Fiber monitoring measurements in the digital space: development of moodle-based e-learning

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Abstract: The rapid development of digital technologies is fundamentally transforming the educational and measurement processes of higher education institutions. In addition to traditional laboratory practices, increasing emphasis is being placed on the digital processing, evaluation, and archiving of measurement results, which not only ensures more accurate data management but also provides a more flexible and accessible learning environment for students. The monitoring and maintenance of optical fiber networks is of paramount importance in modern telecommunications and data transmission systems, as these systems provide the basis for services that require high bandwidth and reliability. The aim of this thesis is to digitize and integrate the measurement process of a traditional fiber optic monitoring system designed by me into the university's e-learning framework, the Moodle platform. Our work includes detailed research using various domestic and foreign sources, which shows how technical education has been transformed in the digital space due to the COVID pandemic, followed by a presentation of how the fiber monitoring measurement processes I have developed can be transferred to an online environment, discussing in detail the steps of digitization, technical implementation, and the challenges involved.

Keywords: Fiber monitoring; Moodle; Digital space; E-learning; Education

1. The Digitization of Technical Education in Light of the Pandemic

The school closures caused by the COVID-19 pandemic have presented education systems around the world with unprecedented challenges. In the spring of 2020, due to the rapid spread of the pandemic, schools in most countries, including Hungary, closed overnight and switched to digital education. This sudden change fundamentally affected not only the learning process itself, but also the daily lives, social relationships, and mental health of students. [1]

School closures caused by the pandemic forced a digital transition in education worldwide in the spring of 2020, especially in technical and engineering training. Institutions and educators had to find alternative online solutions in a short period of time to maintain continuity of learning in the absence of physical presence. During this period, a number of digital tools and platforms became part of everyday technical education. Among the most important technical solutions were learning management systems (LMS) such as Moodle, Blackboard, Canvas, and Google Classroom, which provided a central interface for accessing materials, submitting assignments, completing tests, and direct teacher-student communication. [2] These platforms enabled teachers to share teaching materials in an organized and transparent manner, and students to work on assignments independently or in groups. Video conferencing tools such as Zoom, Microsoft Teams, Google Meet, and WebEx were used to deliver synchronous instruction, including lectures, consultations, and group lessons. These platforms supported in-class communication, presentation sharing, and interactive learning. The learning experience and student motivation were enhanced by various interactive teaching methods, such as the flipped classroom, gamification, online tests, quizzes, video teaching materials, and numerous educational podcasts. These solutions allowed students to work through the material at their own pace, while teachers continuously monitored their progress and intervened when necessary.

1.1.Replacement of laboratories

When the pandemic broke out, maintaining laboratory practices became one of the biggest challenges in technical higher education. In traditional laboratories, students come into direct contact with measuring instruments, perform experiments themselves, and receive immediate feedback on the accuracy of their measurements. However, school closures and mandatory distance learning eliminated this opportunity overnight, forcing higher education institutions to quickly find alternatives so that practical training could continue. Most institutions turned to online laboratories and simulation environments. [3] These digital platforms allowed students to perform measurements and experiments from home, using their own computers, which previously could only be done in a lab. Simulation software such as MATLAB, Simulink, and various electronic and optical simulators, which realistically modelled measurement processes, were widely used in technical education. One of the great advantages of such systems is that students can repeat measurements an unlimited number of times in a safe environment and try out various sources of error that would be harmful or costly in a real laboratory. Some institutions have gone further and created remotely controlled "remote lab systems". [4] In these solutions, students connected to real laboratory equipment via the Internet, which they could control through a software interface. Although this did not replicate the experience of physical presence, it did allow students to work with real instruments, collect data, and evaluate results while the laboratory was physically closed. Another common way of replacing laboratories was the use of detailed video presentations prepared by instructors, which was also implemented at Óbuda University. These recordings showed the measurement processes, instrument handling, and measurement evaluation step by step, often with explanations of typical errors or problems. The students worked through the material independently based on the videos, then discussed their questions and experiences in online consultations, and finally completed knowledge assessments related to the measurements. However, the introduction of online laboratories also brought with it a number of challenges. One of the biggest difficulties was that many measurements required special hardware or software that was not available to all students. For example, running simulations with high computational requirements required modern, high-performance computers, and obtaining software licenses could also be a problem. In addition, important manual skills that can be acquired during laboratory exercises, such as the physical handling of measuring instruments, assembly tasks, and precision adjustments, can only be developed to a limited extent in an online environment. A further problem was that students' motivation and activity levels could decline in the absence of face-to-face contact. [5] It was more difficult to maintain attention on online platforms, and there was no immediate feedback, which is one of the most important elements of practical training. Group work, joint experimentation, and opportunities to learn from each other were also limited, as these processes were less spontaneous in the online space. Replacing laboratory exercises with online alternatives was therefore a necessary solution during the pandemic, which in many cases successfully ensured the continuity of the learning process, but involved numerous compromises. Based on experience, the most effective approach may be a combination of digital and traditional, in-person laboratories: simulations and online tools can complement physical laboratory work well, but they cannot completely replace it. At the same time, the pandemic has accelerated the spread of digital teaching methods and highlighted that blended learning may be the most effective solution for technical education in the future.

1.2.Pandemic benefits in education

Following the COVID-19 pandemic, education has undergone significant changes worldwide, with one of the most striking being the widespread adoption of e-learning applications and digital learning platforms. While digital learning played a more complementary role before the pandemic, during the forced school closures, learning moved almost entirely online, and this experience has brought about lasting changes in educational practice. [6] The development of digital learning did not stop after the pandemic subsided: most educational institutions retained the proven e-learning tools, and alongside traditional classroom teaching, blended models combining online and face-to-face learning became increasingly widespread. The digital competence of teachers and students has improved significantly, as the creation of online teaching materials, the assessment of digital assignments, and even the data-driven monitoring of learning processes have become part of everyday educational activities. [7] The digital transition has had many positive outcomes: education has become more flexible, students have been able to progress at their own pace, access to teaching materials has become easier, and teachers have been given more opportunities for differentiated, personalized teaching. At the same time, digital education has also brought challenges to the surface, such as the digital divide – not all students had access to the right tools or a stable internet connection – and the motivational and social difficulties of online learning. [8] Based on the experiences of the pandemic, it has become clear that e-learning and digital learning tools will remain an integral part of education in the future. Artificial intelligence-based personalized learning systems, virtual and augmented reality applications, and data science tools have emerged in education, enabling educators to more effectively track and support student progress. The spread of blended and hybrid models allows education to be flexible, accessible, and personal at the same time, while also offering new learning experiences and methods through digital tools.

2. The Moodle Framework

Moodle (Modular Object-Oriented Dynamic Learning Environment) is one of today's most widely used open source learning management systems (LMS), used by thousands of educational institutions worldwide, including Óbuda University. The main goal of the platform is to provide a flexible, interactive, and customizable digital learning environment where teachers and students can work together effectively, share course materials, assign and grade assignments, and maintain continuous communication. During the COVID-19 pandemic, Moodle played a key role in ensuring the continuity of education, but based on experience, it has remained a key component of blended and hybrid learning models. [9] The platform allow users to track student activity, continuously update course materials, automate assessment and feedback, and develop the learning process in a data-driven way. Moodle is therefore not only an effective support for distance learning, but also for face-to-face and blended learning, which will remain a key part of both higher education and public education in the long term. On the following pages, we would like to describe the features and capabilities of the platform and present the interactive options that can be used to measure students' knowledge, so that readers can get a general idea of the uniqueness of the platform and its possibilities. The User Interface and Course Management the Moodle teacher user interface is transparent, modern, and specifically designed to support teaching processes. Teachers have full editing, administration, and evaluation rights for each course, allowing them to flexibly customize the entire content, participants, and operation of the courses. Since the aim of my thesis is to show how a previously manual assessment can be converted to a blended mode, I will present the teacher interface to readers, as this is the only way we can create the appropriate course and teaching.

2.1.Managing Courses

After logging in, instructors see a personalized interface where all the courses they teach are easily accessible. Switching between courses is simple, and the most important information is immediately visible on the main page: upcoming deadlines, new assignments, recent messages, or forum posts. This central control panel helps educators stay up to date with course events and respond quickly to student activity. When you enter a specific course, the interface is well-structured and divided into sections or thematic units. You can easily add new content or activities to each section. To do this, you first need to switch to edit mode, after which the "Add new activity or resource" option will appear in each topic. Here you can choose from different content types: documents, presentations, videos, online tests, quizzes, forums, or even interactive learning materials.

Moodle supports simple drag-and-drop file uploads, making uploading learning materials quick and easy. Each piece of content has detailed settings options: for example, you can specify that a given material should only be available during a certain period or only appear for a specific group. Adding students to the course is also not a complicated process. At many institutions (including Óbuda University) [10], students are automatically enrolled in the appropriate courses based on the study system, but of course, it is also possible to manually add new participants. To do this, open the "Participants" menu item for the course, where you can search for students by name or email address using the "Enrol users" function and add them to the course with a single click. Here, you can also set the role of the student (e.g., student, teaching assistant) in the course, and you can create groups to assign differentiated tasks or assessments to students.

The Moodle teaching interface allows you to customize the entire structure of the course. Teachers can decide whether to organize the curriculum on a weekly basis, in thematic units, or even in project-based sections. Individual sections can be easily rearranged, hidden, or highlighted, so the course always remains transparent for students. On the course home page, the editor can highlight the most important information, such as deadlines related to the course material, news, or the most important supporting materials, so that students can always find the content that is relevant to them. It is not necessary to notify students via Neptun messages in every case, as Moodle can also send system messages to users. [10]

2.2.Feedback and Review

In addition to content development, the Moodle interface also supports assessment and feedback. Teachers can provide detailed assessments for each assignment, test, or project submitted, which can be in the form of text feedback, a score, or even a grade based on a predefined assessment rubric. The system automatically notifies students of new assessments, making feedback extremely fast and efficient. Teachers also have access to detailed statistics, activity reports, and progress logs that show when, how much, and how well students have worked on the course. This makes it easy to identify if someone is falling behind and provide targeted assistance. Communication and collaboration also play a key role in the e-learning interface. Teachers can use forums, group or individual messaging, chat, as well as a calendar and notification system. These features allow the instructor to stay in constant contact with students, respond quickly to questions that arise, and organize group work or online meetings. With the support of group work, students can collaborate on specific projects, share materials with each other, and learn from each other.

2.3.Preparation of reports

Within the Moodle course, instructors have access to a number of reports that provide detailed feedback on student activity, progress, and performance. These reports not only help to monitor the learning process, but also support the instructor in identifying problems in a timely manner, providing targeted assistance, and obtaining an objective picture of how the course is functioning. One of the most important reports is the activity report, which shows how many times students have viewed each piece of course material, assignment, or interactive element. This allows instructors to easily identify which course materials were popular or less popular, as well as how many students completed each assignment. Individual activity reports allow the instructor to view the detailed activity, submitted assignments, forum posts, or test results of each student. This is particularly useful when evaluating a student's lagging or outstanding activity. The participation report shows who participated in a given activity (e.g., forum, test, assignment) and how often. The report can be filtered by role (e.g., students only, teachers only), group, and time period, allowing the instructor to quickly see who was active and who did not complete the required tasks. The system also allows you to send a message directly to those who, for example, have not yet submitted an assignment. The log report records every event in the course in detail: who did what and when (e.g., entered the course, opened a material, submitted an assignment, edited, etc.). Logs can be filtered by period, student, activity, or group, allowing instructors to easily search for specific issues, such as when a student attempted to complete a test or uploaded a file. Performance reports summarize student results: scores and feedback are assigned to each assessed assignment, test, or project, and the system automatically calculates the final grades based on these. Instructors can view the current results of all students and the weighting of each assignment on a single interface, and can modify scores or feedback if necessary. Of particular note is the course completion report, which shows whether students have fulfilled the requirements for the course (e.g., submission of all mandatory assignments, achievement of a minimum score). This report is especially useful for large courses or when you want to automatically issue a certificate or transcript at the end of the course. Based on feedback from reports, instructors can easily identify when a lesson or assignment is not motivating enough, too difficult, or too easy. Activity and participation data help them intervene in a timely manner, for example by sending personal messages, offering consultations, or providing additional support materials to students who are falling behind. In addition, the reports provide an objective basis for course development, curriculum revision, and continuous improvement of the learning process.

3. Digitization of Fiber Monitoring Measurements

The measurement, which was carried out in the previous semester, was an examination of a passive optical fiber monitoring system, the purpose of which was to identify, document, and evaluate errors, attenuations, and connection problems occurring in optical networks in practice. This measurement was carried out in the same way as traditional laboratory exercises, i.e., students worked in person in the laboratory with real equipment and used the faculty's standard docx based protocol. During the measurement, they were able to learn and practice the basic methods of optical fiber monitoring and troubleshooting, as well as the use of the most important measuring instruments. [11]

3.1. Digitization of Control Questions

Digitizing the assessment questions was one of the most important and innovative steps in the measurement process, fundamentally changing the way students are evaluated and receive feedback. The questions in traditional paper-based reports, which served to check measurement principles, the tools used, and practical experience, became interactive learning elements on the Moodle platform, providing immediate feedback and versatile assessment. My primary goal during digitization was to ensure that students did not simply "get through" the test questions, but experienced them as a real learning experience that promotes independent thinking, self-assessment, and the practical application of theoretical knowledge. To this end, I strove for variety in the compilation of questions, mixing question types, trying to incorporate gradual levels of difficulty, and ensuring that the questions were related to the specific steps of the measurement protocol so that students could reflect on their own knowledge at every stage of the measurement. The Moodle platform is also extremely easy to use because the system is highly flexible, easy to manage, and has a number of features that meet the basic requirements of modern digital assessment. The Moodle Test module allows questions to be assessed automatically or manually, students to receive immediate feedback on their answers, and teachers to compile detailed statistics, analyses, and learning paths. One of the biggest advantages of digitized test questions is precisely this immediate feedback: students know whether their answers are correct or incorrect as soon as they finish the test, and if the teacher has set it up, they can immediately read the explanation or the correct answer. This feature not only increases motivation to learn, but also facilitates quick self-assessment, immediate correction of mistakes, and a deeper understanding of the material. The wide range of question types available in Moodle allowed us to cover all important aspects of assessment-related control questions. Such as: multiple choice questions, true/false questions, matching questions, gap fill (short answer) questions, calculating questions, essay questions. When compiling the questions, we paid close attention to ensuring that the theoretical control questions included in the measurement report (e.g., "Why is OTDR measurement important after installation?" or "In what cases is VFL used?") were not just facts to be repeated, but also asked about measurement experiences, specific results and errors in the report, and even the interpretation of the measurement results. This allowed students to reflect not only on their theoretical knowledge but also on their practical measurement experience in their answers. The Moodle system allows the teachers to set the random order of questions, the number of attempts, the time limit, the scoring system, and the level of detail in the feedback, which further increases the security and objectivity of the tests and the independent work of the students. During the digitization process, I paid special attention to ensuring that the questions not only tested theoretical knowledge related to measurement, but also developed practical skills and problem-solving thinking. Each student has one attempt to take the test, after which they can begin to prepare the assessment report, which remains closed until then. The test is located under the assessment subheading, so students do not need to search for it, and there is no need to enter a password or meet any other conditions. The instructor does not need to check whether the test has been completed, as the report can only be submitted once the student has successfully completed the questionnaire. Therefore, if the report has been submitted, we can be sure that the student has been able to answer the theoretical questions.

3.2. Digitization of the measurement report

Our primary goal in digitizing measurement tasks was to replace the previously used docx paper-based reporting and evaluation with a modern, transparent, and student-friendly online system. We strove to make every step of the assessment process structured, uniform, and easy to follow, while allowing students to complete the entire report independently but with reliable guidance. One of the most important aspects of digitization was that, instead of manually uploading and editing documents and collecting reports with different appearances and contents, all measurement tasks could be submitted directly in the Moodle system, on an online test interface. This eliminated the need for students to edit separate documents and then upload or email them. Instead, each measurement step appeared as a predefined question in the test. This not only simplified the submission process, but also significantly sped up the evaluation and made it more transparent. I provided clear, uniform guidelines for each assignment on the Moodle platform. These common requirements were clearly displayed on the first page so that students were aware of the technical and content requirements for submission at the beginning of the assessment. For example, images could only be in JPG or PNG format, with a maximum size of 2 MB per image, and for each task, students had to briefly indicate whether the results were acceptable and document in detail any errors detected and the steps taken to correct them. The measurement tasks were designed so that each measurement step had a separate, specific question. We provided a detailed description of each task, including what to measure, the order in which the steps should be performed, and how to document the measurement results like in the first task, students had to identify breaks or connection faults in optical fibers using a VFL (Visual Fault Locator), following the measurement instructions step by step. To submit the task, they had to upload two images (of the instrument and the fiber being tested) and write a short text evaluation of their findings. Thanks to the structure of the Moodle test, we were able to specify exactly what format, content, and order the students had to submit their work in for each task. This greatly helped the reproducibility of the measurement process, the uniform evaluation of the results, and ensured that the students did not miss any important steps. The system automatically organized the uploaded images, texts, and calculations, making the evaluation faster, more transparent, and more objective for the instructors. Throughout the digitization process, we strove to ensure that students received specific, clear instructions for each measurement task (in addition to the main guidelines, the protocol is also available to students during the measurement) and that the submission process was not unnecessarily complicated or time-consuming. The advantage of the online system is that all students receive the same guidelines, submissions are standardized, and assessments are easily retrievable and documentable. This approach not only improves the quality and transparency of assessment, but also develops students' independence, digital skills, and assessment discipline.

Student Feedback

After completing the Moodle measurements, we had the opportunity to have students perform the measurements I had prepared under real laboratory conditions. The students performed the measurements individually as part of the laboratory course entitled Optical Network Technologies and Applications taught by the Department of Information Technology and Infocommunications. The measurements were completed in 3x45-minute intervals and the results were recorded in the Moodle report prepared for the measurement. The purpose of our questionnaire survey was to get an idea of what students thought about the formulation and interpretation of the tasks. In addition, we wanted to find out how well the students were able to apply what they had heard in the theoretical lecture when solving the 'fill-in' tasks and performing the practical measurements.

After completing the measurements, the students filled out a Moodle questionnaire prepared by us, in which we addressed the questions that were most important to us and formulated them in such a way as to ensure that the results obtained were as objectively accurate as possible. For this reason, we asked for most of the feedback in text format rather than numbers, in some cases with checkboxes and in most cases with text. The questionnaire took only 5 minutes to complete and was filled out completely anonymously. A total of 10 students completed the questionnaire (the total number of students enrolled in the course, as the subject is specific, so it is not possible to request more feedback during a semester) who completed the set of measurement tasks. In the rest of this chapter, I will present the results obtained for these questions. Our hypotheses:

- We assume that the students who performed the measurements were able to deepen their theoretical knowledge.
- We assume that the creation of online records made the work easier for students and made the tasks clearer.
- We assume that the measurement tasks I prepared were formulated with sufficient precision.
- We assume that the hybrid nature of the measurements made it easier for students to understand them.

Based on the responses received from students, it can be clearly concluded that the description of the measurement tasks was very easy to understand or easy to understand for everyone, and the majority of respondents rated the measurements as "very useful." Respondents unanimously indicated that there were no measurement subtasks that they found difficult, and everyone found the measurement system "easy to use." The feedback also shows that the measurements contributed significantly to the understanding of the curriculum: several respondents emphasized that it "helped a lot," "I understood completely," and "I got a coherent picture of how networks work." The majority of students did not make any suggestions for improvement; in fact, many emphasized that everything was concise, to the point, and understandable, so they could not change anything. Almost without exception, respondents said that their practical knowledge of optical networks had improved during the assessment, and that the digital submission system had also supported the learning process. Responses to the hypothetical theses:

The students who performed the measurements were able to deepen their theoretical knowledge:

Based on the responses, this hypothesis can be clearly confirmed, as everyone reported that the measurement tasks helped them understand the course material, and several even emphasized that the practical experience made the theory truly understandable.

The creation of online records facilitated the work and made the tasks clearer:

According to the students, the system was "easy to use," the submission process was transparent and did not pose any problems, thus supporting this thesis.

The measurement tasks were formulated with sufficient precision:

The feedback shows that everyone found the descriptions "very easy to understand" or "easy to understand" and there were no misunderstandings or difficulties, so the accuracy of the tasks can also be considered proven.

The hybrid (digital) measurement method facilitated understanding:

The majority of respondents emphasized that the digital system and the measurement tasks contributed significantly to the development of practical knowledge and understanding of the curriculum, thus confirming this assumption.

Conclusions

In our work, I presented in detail how technical higher education teaching practices have changed as a result of the COVID-19 pandemic. I explained the role that digital learning methods, e-learning platforms, and especially the Moodle system have played in distance learning and the digitization of laboratory measurements. I analysed the Moodle interface in detail: I discussed its structure, the user experience for teachers and students, the possibilities for course management, content uploading, evaluation, feedback, and reporting, as well as how the system supports modern online measurement and record-keeping processes. Based on my experiences during the COVID period, my goal was to completely digitize the previously paper-based, analog measurement reporting using a measurement method we developed and to create a clear, step-by-step online submission interface in the Moodle system. I designed the measurement tasks in such a way that I linked clear instructions, submission requirements, and evaluation criteria to each subtask, thereby helping students to work independently, yet safely and transparently. Moodle enabled students to document each step of the assessment process in a structured manner, with images and text explanations, while also making assessment easier and more objective for the teacher. Based on student feedback, the digitized measurement system proved successful in every respect: the tasks were clear, easy to follow, and easy to manage, submitting reports was not a problem, and the measurements truly contributed to deepening theoretical knowledge and developing practical skills. Students particularly emphasized that the digital system was transparent and user-friendly, and that all subtasks could be completed independently based on the measurement instructions.

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