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InfRO@D
EUROPEAN DIGITAL EDUCATION IN RIM

WP3 – Development of techniques for the implementation of the remote teaching and training process with the use of support tools

IO.8 Development of a methodology for conducting laboratory classes with the use of communication tools

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1 ABOUT THE INFRO@D PROJECT

The COVID-19 pandemic has forced a departure from the current functioning of society in many aspects of the economy, travel, work and education, not excluding higher education. The necessity of remote education is one of the ways to maintain social distancing and protect our health and life.

A preliminary assessment of the situation at universities in European countries indicates that academic staff were not sufficiently prepared to conduct attractive and practical classes in a remote format.

The necessity to conduct classes remotely involves developing a dedicated didactic and training process project, considering the specific requirements of interdisciplinary engineering knowledge. Transferring this knowledge in remote education, due to its large scope, requires various didactic tools (lectures, fieldwork, design, practicals, laboratories, student assignments and assessment of the progress and knowledge of students and trainees).

The measurable expected final results are:

- Development of a remote learning methodology for Road Infrastructure Management (RIM) as a model solution to provide a basis for extending the methodology to include further aspects of civil engineering and transport.
- Developing an e-handbook for academic staff supporting the remote learning process.
- Development of model digital teaching and training materials dedicated to technical colleges and training for road management staff on RIM:
  - Road safety audit,
  - Roadside safety management,
  - Safety management of vulnerable road users,
  - Road pavement management.
- Developing an e-learning platform with access to project products.
- Appointment of a panel of experts in road infrastructure management.

The InfRO@D project targets the following groups:

1) Students, researchers, and academic teachers at universities.
2) Road authority staff at national, regional and local levels.
3) Experts, specialists, and practitioners involved in RIM activities, including staff who conduct training in various RIM courses.
4) All users of road infrastructure, as an indirect target group, for whom the risk of road accidents will ultimately be reduced by increasing the effectiveness and efficiency of RIM activities.

The project is also supported by a group of associates who will cooperate with project partners to consult and evaluate the results. They will implement final products and promote the dissemination and accessibility of the project results.

ABOUT OUTPUT IO.8

- **Objective:** Development of a methodology for conducting laboratory classes with the use of communication tools
- **Work package:** The task falls under WP3 – Development of techniques for the implementation of the remote teaching and training process with the use of support tools.
- Target Groups:
  Research and teaching staff from institutions involved in the project and other European institutions.

2 INTRODUCTION TO LABORATORY LESSONS

2.1 Element of the learning system

Laboratory classes should be an integral part of the Road Infrastructure Management curriculum. Laboratories play a pivotal role in the education of future road infrastructure engineers and managers. It allows students and road authority staff to bridge the gap between theoretical knowledge gained in classrooms and the real-world challenges they will face in their future work. It is safe to say that there will not be a good engineer without detailed practical knowledge of the issue in reality, i.e. in the laboratory. Here are some additional points to emphasise its significance:

1) Practical Application: Laboratories allow students, and road authority staff to apply what they have learned in the classroom directly. It offers hands-on experience in assessing, diagnosing, and managing road infrastructure, which is invaluable for their professional development.
2) Problem-Solving Skills: Laboratories often involve unexpected challenges, which require students to think on their feet, problem-solve, and make decisions. These skills are vital in the dynamic field of road infrastructure management.
3) Collaborative Learning: Working in the laboratory encourages collaboration among students, and road authority staff. They learn to work as a team, share work, and communicate effectively – a crucial skill set in the industry.
4) Real-World Challenges: Road infrastructure management involves numerous real-world challenges, from addressing safety concerns to assessing road materials in terms of their properties, characteristics, suitability for use in practice, etc. Laboratories expose students, and road authority staff to these challenges, allowing them to develop practical material solutions.

The teacher also needs to be much better prepared for the laboratory activities. They can expect to be asked problem questions that go beyond the topic under discussion. It should be noted that being together makes such contact much easier and shortens the teacher-student road authority staff distance, making it easier for them to ask questions.

2.2 COVID-19 restrictions

Movement restrictions due to the restrictions put in place during COVID-19 made the process of delivering classes in the laboratory much more difficult or completely impossible. Consequently, the teachers of these classes had the choice of abandoning such classes altogether or using modern technology to deliver IT remotely. The absence of such classes in Road Infrastructure Management would have significantly reduced the quality of teaching and resulted in the non-fulfilment of an essential element in the teaching process. The present methodology will respond to the preparation of materials in the second way, i.e. using IT tools.

Unfortunately, such limitations will result in a much greater workload for the teacher who must prepare and carry out these activities.

2.3 Problem identification

Before the COVID-19 pandemic, the classic form of conducting classes was stationary. It already showed some specific problems that the organisation of a good course should take into account. The need to conduct remote classes, limiting the mobility of people during the global COVID-19 pandemic, showed several other problems faced by the teacher.

Laboratories are the type of classes during which students learn about measurement methods, laboratory tests, devices and test equipment. A characteristic feature is that during laboratory classes, research equipment is used, which is made available by universities for didactic purposes and is not generally available to students (only during classes). Often, due to its size and principle of operation, this equipment is not mobile (non-portable) and is available only on-site (in the laboratory) - e.g. testing machines, rutting testers, dryers, thermal chambers, etc. This feature of equipment causes certain challenges in conducting laboratory classes remotely.

The issue of the monotony of conducting remote classes and the teacher's lack of interest in the topic raised may result in the student's lack of willingness to be active in classes. A frequent manifestation of this is the desire for the simplest, easiest, fastest and non-involving fulfilment of the requirements for passing the subject and moving on to the next subject indicated in the course syllabus.

Another important problem of conducting remote classes in a group is the reluctance of students to speak up - ask questions or answer questions asked by the teacher (addressed to everyone). This problem is a little less critical in the case of classic face-to-face classes (face-to-face contact). Classes conducted remotely, often with the camera image transmission turned off by students, exacerbate this problem.

Unfortunately, the COVID-19 pandemic has highlighted the problem of interpersonal communication between students and the problem of cooperation. Students did not communicate, sometimes for many months, with each other, did not talk, did not act together, and did not cooperate with each other. The loss of direct contact with each other and the lack of communication, conversations, etc., in many cases, caused psychological discomfort or even psychological problems. It was noted that as a result of the pandemic, the number of such cases increased nine times compared to the situation before the pandemic. Communicating with each other and cooperating, talking, and online meetings are critical issues when it is necessary to limit the possibility of meeting and mobility.

To fully conduct some of the types of classes, it is necessary to be able to move around to be mobile. The COVID-19 pandemic has severely limited this mobility. In Poland, for a certain period, you could only move within a radius of up to 500 m from your place of residence. Laboratory classes are an example of classes where the issue of mobility is critical. Material laboratories (e.g. road laboratories) are equipped with largely stationary research equipment (not portable), and laboratory work is only possible on-site (in the laboratory). The use of non-mobile laboratory equipment in didactic classes, in the case of limiting the mobility of students and teachers, causes big problems.

Conducting remote laboratory classes may concern any of the following cases – students participate in classes remotely, + the teacher conducts classes on-site from the laboratory (has direct access to laboratory equipment) or remotely (there is no direct access to laboratory equipment).

2.4 Expected result

The developed methodology includes defining teaching scenarios enabling laboratory classes (both by the teacher and students).

The discussion on effective teaching methods highlighted the importance of creating clear and practical guides. These guides may include multimedia elements such as videos and step-by-step tutorials that help students understand through examples. Additionally, teachers should provide instructions on creating video materials presenting the proper conduct of laboratory classes. Modern technologies, support tools, and cloud collaboration tools can also help students communicate effectively and receive remote assistance in teacher-assisted classes. Additionally, photo and video reports can be used to present substantive content remotely.

Correctly and well-prepared and conducted remote laboratory classes should meet the following criteria:

1) Classes should be prepared in such a way that they can be conducted in **two scenarios** - complete deprivation of mobility (classes conducted entirely outside the laboratory with no access to equipment) or partial limitation of mobility (the teacher conducts classes from the laboratory by connecting remotely with students).
2) Classes broadcast online should be prepared so that devices operating in the laboratory in the background **do not limit the quality of online transmission**.
3) Some laboratory tests require adequate lighting. This **lighting should be prepared** in advance and be consistent with the conditions of a specific test.
4) Some laboratory works require the use of **technical support (laboratory)** because only one teacher cannot carry it out. This fact should be taken into account when preparing for remote laboratory classes.
5) Laboratory classes should be prepared in such a way as to show the equipment, the principles of its operation, sample preparation, the run and completion of the test, and the analysis and interpretation of the obtained results. Particular attention (during preparation for classes) should be paid to those tests that **require a long time** (preparation of samples or the duration of the test itself).
6) Since classes are to be held remotely, it is not possible for students to perform various laboratory work on their own. The teacher should ensure that laboratory classes (initially focused heavily on practical work) do not turn into lectures. Well-prepared laboratory classes **should activate students** in various forms in applicable terms.
7) Laboratory classes largely involve conducting laboratory tests. For these tests, samples of materials are necessary, and these **samples should be prepared well in advance**. Prior preparation of test samples should be carried out in accordance with the required time, depending on the requirements for a specific test.
8) Carrying out laboratory tests may involve (within one test) using equipment located in different rooms. In such a case, you should ensure appropriate **technical equipment for online live-stream**, e.g. a portable recording device, a portable microphone system, a publicly available Internet connection (Wi-Fi), etc.

2.5 Types of laboratory activities

Conducting remote laboratory classes may concern any of the following cases:

- **Case A**, which combines at the same time:
  - remote participation of students in classes
  - conducting classes by the teacher stationary (the teacher has direct access to laboratory equipment);
- **Case B**, which combines at the same time:
  - remote participation of students in classes
  - conducting classes by the teacher remotely (the teacher does not have direct access to laboratory equipment)).

In both cases (A and B) mentioned above, laboratory classes may take various parts:

- lecture form (**L**), which includes e.g
  - theoretical introduction,
  - safety conditions,
  - construction of devices and equipment,
  - research procedures,
  - principles of analysis of results,
  - principles of assessing the properties of materials and their suitability, etc.
- form of exercises (**P**), which includes e.g
  - practical assessment of research results,
  - practical assessment of material properties and their suitability, etc.
- form of design (**D**) which includes e.g
  - designing the composition of materials,
  - designing a research plan, etc.
- practical form (**M**), which includes e.g
  - collecting and preparing samples,
  - preparing and carrying out tests,
  - performing measurements, etc.

In the classic form of classes conducted entirely stationary, laboratory classes require the involvement and own (practical) work of students in the laboratory. In the case of classes taught remotely, students are deprived of this opportunity. The most important issue is that in Case B (classes conducted entirely remotely by a teacher), laboratory classes should not be limited to the teacher's lecture and simply presenting substantive content while depriving students of the opportunity to perform practical work. Activating students during laboratory classes conducted remotely is, therefore, the primary task of the teacher.

Table 1 shows possible (most reasonable) forms of activity for individual cases (A and B) and parts of laboratory activities (L, P, D, M) and a proposal of the most recommended ones.

Table 1 Possible and recommended forms of activity in particular parts of laboratory classes

Laboratory part	Possible (reasonable) forms of activity	Recommended form of activity
***Case A** – stationary (teacher) + remote (students)*		
lecture (L)	only teacher/teacher + students	teacher + students (partly by the teacher and students)
exercises (P)	students + teacher	students + teacher (implemented mainly by students but under the supervision of the teacher)
design (D)	students + teacher	students + teacher (implemented mainly by students but under the supervision of the teacher)
practical (M)	only teacher/teacher + students	teacher + students (implemented mainly by the teacher with a part intended for students)
***Case B** – remote (both teacher and students)*		
lecture (L)	only teacher/teacher + students	teacher + students (partly by the teacher and students)
exercises (P)	teacher + students	students + teacher (implemented mainly by students but under the supervision of the teacher)
design (D)	teacher + students	students + teacher (implemented mainly by students but under the supervision of the teacher)
practical (M)	only teacher/teacher + students	teacher + students (partly by the teacher and students)

While the lecture, exercise and project parts of laboratory classes are easy to complete remotely (online), the practical part of these classes poses severe organisational, logistic, methodological and technical problems. This is, in particular, an essential issue in **Case B**, where the teacher is not in the laboratory and does not have laboratory equipment and devices at his disposal. To carry out the above-mentioned parts of the laboratory classes, you can use PowerPoint presentations, video materials (available publicly or prepared in advance by the teacher) or live streams.

Table 2 shows the general difficulties resulting from using individual forms in implementing the above-mentioned parts of the laboratory classes, separately for Case A and Case B.

Table 2 Difficulties in applying different forms of laboratory classes in other cases

Laboratory part	PowerPoint presentation	Video materials	Live stream
***CASE A** – stationary (teacher) + remote (students)*			
lecture (L)	easy	easy	easy
exercises (P)	easy	easy	easy
design (D)	easy	easy	easy
practical (M)	difficult	easy	difficult
***CASE B** – remote (teacher) + remote (students)*			
lecture (L)	easy	easy	difficult
exercises (P)	easy	easy	difficult
design (D)	easy	easy	difficult
practical (M)	difficult	difficult	impossible

3 METHODS OF TECHNICAL AND LOGISTICAL SUPPORT

Using supporting methods (software, hardware, personal support) will be an essential element to help implement such activities. The mentioned support methods will be discussed in the following subsections.

3.1 Software

The COVID-19 pandemic began the dynamic development of IT tools supporting communication and the possibility of preparing classes remotely. A description of sample programs is presented in part IO.16. Of course, their development is dynamic, and other software may most likely be used in the future. Among the basic ones, we can mention:

- software for remote communication, e.g.
  - Zoom
  - MS Teams, etc.
- software to create multimedia presentations, e.g.
  - ActivePresenter (Figure 1),
  - Lectora,
  - MS PowerPoint, etc.
- software for processing video materials, e.g.
  - CapCut, VLC,
  - Movavi Video Converter,
  - Photoshop, etc.
- software for processing graphic images, e.g.
  - GIMP,
  - Photoshop,
  - CaptureOne, etc.
- software to manage the teaching process, e.g. Google Classroom, etc.

To carry out laboratory classes and, in fact, to conduct laboratory tests, it is also necessary to have software supporting the devices and equipment used. These are specialised programs dedicated to specific research and equipment. They cooperate with devices, support them and are necessary to conduct laboratory tests. However, these are not programs that can be used separately from laboratory equipment and made available to students. They are an integral part of laboratory equipment and devices.

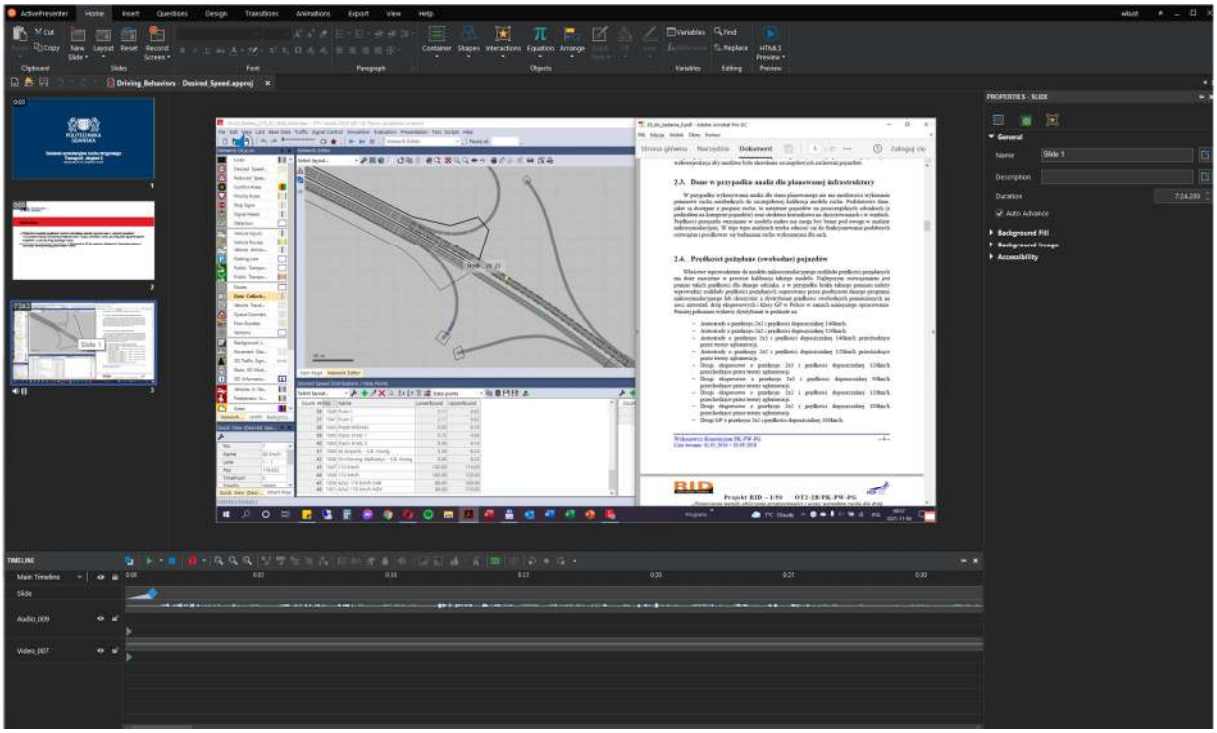

Figure 1. View the prepared presentation using the ActivePresenter software

3.2 Hardware

When preparing the methodology concept, including laboratory classes, the focus was on the possibility of implementing them with relatively low financial outlay for both the academic teacher and the student. This equipment can be divided into image recorders, sound recorders, equipment supporting image recorders, lighting equipment, and research equipment. The issues mentioned above will be discussed in the following paragraphs.

3.2.1 Image recorders

We can use relatively cheap equipment for most of the laboratory work (Figure 2):

- single/multi-camera image recorders,
- GoPro video recorders,
- photo cameras (digital, SLR, mirrorless, etc.),
- mobile phones/smartphones.

The original assumptions (when writing the project application) also included using the VR method, but unfortunately, its use is currently tricky and time-consuming. There is also no dedicated software that could easily translate field research into virtual reality. Therefore, the use of this method for conducting field classes was abandoned.

Source: https://gopro.com

Source: https://70mai.pl

Figure 2. Examples of recording devices

3.2.2 Equipment supporting image recorders

Conducting laboratory tests often requires the teacher to have full manual freedom to perform various activities with both hands. In such situations, he can't hold and operate the recording equipment simultaneously. The solution to this issue is alternatively:

- using the help of an additional person - then one person carries out laboratory work, and the other operates the recording equipment
- the use of additional technical equipment, e.g.:
  - steady tripods,
  - monopods,
  - wearable mounts for mounting recording equipment and gimbals.

Unlike gimbals and monopods, when using tripods and body-mounted recording equipment, there is no need for a second person to help. The disadvantage of using tripods is the inability to reframe/change smoothly the recorded shot. Monopods and gimbals operated by a second person, as well as body-mounted equipment installations, are free from this drawback.

Selected camera mounting systems are shown in Figure 3.

3.2.3 Sound recorders

Since conducting laboratory classes often requires the teacher to have complete manual freedom, it is necessary to ensure sound recording, preferably using lavalier microphones (attached to outer clothing) - Figure 4.

For safety reasons in the laboratory, it is good practice to use wireless Lavalier microphones. This prevents the cable from getting caught on equipment or the cable being pulled in by the operating equipment, thus damaging it or harming health.

In the laboratory, it often happens that other laboratory work is being carried out in parallel to the recording, with equipment operating in the background, which may generate additional noise. This noise may interfere with the correct recording of sound (teacher's comments). It is

therefore recommended to use wireless Lavalier microphones with directional sound recording functions.

a) tripod with fluid head *b) monopod* *c) gimbal*

Figure 3 Examples of camera montage system (source: https://www.manfrotto.com)

a) *b)*

Figure 4 Examples of Lavalier microphone systems
- source a): https://mitoya.pl; source b): https://gear4music.pl

3.2.4 Lightning equipment

Some laboratory tests require appropriately selected lighting equipment. Such tests include for example, asphalt affinity testing for aggregates, bitumen penetration testing and other similar tests. Additionally, some tests that end with detailed photos of samples, results, etc., also require good lighting.

Lighting can be implemented by various means, unique and appropriate to the intended effects. Therefore, lighting equipment (if necessary) should be selected independently in accordance with the expected results and needs. When choosing lighting, it is worth considering lighting intensity, light colour temperature and degree of light dispersion. To disperse light, diffusing reflective umbrellas, softboxes, shadowless tents or illuminating/reflecting screens/blends can be used. Examples of various additional lightning equipment are shown in Figure 5.

a) softbox

b) reflective umbrella

c) blendes

d) shadowless tent

Figure 5 Examples of additional lightning equipment (source: https://mitoya.pl)

3.2.5 Research equipment

Laboratory research equipment should be provided for the specific work, tasks and laboratory tests we want to use in laboratory activities. It should be selected in accordance with the appropriate standard assigned to each laboratory test.

4 METHODOLOGY FOR LABORATORIES

4.1 Assumptions

As part of the preparation of the methodology, the following was taken into account:

- cases of forms of conducting activities: A - the teacher conducts classes stationary via audio-video transmission from the laboratory, and students participate in classes remotely; B - the teacher conducts classes entirely remotely using audio-video transmission from outside the laboratory, and students participate in the classes remotely;
- possible parts of laboratory classes: L - lecture part, P - exercise part, D - design part, M - practical part;
- possible activities: T - only teacher activity, T/S - mainly teacher activity, a more minor students' activity, S/T - activity mainly on the side of students with current control from the teacher, TS – partly activity on the side of teacher and students.

Based on the above assumptions and the recommended activities from section 2.5, several scenarios were prepared and presented in Table 3.

Table 3 Selected scenarios for implementing various parts of laboratory classes

Lab part	Scenario	Description
L	A-L-TS B-L-TS	Regardless of the form (stationary/remote), issues related to the lecture part of laboratory classes are distributed evenly between the teacher and students.
	A-L-T/S B-L-T/S	Regardless of the form (stationary/remote), issues related to the lecture part of laboratory classes are mainly the instructor's responsibility, who presents most of the issues. In this case, only a small part of the lecture topics is assigned to students.
	A-L-S/T B-L-S/T	Regardless of the form (stationary/remote), issues related to the lecture part of laboratory classes are distributed evenly between the teacher and students.
P	A-P-S/T B-D-S/T	Regardless of the class form (stationary/remote), most of the tasks should be completed and presented by students. The teacher should only provide assistance, control and checking.
D	A-D-S/T B-D-S/T	Regardless of the class's form (stationary/remote), most of the tasks should be completed and presented by students. The teacher should only provide assistance, control and checking.
M	A-M-TS A-M-T/S	Suppose it is possible to conduct classes by a teacher from the laboratory (stationary). In that case, this should be used to provide a live report of practical laboratory work and how the research was carried out. The main action in this case should be on the teacher. Some tasks can be delegated to students.
	B-M-TS B-M-T/S B-M-S/T	If conducting classes by a teacher from the laboratory is not possible, the tasks related to the practical part can be divided into different ways - equally for the teacher and students, with emphasis on the preparation of materials by the teacher or with emphasis on the preparation of materials by students.

4.2 Methodology for various parts of laboratory classes

4.2.1 Lecture part

Lectures are this type of class during which students get acquainted with new knowledge differently. During lectures, speakers present content to other people (listeners). This method may involve the teacher alone or involve some or all of the students. Therefore, this class type boils down to the basic issue of providing specific theoretical knowledge. Since lectures are most often a presentation of new knowledge, they should include the possibility of asking questions from students, comments from the teacher and answers to doubts. The lectures must concern the most current trends and current knowledge used in the world. The knowledge provided to students within a given course must be up-to-date and updated on a regular basis.

Lecture part (L) of laboratory classes should include, e.g. theoretical introduction to the topics and lab tests, safety conditions during laboratory classes, construction of devices and equipment, research and test procedures, principles of analysis of results, principles of assessing the properties of materials and their suitability, etc.

For the lecture part of laboratory classes, it is possible to apply various material resources, e.g. PowerPoint presentation (prepared by teacher or students), video materials (videos designed earlier by the teacher, YouTube resources, interviews, webinars, etc.), live-stream transmission, etc. An example of homework for students related to the lecture part of laboratory classes is shown in Figure 6. Details regarding the preparation of these forms of source materials are described in a separate part of the methodology and final reports.

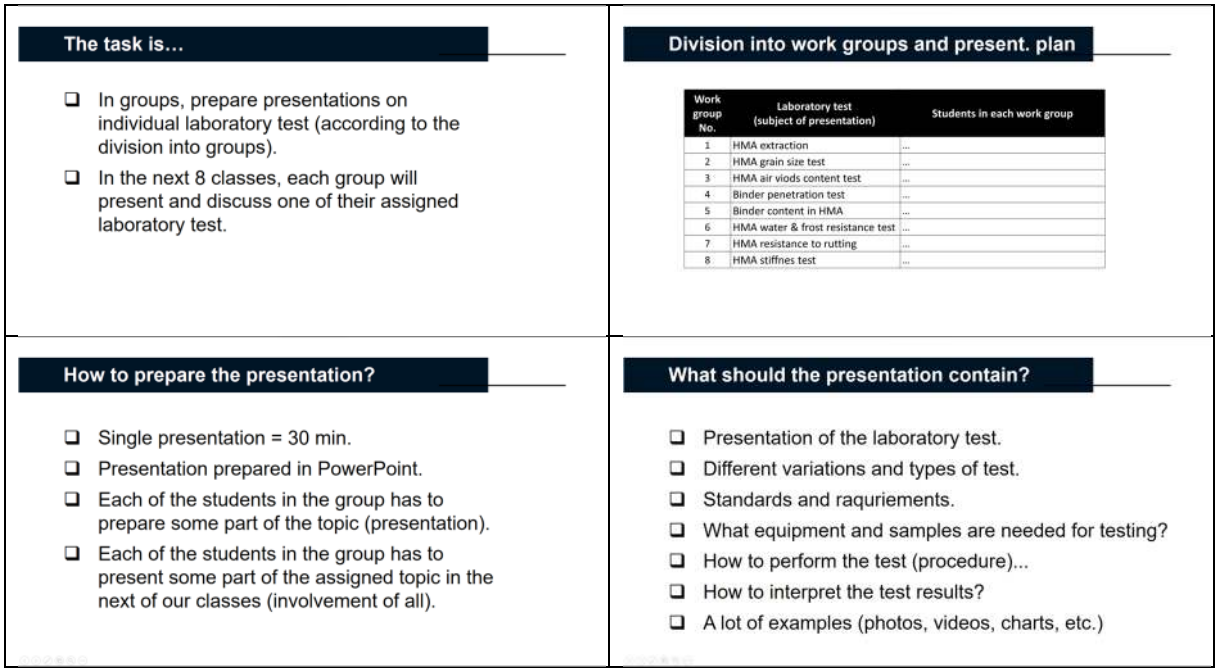

Figure 6 Example of homework for students related to the lecture part of laboratory classes (example of B-L-S/T scenario)

4.2.2 Exercise and design parts

Exercise and design are the types of classes during which students gain practical knowledge or skills. The basic form of practical classes is, of course, the performance of specific tasks (calculations, measurements, evaluation, assessment, design, etc.). Here, it is worth noting that the practical application of knowledge in this regard must entail its prior transfer (e.g. in the form of lectures of various kinds). The classes can also take the form of a lecture. In such lessons, the speaker presents practical principles, methods and ways of performing various practical tasks and works. It is worth emphasising that the practical tasks to be solved do not have to refer to the most current issues. Their basic task is to transfer knowledge for practical application or practice the knowledge acquired earlier. Of course, students should work on the most recent issues, but this is not the main priority for practical lessons.

Exercise part (P) of laboratory classes should include, e.g. practical assessment of research results, practical assessment of material properties and their suitability, etc. Design part (D) of laboratory classes should consist of, e.g. designing the composition of materials, designing a research plan, etc.

For exercise and design parts of laboratory classes, it is possible to apply various material resources, e.g. PowerPoint presentation (prepared by teacher or students), video materials (videos prepared earlier by the teacher, YouTube resources, interviews, webinar, etc.), live-stream transmission, etc. Details regarding the preparation of these forms of source materials are described in a separate part of the methodology and final reports.

4.2.3 Practical parts

The practical part of laboratory classes is the type of classes during which students learn about measurement methods, laboratory tests, devices and test equipment. A characteristic feature is that during laboratory classes, research equipment is used, which is made available by universities for didactic purposes and is not generally available to students (only during classes). Often, due to its size and principle of operation, this equipment is not mobile (non-portable) and is available only on-site (in the laboratory) - e.g. testing machines, rutting testers, dryers, thermal chambers, etc. This feature of equipment causes certain challenges in conducting practical parts remotely.

One of the methods of dealing with this problem is to conduct "live" laboratory classes - based on online broadcasts. However, this solution has one major disadvantage - a very large part (most) of laboratory tests are long-term or even very long-term. The preparation and conditioning of samples for a given test is often a multi-day process. In addition, laboratory tests, due to multiple loads (such as fatigue life tests), take several days. For this reason, the live transmission of laboratory classes, in many cases, does not solve the problem.

Another method of dealing with this problem is using audio-visual recordings (movies). The use of videos in remote laboratory classes allows (in the case of long-term works) to show only the key, most important moments. Preparing a high-quality film, useful in didactic classes, is not a simple matter and entails the need to cope with many aspects, such as the proper organisation of parallel work in the laboratory, the need for additional people to help with recordings, the use of appropriate equipment for audio-visual recording, appropriate lighting

and many others. Currently, there are many free educational videos of high didactic value on laboratory research available on the Internet. An important issue in the case of laboratory classes is that such classes should be conducted after the knowledge previously acquired by students, e.g. during lectures.

Practical part (M) of laboratory classes should include, e.g. collecting and preparing samples, preparing and carrying out tests, performing measurements, laboratory works, etc. Details regarding the preparation of various forms of source materials are described in a separate part of the methodology.

For practical part of laboratory classes, it is possible to apply various material resources, e.g. PowerPoint presentation (prepared by teacher or students), video materials (videos prepared earlier by the teacher, YouTube resources, interviews, webinars, etc.), live-stream transmission, etc. An example of laboratory video material for the practical part of laboratory classes is shown in Figure 7. Details regarding the preparation of these forms of source materials are described in a separate part of the methodology and final reports.

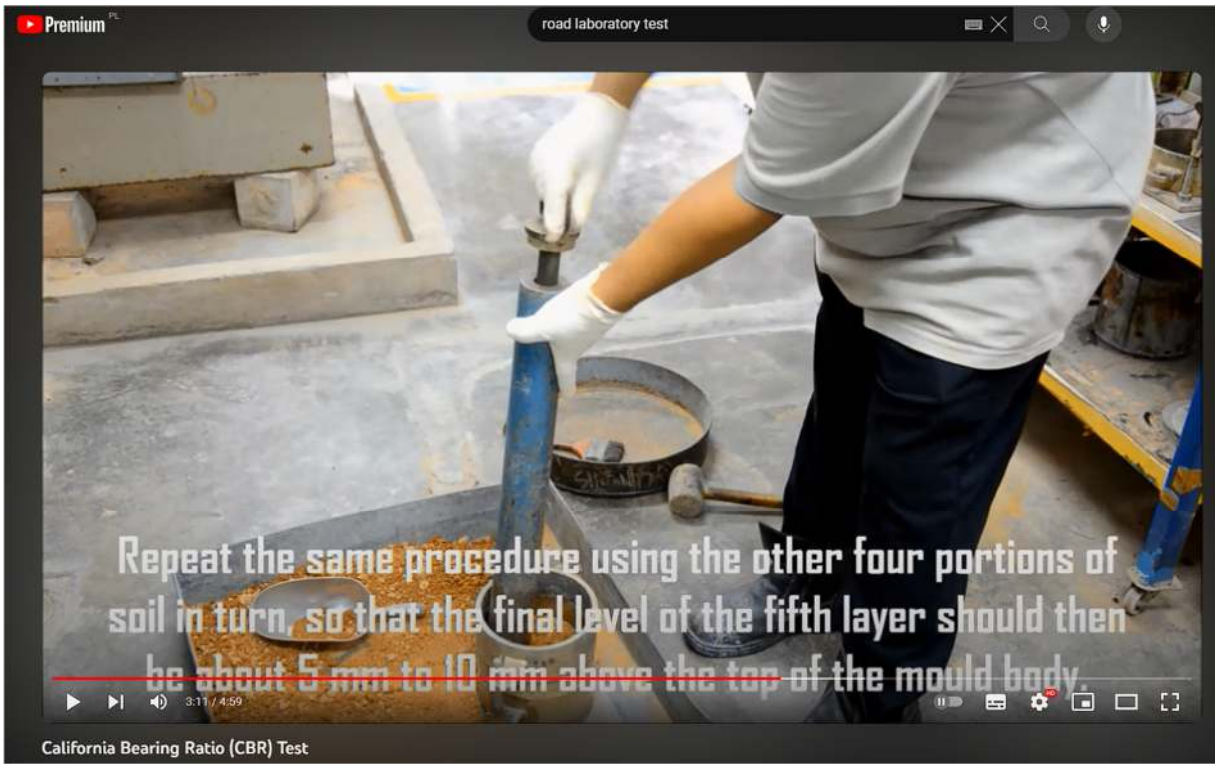

Figure 7 Example of laboratory video material (YouTube platform, author: Sustainable Asphalt Research Group, source: https://www.youtube.com/watch?v=IQ-cyCB2-so)

4.3 Framework plan for preparing laboratory classes

To properly prepare laboratory classes, it is good practice to follow the following plan:

1) Determining the goals of laboratory classes and learning outcomes.
2) Determining the detailed topics and scope of laboratory classes.

3) Scheduling laboratory classes for individual lessons (in accordance with the scheduled hours).
4) Division of planned lessons into several parts of laboratory classes – lecture/exercise/design / practical part of laboratory classes.
5) Determining the form of classes (stationary/remote) for each part and several lessons.
6) Determining activities for each of the forms and parts of laboratory classes (students/teacher activities).
7) Determining the necessary equipment, devices, road materials, samples and supplies
8) Determining the type of material resources for each of the parts of classes and lessons.
9) Agreeing with the laboratory manager and laboratory staff on the details of the classes (date, schedule, type of classes, necessary equipment and other needs). Possible correction of the plan after consultation.
10) Completing the necessary equipment, devices, road materials, samples and supplies.
11) Providing possible support from laboratory technicians or other people.
12) Preparing material resources for each part of laboratory classes and several lessons.

4.4 The order of content presented during laboratory classes

It is good practice to conduct laboratory classes in accordance with the following order of content:

1) Introduction to the topic of laboratory classes.
2) Information about the scope, form, type and schedule of laboratory classes.
3) Information about the conditions for passing the classes.
4) Implementation of the theoretical part (lecture, L) of laboratory classes.
5) Implementation of the practical (P) / design (D) / practical (M) parts of laboratory classes.
6) Summary of the work performed and content provided during all laboratory classes.
7) Evaluation of students' knowledge acquired during laboratory classes (test, examination).

Each part of the laboratory classes (L, P, D, M) should consist of the following elements:

1) Work topics to be completed within a given part of laboratory classes.
2) The purpose of carrying out work within a given part of laboratory classes.
3) The scope of work to be performed within a given part of the laboratory classes.
4) The way/method of carrying out the work within a given part of the laboratory classes.
5) Necessary tools to perform the work (here also: laboratory equipment, construction, service, etc.).
6) Assigning topics/tasks to be completed within a given part of laboratory classes.
7) Implement topics/tasks within a given part of laboratory classes.
8) Teacher's control over the results of completed work/tasks.
9) Analysis and evaluation of the results obtained due to implementing topics/tasks.
10) The teacher's control over the results of the performed analyses.
11) Summary of completed work/tasks by the teacher.
12) Summary by the teacher of the entire part of the laboratory classes.

5 VARIOUS PROBLEMS AND SUGGESTED SOLUTIONS

This chapter describes additional problematic issues that may arise when organising and conducting remote laboratory classes. The consequences of these problems are defined, and methods of dealing with these problems are proposed.

5.1 Students do not participate directly in laboratory classes

5.1.1 Description, consequences of the occurrence

Students do not have the opportunity to practically perform laboratory work and tests on their own (remote student presence). Consequently, they will not be able to learn them correctly and completely. Some laboratory tests require an attempt to be performed on your own because live Internet live-streams or recordings (video material) cannot correctly and fully reflect their course and method of carrying out.

5.1.2 Proposed solution method

All laboratory work as part of remote classes should be carried out and presented by the teacher, possibly with the help of technical staff.

Difficult research on visually showing their nature during a "live" Internet broadcast should be supported by preparing a demonstration film in advance, made with great care, in perfect lighting conditions, and with appropriate prior preparation of the recording station.

If it is impossible to visualise the nature of the study, both during live transmission and recorded film material, diagrams, illustrations and drawings may be prepared to show the issue related to such a study that is difficult to convey in audio-visual transmission.

5.2 Time-consuming performance of some laboratory work and tests

5.2.1 Description, consequences of the occurrence

Some laboratory works and tests are characterised by long or even very long completion times, significantly exceeding the time allocated for a single laboratory class. For this reason, students would not have the opportunity to participate "live" in the entire research process, including preparation, test start, test run, the key moment and completion.

5.2.2 Proposed solution method

The issue of the time-consuming performance of some laboratory tests can be solved by showing in a live stream: an overall view of the test in progress, a previously prepared film covering long-term or critical stages of the test (preparation, start, key moment and the end of the test).

5.3 Difficulty in carrying out some laboratory work and tests

5.3.1 Description, consequences of the occurrence

Some laboratory works and tests are characterised by certain difficulties resulting from the following issues:

- the key moment of the test is difficult to obtain (e.g. the moment of material cracking), the occurrence of which is impossible to predict, especially in the case of materials obtained from real road surfaces;
- a difficult, complicated and extensive theory behind the study, which is necessary to understand it, properly conduct it and properly evaluate the results obtained from it.

5.3.2 Proposed solution method

The difficulty of research resulting from a key moment that is difficult to capture can be solved by showing students a previously prepared demonstration film illustrating this moment during a live stream.

The difficulty of research resulting from the complicated theory and the necessary substantive basis behind the research can alternatively be solved by, for example:

- presenting the research and theory in a short, general way;
- a task given to students regarding prior (prior to laboratory classes) familiarisation, as part of their own work, with the theory related to a specific study.

The problem can be solved alternatively or in parallel by:

- providing the necessary explanations during lectures (moving the topic from laboratory classes to lectures);
- prior (e.g. during laboratory classes) instructing students to familiarise themselves with substantive issues related to a specific study that they will carry out as part of their own work.

5.4 Difficult freedom of movement of the teacher around the laboratory

5.4.1 Description, consequences of the occurrence

Some laboratory work and tests require the operator to move around various zones, areas and rooms located in the laboratory building. This may be dictated by the need to use various laboratory equipment and devices, or to transfer samples between different areas/devices.

Then the problem may turn out to be:

- risk of collision with parallel laboratory work, service work, supplies of laboratory equipment and materials, etc.;
- conducting "live" broadcasts while the presenter moves around the laboratory and performs parallel activities.

5.4.2 Proposed solution method

Issues related to difficulties in the teacher's free movement around the laboratory during "live" classes can be solved by:

- Prior agreement with the head of the laboratory on the schedule of various types of work, deliveries and research, as well as remote laboratory classes for students.
- Using a third party as the device operator transmitting an Internet audio-visual stream that follows the presenter around laboratory areas and rooms. This involves the need to:

- developing a scenario in advance so that the presenter and operator do not interfere with each other's transmission;
- ensuring that the operator will correctly, sufficiently (completely), and perform the "live" online audio-visual transmission - it cannot be a person unfamiliar with the method and sequence of work, location of samples, equipment and devices, research procedure, key moments laboratory work, the necessity and sometimes the need to convey the message in the form of a wide frame and close-ups of key elements, etc.

5.5 Difficult freedom for the teacher to perform laboratory work

5.5.1 Description, consequences of the occurrence

All laboratory work and tests shown by the teacher require the use of both hands. Due to this, the person conducting laboratory classes cannot also be the operator of a live Internet broadcast. The need for image stability, close-ups and wider frames precludes the installation of a device recording and transmitting the audio-visual stream on the person of the presenter. The need for the teacher to move around the zones, areas and rooms of the laboratory excludes the possibility of stationary placement of the device recording and transmitting the audio-visual stream (e.g. on a tripod).

5.5.2 Proposed solution method

Using a third person as an operator of a device transmitting an audio-visual stream, following the lecturer around the laboratory rooms, and taking appropriate shots. At the same time, it is necessary to:

- developing a scenario in advance so that the presenter and operator do not interfere with each other's transmission;
- ensuring that the operator will correctly, sufficiently (completely), and clearly perform the "live" online audio-visual transmission - it cannot be a person unfamiliar with the method and sequence of work, location of samples, equipment and devices, research procedure, key moments laboratory work, the necessity and sometimes the need to convey the message in the form of a wide frame and close-ups of key elements, etc.

5.6 Collision of laboratory classes with scheduled work carried out in the laboratory and its surroundings

5.6.1 Description, consequences of the occurrence

Laboratory classes may conflict with the scheduled work carried out by laboratory employees, and work carried out in its surroundings (service, repair, etc.). During remote classes, this may cause noise that prevents proper remote communication between the teacher and the student, difficult teacher movement around the laboratory and free use of research equipment and devices.

5.6.2 Proposed solution method

Issues related to the collision of laboratory classes during the live-stream with scheduled work carried out in the laboratory and its surroundings can be resolved by prior agreement with the

laboratory manager on the schedule of various types of work, deliveries and tests and the date of remote laboratory classes for students (live-stream).

5.7 Loss of electrical power in the laboratory

5.7.1 Description, consequences of the occurrence

Loss of electricity supply may be temporary, short-term or long-term, and may result from unexpected failures or planned works on the power grid. Loss of electrical power may affect:

- disconnection of the Internet transmission connection between the teacher and the student and subsequent re-establishment of the connection with all students is difficult;
- stopping the operation of laboratory devices and equipment (interruption of operation of some laboratory devices and equipment cannot be restored immediately, even due to a very short interruption in energy supply, and in the case of some tests, even the entire test must be repeated from the very beginning);
- turning off the lighting necessary for proper image transmission (visibility of the transmitted video stream).

5.7.2 Proposed solution method

We cannot predict the effects of a sudden interruption in the power supply resulting from sudden failures. The method to solve the problem is to equip the laboratory with appropriate power generators and current protection against a temporary or longer-term drop or loss of power in the power grid. However, not all laboratories have such systems, and their purchase and installation are expensive.

You can protect yourself against interruption of the Internet transmission connection resulting from the loss of power supply by using external modems and routers that are not connected to the general power grid and operate on their own battery power supply.

In the case of tests that cannot be restored after power is restored, you can, as a precaution, prepare demonstration films in advance that illustrate such tests and which will be made available to students earlier or only after the failure occurs.

In the event of planned interruptions in energy supply (e.g. as a result of network maintenance work), the date of remote laboratory classes should be adjusted in advance to this plan.

5.8 Loss/unstable/poor Internet connection in the laboratory

5.8.1 Description, consequences of the occurrence

Loss of Internet connection or its poor quality may be short-term (incidental) or longer and may occur in the case of voltage loss in the laboratory's power network, failure of network devices and university networks; staying in laboratory rooms where the Internet signal is weak (shielding phenomenon); staying near devices and equipment that may interfere with the Internet connection signal.

5.8.2 Proposed solution method

You can protect yourself against the loss of the Internet connection resulting from a power outage or various types of failure by using an off-campus data transmission system (Internet connection) with its own (battery) power supply.
The problem of signal fading or loss due to the nature of the room or the proximity of certain devices and equipment can be solved by displaying a demonstration film previously prepared in a given room/equipment in a live stream.

5.9 Insufficient quality of the transmitted audio track

5.9.1 Description, consequences of the occurrence

Insufficient quality of the transmitted image may make it difficult to receive and understand the course content or even make it impossible to conduct remote laboratory classes at all (the video track is, therefore, much more important than the audio track). It may result, for example, from:

- the inability of the image recorder to record various types of shots (wide-angle, narrow-angle, macro), often necessary for proper and complete depiction of the presented content;
- image recorder (camera) of insufficient quality;
- shaky image due to hand-held transmission; may prevent you from fully seeing important details; necessary especially when taking close-up shots - macro type;
- insufficient lighting of the room and equipment, workstation, sample or detail;
- flickering of the transmitted image as a result of the use of fluorescent lighting (Warning! It may, in some cases, cause an epileptic attack in the viewer).

5.9.2 Proposed solution method

Providing proper lighting in equipment and facilities rooms, workstations, samples, and details is one of the most important issues.

The displayed elements should preferably be illuminated with light with a neutral colour temperature, enabling the colours to be perceived as close to correct as possible.

Details, close-ups and details should be additionally illuminated due to the decrease in image brightness when recording this type of frame.

A diverse way of presenting class content in the form of different shots (wide-angle, narrow-angle, macro) can be ensured by equipping an appropriate image recorder (camera) with suitable good-quality optics.

The flickering of the transmitted image resulting from the use of fluorescent lighting can be effectively reduced by equipping an image recorder (camera) with a function that eliminates this effect - this may be a function such as Flickr Cancel, Flicker Reduction or another similar function. Another solution (the simplest) is to use the appropriate type of lighting (other than fluorescent).

A shaky image resulting from the operator holding the image recorder in his hand (especially in one hand) can be eliminated using an external gyroscopic image stabiliser during the live stream - e.g., a gimbal.

5.10 Temporary unavailability of laboratory devices and equipment

5.10.1 Description, consequences of the occurrence

Temporary unavailability of laboratory devices and equipment may result from sudden failures and incidental events from various types of work carried out in the laboratory (e.g. service, calibration, accreditation, repair and renovation); other…

5.10.2 Proposed solution method

Issues related to the collision of laboratory classes during the "live" broadcast with scheduled work carried out in the laboratory and its surroundings may be resolved by prior agreement with the head of the laboratory on the schedule of various types of work, deliveries and tests, as well as the date for the implementation of remote laboratory classes. For students (live Internet broadcast).

You can protect yourself against incidental events by preparing in advance (in reserve) a recording of entire laboratory classes and playing it back to students when unfavourable conditions in the laboratory occur that make the conventional form of "live" remote classes impossible.

5.11 Difficult communication with students due to other external reasons

5.11.1 Description, consequences of the occurrence

Difficult communication may result from poor quality of the Internet connection on the part of students (low-quality computer equipment, weak network signal, etc.).

5.11.2 Proposed solution method

The teacher cannot solve this problem. It is the responsibility of the listener (student) to ensure the proper quality of the connection or computer equipment necessary for correct and effective participation in remote classes.

6 SUMMARY

The methodology presented provides knowledge on preparing laboratory classes on Road Infrastructure Management – Road Pavement Management. The methodology presents intended effects; division and methodology of laboratory classes in terms of their types, forms and components; identifying various problems in organising classes and methods of dealing with them; necessary technical equipment and logistical support for managing and implementing laboratory classes; tips for the teacher, method of scheduling classes, order of presenting the content, etc.

The work includes various scenarios for conducting classes using materials prepared by the teachers, students of civil and transportation engineering or road authority staff at a national, local and regional level.