Using this tool, the video can become interactive. By inserting questions into the video, the student becomes a more active participant, not just a passive viewer/listener. For example, the video will not continue to be played, if the student did not answer the question correctly. In addition, it can be requested that if the answer is incorrect, the student must watch the given section of the video again.
- BigBlueButton: an open-source web conference system is used in Moodle for synchronous teaching, i.e., in a real-time online classroom (Figure 5.4).



Documents

Video manuscript (transcript) PDF

This manuscript is the transcript of the video where you can more info about the lecture in a written form.

Literature

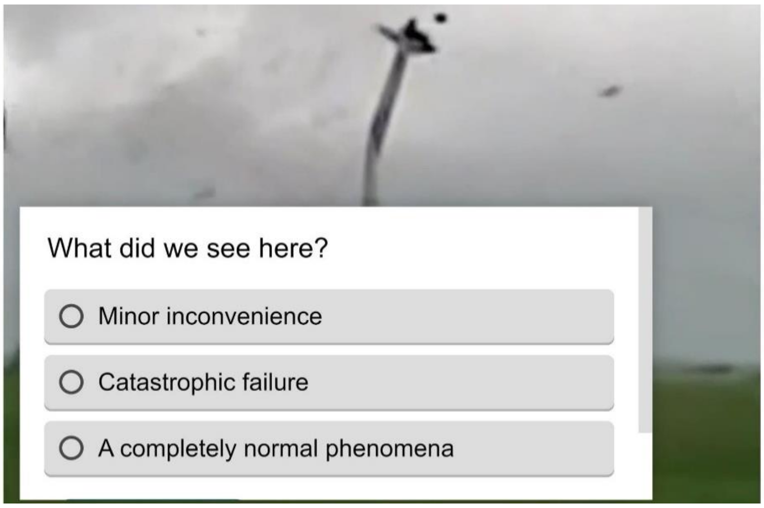
Here you can find literature and their brief description that could aid you to better understand the determination of compressive strength of the masonry walls.

Video material

In this folder you can find the materials that were used to make this video.

Your progress

Figure 5.2: Example of different types of uploaded documents in Moodle (PARFORCE, 2021).



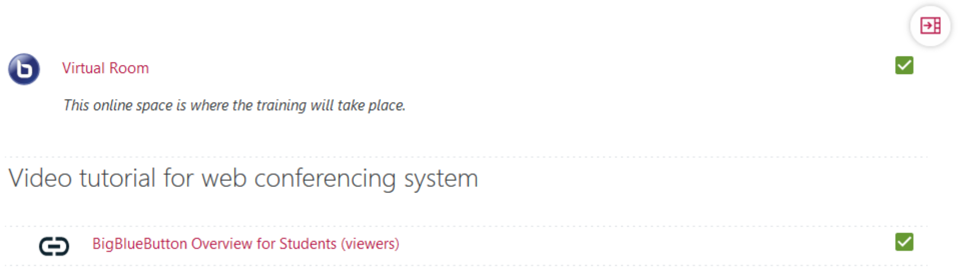
What did we see here?

○ Minor inconvenience

○ Catastrophic failure

○ A completely normal phenomena

Figure 5.3: Example of an H5P question integrated into a video (PARFORCE, 2021).



Virtual Room

This online space is where the training will take place.

Video tutorial for web conferencing system

BigBlueButton Overview for Students (viewers)

Figure 5.4: BigBlueButton in the Moodle (PARFORCE, 2021).

Table 5.1 Moodle tool guide

	Information Transfer Is it a tool for disseminating information from you to your students?	**Assess learning** Will this tool allow you to assess your students' learning?	**Communication & colaboration** Can it be used for communication and interaction among participants?	**Bloom's Allows what thinking order?** Remember, Understand, Apply, Analyse, Evaluate, Create
Forum	🟨 Share resources as links or files. High message volume? Risk of losing info.	🟨 Forum is versatile & allows this, e.g. design a formative assessment activity.	🟩 Yes. Students communicate and collaborate with teacher & peers.	🟩 5/6 Understand, Apply, Analyse, Evaluate, Create
Wiki	🟩 Yes. Use as information site. Allow editing only by teachers or by any participant.	🟨 Wiki is versatile & allows this, e.g. design a formative assessment activity.	🟩 Not suited for discussions. It is great collaboration activity.	🟩 5/6 Understand, Apply, Analyse, Evaluate, Create
Glossary	🟩 Use glossary to define terms or present info. Better yet, let the students add to it.	🟨 Glossary is versatile & allows this. But you need to design the right learning activity.	🟨 Not suited for discussions. Students can read other entries & comment or rate.	🟩 5/6 Understand, Apply, Analyse, Evaluate, Create
Quiz	🟧 The quiz is aimed at assessment, not as distribution channel. Tip: use as self-test.	🟩 Quiz can be timed & secure. Has essay, mc, true/ false, matching, & other questions	🟧 No	🟨 6/6 Can test all 6 but this requires you to be creative in your assessment.
Workshop	🟧 No	🟩 Yes. Students can be assessed on their contribution and on their review of others.	🟨 No. Allows for feedback but overall limited interaction.	🟨 6/6 Indirectly. Depends on your assessment design.
Assignment	🟧 No	🟩 Yes	🟨 No. Only allows very limited interaction between teachers and student.	🟨 6/6 Indirectly. Depends on your assessment design.

🟧	Not the best tool for the job
🟨	Can work with some learning design
🟩	Great fit

We emphasize that the classification of activities in this section is not unique, that is, the activities listed in one group can often be used in another group as well. For example, we can also evaluate all communication and collaboration activities. In Table 5.1, we can see the assessment of the usefulness of the listed Moodle activities regarding what we want to achieve from the pedagogical aspect. The content of Table 5.1 was taken and adapted from the posters (Seitzinger, 2010) and (Louise, 2019).

5.2. Moodle: Test Trials in September

The essence of the strategy and action plan for digitalization of Ss. Cyril and Methodius University (UKIM) in Skopje is the improvement of the existing and developing of new integral digital systems (Figure 5.5) (Rector's report, 2021). Within the scope of the PARFORCE project, the most interesting part of the UKIM platform is the digital system for teaching and students which consists of several components (Figure 5.6).

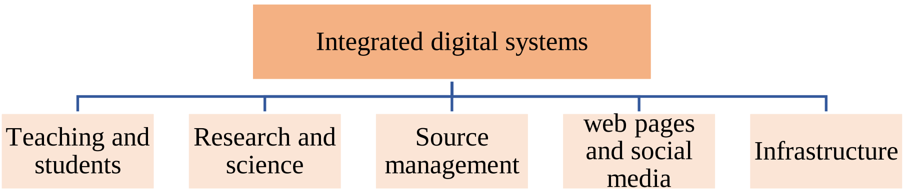


Figure 5.5 UKIM integral platform

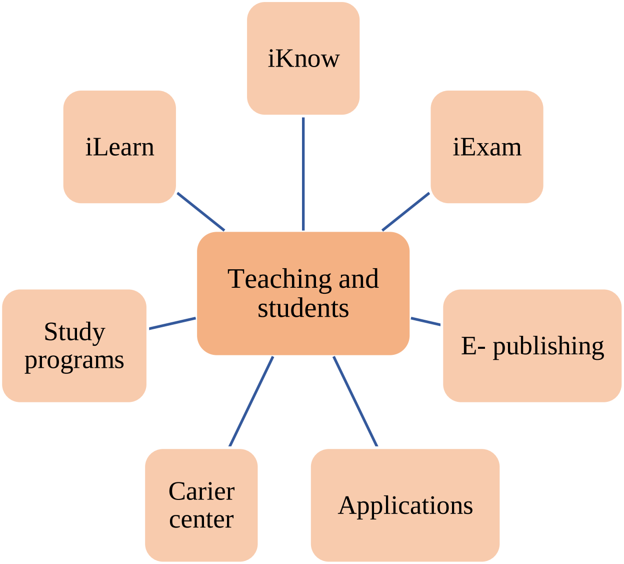


Figure 5.6: Digital Systems for Teaching and Students

In the academic 2020/2021, UKIM started with the pilot project for the establishment of an integrated digital iLearn platform as a mechanism for modernization and digitalization of the educational process based on its resources. This pilot project is part of the integral digital systems network of the University (Figure 5.5 andFigure 5.6) as a strategic orientation for digital education. A comprehensive and comparative analysis of different commercial an open-source solutions was carried out leading to the Moodle platform as the most efficient solution. The phases of implementation and time frame are given in

Various support materials (e.g. tutorials), as well as workshops and training sessions for different target groups, were organized to facilitate the implementation of the iLearn platform. There have been 7 workshops held by experts from the Faculties of Computer Science and Computer Engineering and Faculties of Electrical Engineering and Information Technology, 12 workshops for teachers, and one workshop for students. Finally, the workshop entitled "Distance Learning Opportunities through the Implementation of a Digital Platform", held on 23-Sept-2021 represents the formal start of the implementation of the iLearn platform at UKIM. So far, the platform is used by 9 faculties from a total of 28 University members and 2903 students distributed over 1612 courses, which mainly come from graduate studies, (Rector’s report, 2022). Implementation of the *iLearn* platform at the IZIIS as a member of UKIM is in its initial phase. The integrated digital *iLearn* platform is accessible on the link https://ilearn.ukim.edu.mk/?lang=en. Further activities are to connect the *iLearn* platform with the platform for student services, *iKnow*.

Table 5.2.

Various support materials (e.g. tutorials), as well as workshops and training sessions for different target groups, were organized to facilitate the implementation of the iLearn platform. There have been 7 workshops held by experts from the Faculties of Computer Science and Computer Engineering and Faculties of Electrical Engineering and Information Technology, 12 workshops for teachers, and one workshop for students. Finally, the workshop entitled "Distance Learning Opportunities through the Implementation of a Digital Platform", held on 23-Sept-2021 represents the formal start of the implementation of the iLearn platform at UKIM. So far, the platform is used by 9 faculties from a total of 28 University members and 2903 students distributed over 1612 courses, which mainly come from graduate studies, (Rector’s report, 2022). Implementation of the *iLearn* platform at the IZIIS as a member of UKIM is in its initial phase. The integrated digital *iLearn* platform is accessible on the link https://ilearn.ukim.edu.mk/?lang=en. Further activities are to connect the *iLearn* platform with the platform for student services, *iKnow*.

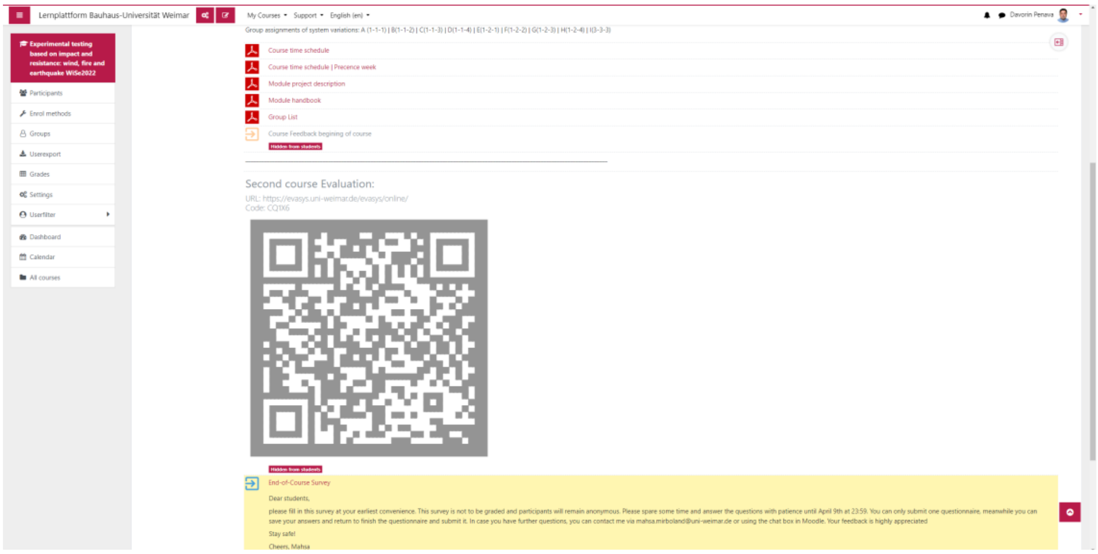
Table 5.2: Phases of implementation and time frame

IMPLEMENTATION	Fist period (up to 19.04.2021)									Second period (19.04.2021-31.08.2021)	Third period (01.09.2021-31.08.2022)
	W1	W2	W3	W4	W5	W6	W7	W8	W9		
Phase 1: Project Management	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
Phase 2: Defintion of the platfrom funcionalities	▨	▨	▨	▨	▨						
Phase 3: Establishment of the inbfrastructure					▨	▨	▨				
Phase 4: Instalation of the system						▨	▨	▨	▨		
Phase 5: Definiton of the categories and administrators credentials							▨	▨	▨		
Phase 6: Elaboration of guidelines and video materials							▨	▨	▨		
Phase 7: Training of the studenst, teachers and administrative staff								▨	▨		
Phase 8: Testing of the platform								▨	▨	▨	
Phase 9: Workshops for sharing experiences using Moodle learning platform							▨	▨	▨	▨	
Phase 10: Maintenance of the system											▨
Phase 11: User support											▨
Phase 12: Infrastructure maintenance											▨
Phase 13: Monitoring mechanisams											▨
Phase 14: Integration with iKnbow (optional)											▨
Phase 15: Reporting											▨

5.3. Use of Moodle During the Pilot Course and Other Project Activities

Based on the description of the possibilities of the Moodle platform in section 5.1. This section describes which of them were applied so that all project activities, especially the pilot course, were successfully implemented, and which can serve as a template for future use. While the platform was mostly used for video conferences, i.e. holding distance / hybrid classes and meetings and sharing teaching and other (interactive) content (virtual tours, audio, video, applications, and text data), among the tools available within the platform, tools for surveys, quizzes, tests, or in general, tools for the evaluation of implemented activities were used. Figure 5.7 shows the user interface of the platform set up for the implementation of the pilot course "Experimental testing based on impact and resistance: wind, fire and earthquake" with the main menu and invitation to participate in the evaluation.

The Moodle platform allows for a register of course activities (either online, hybrid or exclusively live), and it is enriched with various tools that enable more enriched classes. Whether it was a meeting or a class, the practicality of this approach was obvious. Collecting data (eg quiz or evaluation) and processing it is straightforward. Within the framework of the specially designed project activities Advanced Training Course 2023, Moodle support was also necessary, considering that it was a hybrid approach to the improvement of doctoral students, and among other things, the development of learning outcomes for classes within E-course. In general, Moodle was used as an information and platform to support the implementation of the teaching curriculum of e-colleges as well as other project activities, primarily due to its effectiveness as an intermediary server, easy access and quick mastery, and which perfectly fits and connects the contents of different formats, in an international environment.



Group assignments of system variations: A (1-1-1) | B(1-1-2) | C(1-1-3) | D(1-1-4) | E(1-2-1) | F(1-2-2) | G(1-2-3) | H(1-2-4) | I(3-3-3)

Course time schedule

Course time schedule | Precence week

Module project description

Module handbook

Group List

Course Feedback begining of course

Second course Evaluation:

URL: https://evasys.uni-weimar.de/evasys/online/
Code: CQ1X6

End-of-Course Survey

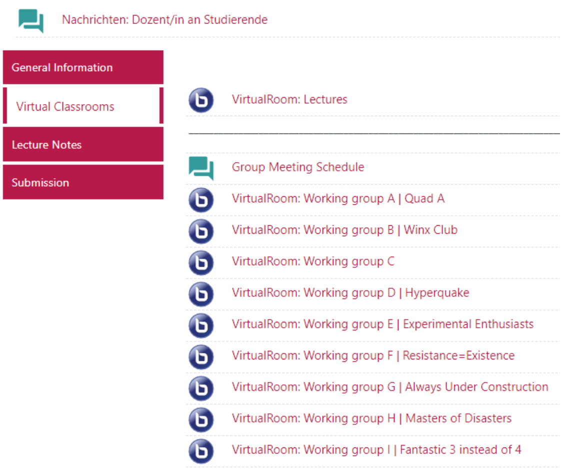
Dear students,

please fill in this survey at your earliest convenience. This survey is not to be graded and participants will remain anonymous. Please spare some time and answer the questions with patience until April 9th at 23:59. You can only submit one questionnaire, meanwhile you can save your answers and return to finish the questionnaire and submit it. In case you have further questions, you can contact me via mahsa.mirboland@uni-weimar.de or using the chat box in Moodle. Your feedback is highly appreciated

Stay safe!

Cheers, Mahsa

(a)



Nachrichten: Dozent/in an Studierende

VirtualRoom: Lectures

Group Meeting Schedule

VirtualRoom: Working group A | Quad A

VirtualRoom: Working group B | Winx Club

VirtualRoom: Working group C

VirtualRoom: Working group D | Hyperquake

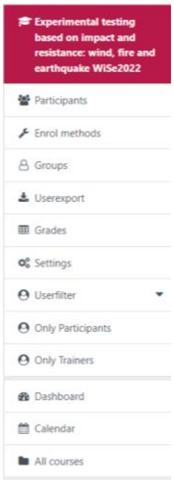
VirtualRoom: Working group E | Experimental Enthusiasts

VirtualRoom: Working group F | Resistance=Existence

VirtualRoom: Working group G | Always Under Construction

VirtualRoom: Working group H | Masters of Disasters

VirtualRoom: Working group I | Fantastic 3 instead of 4



(b) **(c)**

Figure 5.7 (a) E-course home page layout example; **(b)** distribution of virtual classrooms for classes and discussions; **(c)** the main menu of the E-course platform (PARFORCE, 2021).

6. Supporting Measures

6.1. Online Teaching Databases and Remote-Access Experiments

The teaching database and the remote access experiment are presented as additional tools that can be made available to support a virtual teaching and learning experience. The remote access experiment is presented as part of the E-Tutor training lecture and the teaching database as an existing example.

6.1.1. Teaching Database

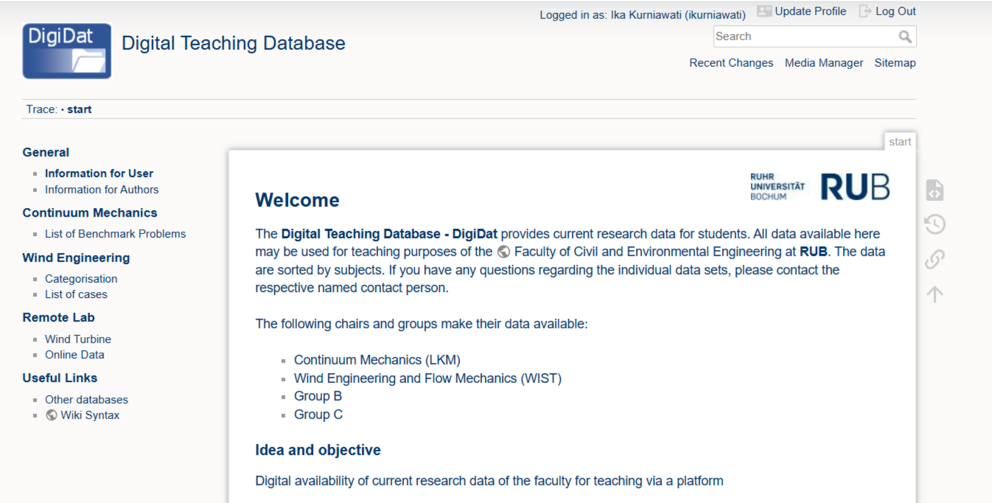
A digital teaching database is an essential element that should be provided to store data and materials needed for teaching and learning. For virtual experimentation activities, there will be a need for at least one database which will be accessible to both students and teachers from a distance. The online teaching database is the implemented solution where research materials and data can be made available. Moreover, various collaboration opportunities also become possible when the teaching database gathers multidisciplinary research data.

Technically, organized internet-based cloud systems may be sufficient. However, without eLearning tools such as Moodle, a simple online cloud can be less attractive and less interactive. For example, documentation of procedures in a virtual experiment or a preliminary introduction to a lecture cannot be freely displayed with a cloud alone.

The Faculty of Civil and Environmental Engineering at the Ruhr University Bochum has developed a joint digital teaching database (DigiDat) between the Chair of Continuum Mechanics and the Chair of Wind Engineering and Flow Mechanics (WISt). DigiDat is a form online website that provides summarised case studies in the related fields, the procedure of analysis, and a linked online database. DigiDat is designed to provide a single source of information for teaching and learning. Simultaneously, DigiDat will become a repository of case studies and experimental investigations as an open-access database. The sustainability of the database can be maintained by allowing the next teaching agents to access and develop the DigiDat, which is made possible by the simple blogging interface of DokuWiki in DigiDat. Figure

6.1 shows the DigiDat interface as a website that can be linked to a virtual laboratory or accessed in the conventional and/or digital classroom.

From a repository perspective, wind tunnels have hosted numerous noteworthy experiments over the decades. Some of the wind tunnel cases are strategic to demonstrate the principal knowledge of wind engineering suitable for teaching and learning. Figure 6.2 shows the stored database and one-stop documentation of wind tunnel experiments on flow over a cubic building. To always be able to reuse the website with compact information, the description, procedural information, and experimental data are stored in DigiDat. The interface of a website presenting the database is wiki-like, which can provide a different user experience compared to other eLearning platforms.



General
- **Information for User**
- Information for Authors

Continuum Mechanics
- List of Benchmark Problems

Wind Engineering
- Categorisation
- List of cases

Remote Lab
- Wind Turbine
- Online Data

Useful Links
- Other databases
- Wiki Syntax

Welcome

The **Digital Teaching Database - DigiDat** provides current research data for students. All data available here may be used for teaching purposes of the Faculty of Civil and Environmental Engineering at **RUB**. The data are sorted by subjects. If you have any questions regarding the individual data sets, please contact the respective named contact person.

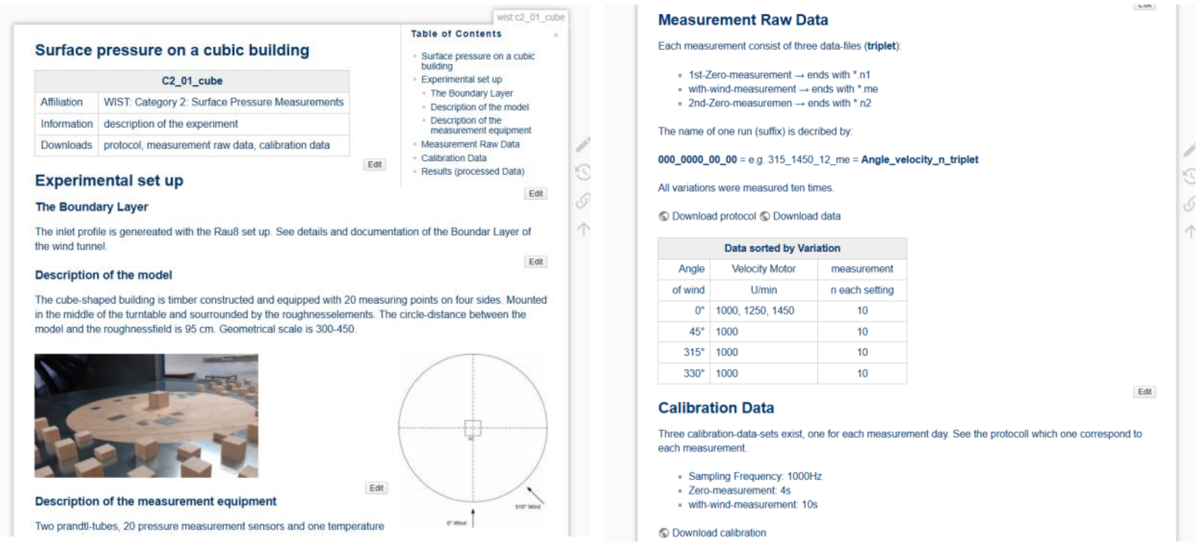
The following chairs and groups make their data available:

- Continuum Mechanics (LKM)
- Wind Engineering and Flow Mechanics (WIST)
- Group B
- Group C

Idea and objective

Digital availability of current research data of the faculty for teaching via a platform

Figure 6.1: Home of Digital Teaching Database (DigiDat)



Surface pressure on a cubic building

C2_01_cube	
Affiliation	WIST: Category 2: Surface Pressure Measurements
Information	description of the experiment
Downloads	protocol, measurement raw data, calibration data

Table of Contents
- Surface pressure on a cubic building
- Experimental set up
  - The Boundary Layer
  - Description of the model
  - Description of the measurement equipment
- Measurement Raw Data
- Calibration Data
- Results (processed Data)

Experimental set up

The Boundary Layer

The inlet profile is genereated with the Rau8 set up. See details and documentation of the Boundar Layer of the wind tunnel.

Description of the model

The cube-shaped building is timber constructed and equipped with 20 measuring points on four sides. Mounted in the middle of the turntable and sourrounded by the roughnesselements. The circle-distance between the model and the roughnessfield is 95 cm. Geometrical scale is 300-450.

Description of the measurement equipment

Two prandtl-tubes, 20 pressure measurement sensors and one temperature

Measurement Raw Data

Each measurement consist of three data-files (**triplet**):

- 1st-Zero-measurement → ends with *.n1
- with-wind-measurement → ends with *.me
- 2nd-Zero-measuremen → ends with *.n2

The name of one run (suffix) is decribed by:

000_0000_00_00 = e.g. 315_1450_12_me = **Angle_velocity_n_triplet**

All variations were measured ten times.

Download protocol Download data

Data sorted by Variation		
Angle	Velocity Motor	measurement
of wind	U/min	n each setting
0°	1000, 1250, 1450	10
45°	1000	10
315°	1000	10
330°	1000	10

Calibration Data

Three calibration-data-sets exist, one for each measurement day. See the protocoll which one correspond to each measurement.

- Sampling Frequency: 1000Hz
- Zero-measurement: 4s
- with-wind-measurement: 10s

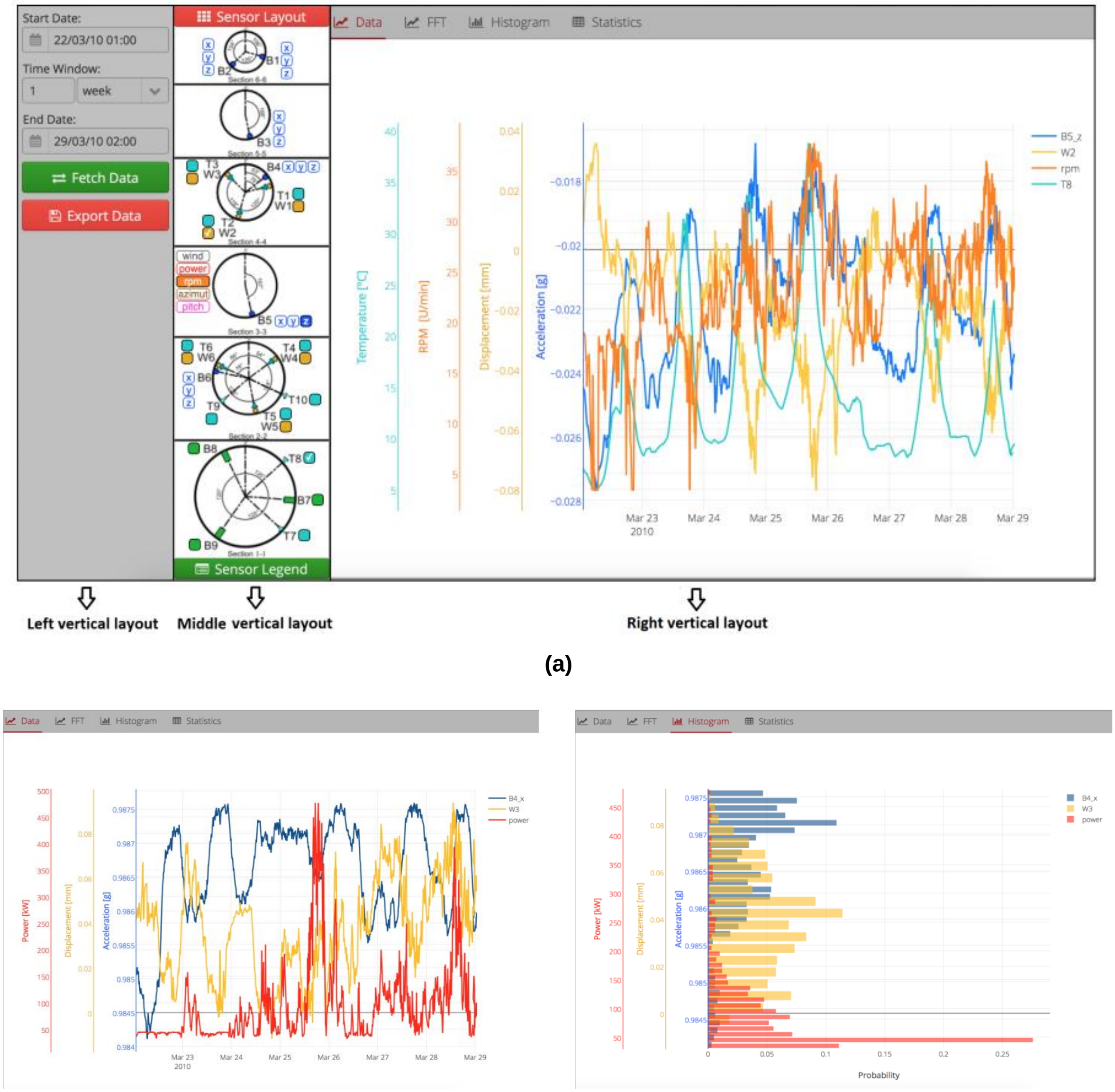
Download calibration

(a) **(b)**

Figure 6.2: A case study of surface pressure on a cubic building available as a database in DigiDat.

6.1.2. Remote-Access Experiments

In the case where a structure is monitored over a period of its life, engineers can better assess the risk and reliability of the structure. This leads to better risk management and minimization strategy. For example, existing structures approaching or exceeding their design life require monitoring. In another case, an operating wind turbine exposed to wind and operational dynamic loading needs to be monitored. At the industrial level, monitoring an operating structure usually consists of an integrated monitoring and data logging system. Internet and cloud-based database is commonly used. Most engineers in the company do not need to visit the monitoring sites to analyze the data. Projecting such normality in industrial work into the teaching and learning environment can be addressed by remote access experiments. A combination of a digital database and real-time monitoring of a structure, a remote access experiment is an activity where both teaching and learning agents can access real-time data and conduct evaluations from anywhere in the world. Basic data post-processing and display are usually included in the remote access interface.



Start Date: 22/03/10 01:00

Time Window: 1 week

End Date: 29/03/10 02:00

(a)

(b) **(c)**

Figure 6.3: Interface of the web application for structural health monitoring on AIRWIN DEW21.

An example of a remote experiment using a website application and the internet is developed for an operating AIRWIN DEW21 wind turbine in Dortmund, Germany. The wind turbine is Enercon E40 - 500 kW series with 65 hub height and is being measured since 2010. The web application allowed the user to access the monitoring database interface through a common browser. Figure 6.3 shows the initial development of a web application for real-time structure health monitoring on the AIRWIND DEW21. In this example, the web application was developed using Eclipse Java EE IDE for web developers, Vaadin's Eclipse Plugin 3.0.0 and LAMP stack XAMPP 7.0.8-0 local database. The example provides the following didactic and access features, which are useful in order to conduct an experiment with remote access:

- Collect data from the database to the user's storage (e.g. computer storage, cloud);
- Selection of time period for monitoring data display or acquisition;
- Basic monitoring and post-processing (e.g. time history plotting, statistics of the data);
- Good user experience (UX) and user interface (UI).

6.2. Training of Advanced Tutor (E-Tutor)

In cooperation with the eLearning Lab “eLab” of BUW, and with support from the project partner Ruhr University Bochum (RUB), the project coordinator Bauhaus-University Weimar (BUW) organized and implemented a training course in digital tools, as well as possible application scenarios in teaching including a comprehensive overview of the possibilities and offers of eLearning and Moodle functionalities. The training course which took place between September 27th to October 1st, 2021, at Bauhaus-University Weimar was participated by 13 MSc and PhD students selected from each partner university. Due to the ongoing Covid-19, the training course was held in a hybrid format, where participants who could not travel to Weimar joined the training remotely.

The following topics were addressed in the framework of the training:

- Making an educational movie with a low budget and high effect;
- Media didactics and media concept for e-learning and e-teaching: storytelling, media usage, and concepts;
- Moodle environment and online examination;
- Remote access experiments: Structural Health Monitoring of a Wind Turbine.

Figure 6.4: Participants and organizers of the e-tutor training course, which took place between September 27th to 1st October 2021 at the Bauhaus-University Weimar.

The course served for the training of e-tutors for the technical support and implementation of different learning media within the project PARFORCE and beyond that in the context of further consolidation at the partner universities, an eTutor will be a student assistant who supports lecturers in creating digital content for their courses. The tutor training provided theoretical knowledge about e-learning tools, methods, and techniques as well as hands-on training by working on individual project ideas designed by participating lecturers. The following didactical aspects are addressed and implemented in the E-Tutor program:

- Inverted classroom and hands-on group project that combines all related seminars given in the event;
- Hybrid seminar;
- Introduction of digital and online teaching tools;
- Evaluation and feedback of the project as well as the evaluation of the programs by the participants;
- Interaction and teamwork for the participants concerning acquired intercultural, social, and language skills.

Also, within the framework of the training a first trial for a remote access experiment was carried out by (Ruhr University Bochum), where participants of the training experienced a first remote access experiment of the effect of wind turbines on different types of structures through a teleconference meeting, moments from the experiment is shown in Figure 6.5.

Figure 6.5: Presentation of the access experiments regarding structural health monitoring of a wind turbine.

6.3. Patternpool

The concept of the Pattern Approach, first introduced by the architect Christopher Alexander in the 1970s, introduces design patterns to make information about proven solutions to particular problems available to others. The Pattern Approach is now also being used in higher education didactics, as there are often challenges in teaching for which tried and tested solutions already exist. Patternpool systematically records and presents design patterns according to the following categories: Problem, Solution, Consequences, Forces, Context, and Details in the form of an online journal with its own ISSN. For authors, the publication is therefore advantageous in the sense that their proven teaching practice is treated as a publication and is also provided with a DOI. (Patternpool, 2023). Technically, it is an Open Access infrastructure based on WordPress. The samples are published under the CC-BY license. Other licenses can be issued at the request of the authors. In Patternpool, you can find didactic solutions based on the needed application by selecting the related event format (e.g. seminar, lecture, experiment) and/or by selecting the related field and/or by selecting the target group.

6.4. Training in Technical English

Language skills have become of vital importance for engineers in our globalized world. It is no longer an option to focus exclusively on the content of engineering study programs; language programs are an important part of a well-rounded education. Graduates of the engineering disciplines are often employed in companies that work in multi-cultural contexts across different countries. Thus, engineers need to be able to communicate and collaborate with colleagues from all over the world (Johri & Jesiek, 2014). A second aspect is the fact that supranational issues like climate change, pollution, and similar threats are affecting the entire world population and engineers play a vital role in finding solutions to such issues (Jones, 2018), making it obligatory to communicate with fellow engineers across the world. The language that is most important in these scenarios is of course English as a worldwide lingua franca. To meet these needs, two language programs complement the course of study: on the one hand, the language learning program Tandem.MINT, on the other hand, has two classes on technical English for civil engineers.

6.4.1. Tandem.MINT

Tandem.MINT is a unique language program where students with different native tongues, but similar fields of study help their partner in advancing their general but also subject-specific language skills. While language tandems are not new in higher education (Spänkuch et al., 2017), a tandem program specifically designed for STEM students is indeed an innovation. Being paired with a student from the same or a similar study program leads to a higher exchange of subject-specific knowledge and language skills. Students not only become more fluent in speaking a language but feel more comfortable talking about subject-specific topics, something required in academia at conferences as well as in later working life.

After initial introductory workshops on tandem learning and methods to structure their individual meetings, the students are responsible for their success in advancing their language skills. They are free to decide how they want to structure their meetings and what kind of material they want to work with. This way, they have the chance to improve exactly those aspects that they feel are important for their future linguistic success. In case the students require further guidance, they are supported by coaching offers provided by experts from the language learning center, and additional material in an accompanying Moodle course. The Moodle course offers topic suggestions, methods to approach topics, collections of supporting materials such as word lists or online databases, and a tandem portfolio to keep track of the learning success and likeliness. In addition, it functions as an exchange platform for the participants. Tandem learning has several advantages over traditional language classes. The content can be tailored to the needs of the participants, it does not follow a strict schedule or course book. This way the learning outcome is much higher because topics that seem less important or are not of interest to the partners can be ignored, while they can concentrate in-depth on material they are interested in. In addition, language classes rarely offer the chance to practice speaking to the extent required to become fluent. Only real conversations with native speakers or proficient speakers of a language will lead to the achievement of a proper level. In tandem learning, the level of oral interaction is much higher and much more authentic than any language course would ever be able to offer (Brammerts, 2003).

While tandem learning of course offers more languages than just English, this is the language most often chosen and often taught with the help of a proficient speaker (at least C1[1]) who is not necessarily a native speaker. The request for English from German native speakers is usually higher than vice versa – a problem that was tackled by using the potential of highly sufficient non-native speakers (Salzinger et al., 2022). This offers the solution to two problems.

---

[1] According to the Common European framework of references for languages (CEFR)

Firstly, it solves the issue of the uneven distribution of demand and supply when it comes to English. Secondly, it gives the advantage of learning from a non-native speaker, who is usually firmer in grammatical rules as they were acquired through formal teaching rather than unconscious first language acquisition. In addition, the learner gets used to a non-native accent. In real life, it is far more common that engineers will work with colleagues who are not native speakers of English but use this language as a lingua franca. Having the chance of becoming familiar with non-native accents is thus of utter importance and is gladly received by engineering students (other students tend to reject matches with non-native speakers). Feedback from the students verifies this and the advantages of being matched with a non-native speaker are often specifically mentioned as a very positive experience for exactly the aforementioned reasons.

6.4.2. Technical English

The second language program for engineers is a traditional language class with a focus on subject-specific content. The class is open to all students in the Department of civil engineering from Bachelor to Master and across all courses of study. It is offered with different foci as Technical English for Civil Engineers I in the winter semester and Technical English for Civil Engineers II in the summer semester. Both classes have four hours of class time in addition to time spent in self-study at home (individually or group work).

The classes include various innovative learning methods that are applied in the weekly traditional classes in person as well as asynchronously on Moodle. The weekly classes in the classroom teach and practice all four aspects of language learning: writing, listening, speaking, and reading. In Technical English I, the required entrance level for the class is B1 and the focus is on retrieving and strengthening existing skills. For this reason, the class is rounded off by an asynchronous grammar module on Moodle. The grammar course has a high level of interactive and gamification elements. The students can compete anonymously for the highest scores. They will see their results in comparison to the rest of the class on a scoreboard which tends to motivate learners to advance faster in the course or re-do tasks to get a higher score. They can choose an avatar that will be displayed on the scoreboard. The tasks are set up in different ways and the approach varies. They include word-matching, memory tasks (like the game), drag and drop, single or multiple choice, etc. to ensure variety and resulting from this interest in grammatical structures that are often considered boring.

The in-class sessions will be based on subject-specific literature from different course books, video material from YouTube, and problem-based learning tasks. There will be a strong focus on speaking since in the end it is more important to feel comfortable communicating with colleagues and co-workers than mastering the language perfectly. Problem-based learning (PBL) is ideal for a high level of discussion in class. Originally, it was not intended for language learning, but it offers great opportunities that allow one to advance more than just linguistic knowledge. This method is based on relevant, contextual, and real-life situations and allows the students to learn how to define problems independently and acquire new learning and thinking strategies that will be helpful in later (professional) life. PBL is based on a short, rather general description of a case, e.g. a birthday party with the family where one person starts a discussion about the usefulness of renewable energy and the advantage of nuclear power. This creates a conflict in the group and is the starting point for PBL. The process is divided into seven steps below, where six of them require teamwork, one lets the students work by themselves.

- Step 1: Define terminology;
- Step 2: Define the problem;
- Step 3: Analyze the problem;
- Step 4: Order explanations;

- Step 5: Formulate learning objectives;
- Step 6: Gather information;
- Step 7: Exchange information.

In regular PBL, the first step is used to make sure that everyone understands the terminology used in the description of the case. If technical terms are unclear, the participants are requested to look them up. This step is ideal in language learning to check if the technical terms are also known in the foreign language and this will lead to new, subject-specific vocabulary that can be applied in the next steps – an advantage over vocabulary lists that are used to understand a text but are normally never actively applied. In addition, the lists are generic and are thus not tailored to the vocabulary knowledge of the individual learner.

The second step will already allow or even require to use of the terminology defined and translated in the first step because here the most important topics and sub-problems need to be defined and ordered. This step demands a certain level of communication to work out and agree on the problem(s).

In the third step, the participants are asked to brainstorm what and how much they already know about the topic. This activates prior knowledge and lets the students reflect if they have the necessary vocabulary to formulate hypotheses. It needs to be clear that this is exclusively about prior knowledge, associations, etc., and has to be strictly separated from the following discussion in step 4 where the hypotheses are discussed and prioritized.

Step five is about identifying learning objectives: what is unclear? What needs to be researched for a better understanding? What do we want to take away from this? The group needs to divide the compulsory research. All steps so far involve a lot of communication within the group, which is ideal to use a foreign language. The advantage of this method is that the students are in a peer group which lowers the inhibition of speaking English, something which is often difficult in front of the whole class and the teacher.

The next step (6) has to be done by each student individually and outside the classroom. They have to research and find answers to the questions they came up with. In addition, this step helps the students practice working academically since they have to write down their new knowledge and insights and observe the rules for good and fair academic work (no plagiarism, citing sources, evaluating the quality of scientific sources, etc.).

Step 7 brings the group back together to present their findings and discuss proposed solutions. Every participant in the group is here asked to actively present their research from the previous week, discuss it, correct it, etc. The students can suggest new questions or new approaches. In the end, they have to collect all suggested solutions and present them to the other groups. This step is ideal not only to learn how to discuss topics in a foreign language but also for how to present subject-specific content. Working on one case takes about 3 weeks with the last week exclusively reserved for the presentation of the results. In addition to regular class work with listening, reading, writing, and speaking tasks, two cases are ideal for one semester, leaving about half the semester for each part (regular class work vs PBL). The course will finish with a written test. The test includes listening comprehension and grammatical tasks. The results from the written as well as the speaking part will be taken from one of the two cases and included in the final grade.

Technical English II has a slightly different structure than Technical English I. Both classes can be taken individually. The suggested entrance level for the second course is B2. A grammar Moodle will be available as well with more advanced material which can be worked on asynchronously again. The final grade in Technical English II is based on projects rather than a regular exam and results from the presentations at the end of the semester that will be held in class in the form of a small conference. The topics for the projects are developed together with the different engineering chairs so that the students can work on real cases. A lot of the project work will be done outside of class, which leaves room to extend oral and written communication skills that will be required in a professional environment like business correspondence, work emails, professional presentations, conducting negotiations at work, etc. In addition, two cases of PBL with a more specific focus on working life will round off the class

6.4.3. Training Session in the Pilot Course: Scientific Working, Writing, and Presenting

This subsection reviews shortly the training introduced in the pilot course. The training, called "Scientific working, writing and presenting", is applied in the form of extensive sessions on one of the days of the week when the participants attended the course in their presence. The sessions, built as a workshop, are designed in such a way that students' participation is required throughout the lessons. The workshop starts with a short seminar about scientific working, writing, and presenting. In the following part of the workshop, the students have to prepare presentations where they can apply the knowledge they have acquired in the first part of the workshop. In addition, the students could receive feedback directly from the experts during their presentations. The design of the workshop also encourages collaboration within the groups to present together and prepare their project work through documentation and presentation. In this workshop, the following key points of scientific work, writing, and presentation are worked out:

- Understanding the main purpose of the presentation. Discussion on the role of the presenter, the aim of the given presentation, the audience of the presentation, and the choice of media for the presentation;
- Discuss the different types of aims that can be achieved when presenting;
- Structure of documentation and presentation;
- Recommendation to build the documentation or presentation;
- Guidelines on how to formulate feedback.

7. Evaluation and Further Improvements of the Pilot Course

7.1. Evaluation of the Pilot Course

Upon completion of the pilot course was evaluated based on a questionnaire that was filled out by the students to gather insights into their experience and perceptions of the course. The questionnaire covered various aspects, including familiarity with lecture topics, knowledge progression, content flow, learning objects, project satisfaction, course planning preferences, and virtual reality (VR) experiences. Key findings from the evaluation of the questionnaire are described in the subsections below.

7.1.1. Familiarity and Knowledge Progression:

- Some students reported a basic knowledge of the lecture topics before the course, indicating previous work on related subjects.
- Throughout the course, students demonstrated significant improvement and showcased high proficiency in the field. Figure 7.1 shows the comparison between the student's familiarity with the topics of wind engineering (Wind), earthquake engineering (Earthquake), and fire resistance of buildings (Fire) before the pilot course and the student's knowledge of the related topics after the course, based on the survey conducted.

7.1.2. Content Flow and Lecture Feedback

- Some students found specific sections, particularly the fire resistance-related topics, challenging and expressed a need for further clarification and support in those areas.
- Feedback also highlighted the importance of establishing stronger coherence and connection between lectures.
- Specifically for the quality of online content, the students rated 3.9 out of 5. (1 is the lowest quality and 5 is the highest quality).

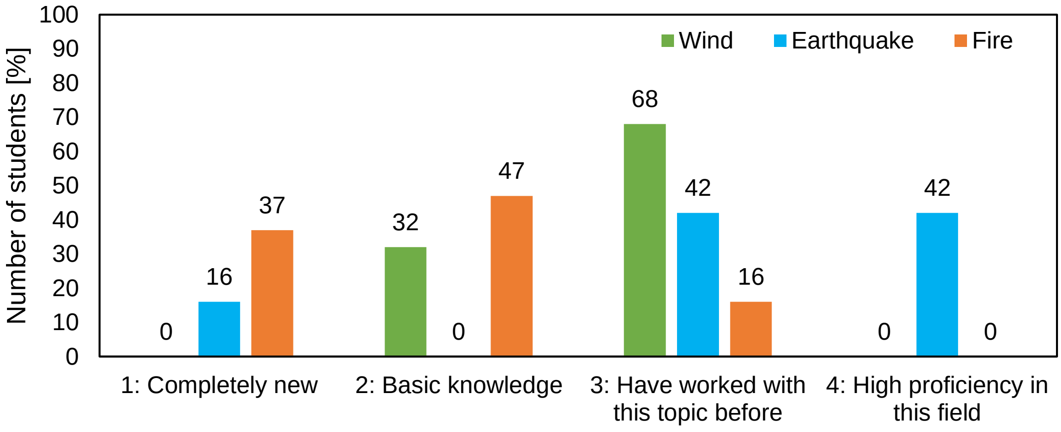
7.1.3. Learning Objectives and Course Satisfaction

- The learning objectives provided were well-received by the majority of the students, who found them suitable for the course content. (95% out of 100% of students).

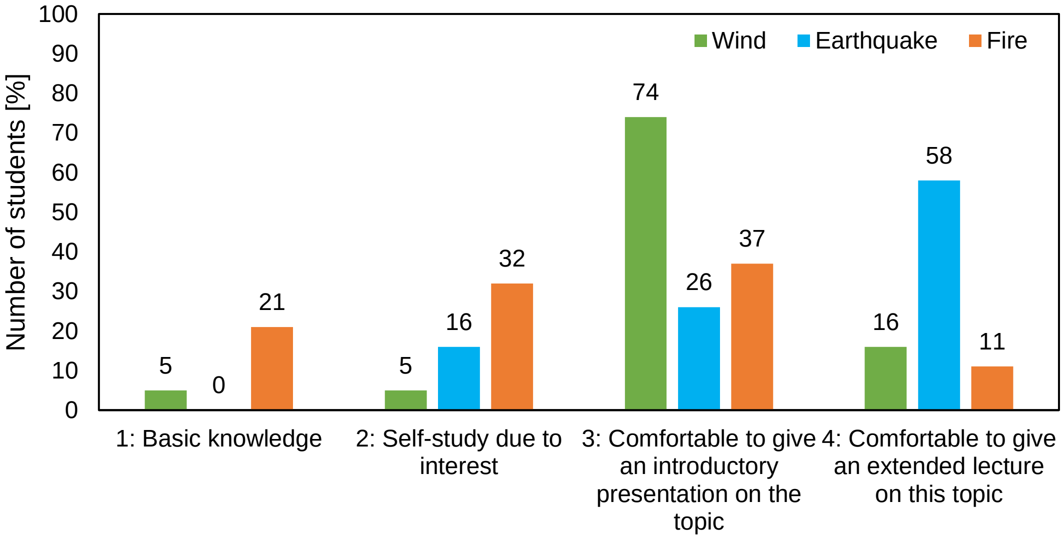
- A majority of students expressed their willingness to recommend the course to their colleagues. (95% out of 100% of students).
- Most students reported satisfaction with the defined learning objectives of the project work, while a small portion expressed some level of dissatisfaction.

7.1.4. Course Planning and In-Person Phase

- All students think that face-to-face meetings are beneficial for the project work of the course.
- Opinions varied regarding the suitability of the one-week in-person training at the end of the course, suggestions included conduction of the in-person week in the beginning or the middle of the course.
- Further recommendations for improving the in-person course format included incorporating more site visits, introducing additional opportunities for in-person interaction, and extending the duration of in-person collaboration.



(a)



(b)

Figure 7.1: Students of the pilot course rated their familiarity and knowledge of the introduced topics (a) before the course and (b) after the course.

7.1.5. Virtual Tours and VR Experience

- Students actively engaged in the virtual tours on the desktop version, exploring experiments such as the wind tunnel, fire resistance test, and quasi-static test.
- The content and understanding of the experiments were generally well-received by students. Students rated 3.6 out of 5 for content and understanding of the experiments through virtual tour experience (1 is marginal/poor content and 5 is for the extended/profound content).
- Some students had limited prior experience with VR glasses, and their feedback varied. While some encountered issues like discomfort, blurry images, or motion sickness, others found the immersive experience engaging and enjoyable.
- Despite the mixed VR experiences, the majority of students expressed their willingness to try virtual tours on VR glasses again and found VR tours to be a suitable alternative to hand on experiments.

Overall, the survey findings indicate positive progression in students' knowledge and their overall satisfaction with the course content and learning objects. Students provided feedback on specific areas for improvement, such as clarifying challenging topics and enhancing the coherence between lectures. The survey also highlighted the potential benefits of incorporating additional in-person interactions and extending the duration of in-person collaboration. Virtual tours and VR technology were seen as valuable additions to the course, despite some challenges associated with VR glasses. These insights provide valuable guidance for future course planning and the integration of technology in educational settings.

7.2. Further Improvements and Support for Subsequent Courses

The main finding is that the involvement and the interaction of the students can be improved if the face-to-face course part is intensified and shifted to the initial phase of the course as otherwise, the online phase suffers from a lack of group interaction and self-motivation. Automatically, a face-to-face meeting at the beginning of the course will bring greater improvement to internal group communication. The following improvements are suggested:

- The time of the face-to-face course part needs to be set at the beginning of the course to support team building and facilitates any further communication. The final presentations of the study outcomes can be easily held online.
- The teamwork needs to be more intensively supervised by providing additional consultation hours.
- The project work needs to be supported by experts in the fields (tutors from expert institutions) to address more properly highly specialized fields such as earthquake engineering, wind engineering, and especially fire resistance engineering.
- Increase the information of students through advertising guest lectures at interested institutions of higher engineering education.

8. Summary

Documentation of potential didactic methods and activities closely related to higher engineering education is given as an outcome of PARFORCE (Partnership for virtual laboratories in civil engineering) in this instructional design guide. In the single chapters, different teaching units using special didactic methods are discussed and presented with related references. The following areas are covered:

- Design of Teaching in Engineering Education with a focus on Digitalization;
- Virtual Laboratories in Engineering Education;
- Mobility in Learning and Teaching in an International Environment;
- Collaborative Moodle Tools;
- Supporting measures such as Online Teaching Database and Remote Access Experiments.

The discussed didactic approaches serve as references to activities to be implemented into a teaching and learning strategy. This is tested and evaluated in the example of a pilot course. The implementation of the didactical methods in the framework of the pilot course is described in the last part of each chapter.

Furthermore, the PARFORCE project also involves additional learning programs such as E-Tutoring and Advanced Training Courses. Considerations of both programs are reported in this document. This Instructional Design Guide is made available as an online report on suitable e-platforms to give insights into various aspects of the conducted works and to disseminate further information on digital learning in engineering.

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