NEW TEACHING AND LEARNING METHODS FOR THE POST-PANDEMIC TIME

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This material was funded by the European Commission within the Erasmus+ project
Applying some advanced technologies in teaching and research, in relation to air pollution
Project Code: 2021-1-RO01-KA220-HED-000030286

Funded by the European Union

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ISBN
978-625-399-053-4

Book Title
New Teaching And Learning Methods For The Post-Pandemic Time

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Publishing Coordinator
Yasin DİLMEN

Page and Cover Design
Akademisyen Dizgi Ünitesi

Publisher Certificate Number
47518

Printing and Binding
Vadi Matbaacılık

Bisac Code
EDU029000

DOI
10.37609/akya.2497

Kütüphane Kimlik Kartı
Library ID Card
Tınca Udrıstıoıu, Mihaela.
New Teaching And Learning Methods For The Post-Pandemic Time / Mihaela Tınca Udrıstıoıu, editörs: Zhelyazka Raykova, Janka Raganová Hasan Yıldızhan.
Ankara : Akademisyen Yayınevi Kitabevi, 2023.
140 page. : figure, table. ; 160x235 mm.
Includes Bibliography.
ISBN 9786253990534
1. Education.

GENERAL DISTRIBUTION
Akademisyen Kitabevi A.Ş.
Halk Sokak 5 / A Yenişehir / Ankara
Tel: 0312 431 16 33
siparis@akademisyen.com

www.akademisyen.com

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INTRODUCTION

Science, Technology, Engineering, and Mathematics (STEM) education, a form of interdisciplinary education, successfully applies competency-based learning to teaching the younger generation at all levels. Technical universities that train specialists in the STEM field make an essential contribution to promoting the development of human capacity and talent to improve young people's employability and ability to solve complex problems. The transformation of education is a continuous process. Technological advances, new concepts and challenges, and global situations such as the COVID-19 pandemic require educational models in the same rhythm of change and adaptation. These challenges need educators to be increasingly trained, open, receptive, and ready to face challenges through continuous learning. The 2020 pandemic has changed traditional educational methods. Also, technical and pedagogical innovations have evolved in reaction to the changes brought about by COVID-19.

A team of faculty from four universities - University of Craiova (UCv), Plovdiv University (PU), Matej Bel University Banská Bystrica (UMB), and Adana Alparslan Türkeş Science and Technology University (ATU) are working on the project „Applying some advanced technologies in teaching and research, in relation to air pollution." Part of the project activities relates to applying modern technologies to students' education, future engineers, and scientists. This book includes their study findings, opinions, and theories regarding using several cutting-edge technology and instructional strategies in the years leading up to and following the epidemic. The authors addressed topics like online-based pedagogical environments, online conferencing, and collaboration platforms in this book. Good practices described integrative, and research approaches and strategies in training future engineers and scientists are shared. The project team discusses some common challenges in learning practice during the COVID-19 pandemic. In recent years, technology development has greatly influenced the traditional course of the educational process in universities that prepare engineering majors and specialists in science. This impact was amplified during the pandemic as their embedding in the learning environment brought changes that helped us cope with the learning process in the pandemic environment. Every change is an opportunity for innovation.

The role of new technologies and their place in higher education created conditions for the innovative application of familiar approaches and methods. They created proper conditions for the distance form of education to be alternative and predominant. Their wide application allowed us to appreciate the good opportunities they offer us for more active involvement of our students during self-study in project activity. They have been conducting online training for a long time, bringing to educators' attention the need for access to electronic means for the quality conduct of the training and the need-to-know different educational platforms and new educational technologies. The pandemic brought unprecedented opportunities for teaching and learning. The educators realized that there was much to learn—to understand better uncertainty, be willing to take the risks of change, and appreciate new technologies' possibilities and importance.

This book shares good practices and some ideas of professors who teach students in engineering majors and physics from the four universities - UCv, PU, UMB, and ATU on how to use new technologies successfully in the educational process. In general, the experience of conducting training during the pandemic has shown that moving away from traditional forms and ways of working is not fatal for anyone. The future is seen as training - combining face-to-face training and electronic distance learning.

Chapter 1 describes the educational possibilities of some new technologies and approaches the role and place of some SMART technologies for training students in physics and technology. This chapter describes some of the applications of augmented reality in the education of future engineers and physicists/scientists achieved in educational practice. The authors present some didactic possibilities of artificial intelligence in training engineers and scientists and give special attention to the possibility of conducting experiments with remote access. Forming practical skills and competencies for experimental work is essential for future engineers and scientists. This chapter also describes learning technologies, such as hybrid and blended learning, which remain relevant in the post-pandemic era. Understanding the differences between these and knowing their advantages and disadvantages is helpful for educators when choosing their teaching style. Educators knew the flipped classroom technology before the pandemic. At that time, its place was mainly related to higher education, but its application as an approach was not widespread. The experience during the pandemic showed that implementing the flipped classroom as an approach has a place in all levels of education. Still, it has a special place in the future training of scientists and engineers and deserves educators' attention. The book's first chapter pays attention to this approach. Some questions about its application technology, and it describes the related activities of faculty and students.

The second chapter focuses on cloud technologies' place and role in higher education. Here is the experience of using the most popular educational platforms; on this basis, some of their educational possibilities are assessed. Applying new technologies in the learning process offered a new perspective on using known educational methods such as project-based learning, research, and integrative approaches.

The application of project-based learning is closely related to integrative and exploratory approaches to learning. Chapter 3 presents the role of integrative methods in future engineers' and scientists' training, as well as the experience of the faculty from the four universities, are described.

It is a well-known principle that universities teach by doing science. Understanding the role and place of student involvement in research is part of the student learning experience at the four universities. In Chapter 4, the authors examine some challenges posed by the form of training during the pandemic for the involvement of students in scientific research.

Despite the accumulated experience that has helped us in recent years to deal more calmly with conducting the educational process using modern technologies, we are aware that there are still challenges and unresolved problems ahead of us.

This book shares some of our ideas about the new challenges in educating STEM university students in the post-pandemic period. We believe modern educators should know how to organize the learning process remotely online and through a blending and hybrid form. Educators must be mindful of how to most effectively integrate new technologies with traditions in preparing future engineers and scientists to conduct quality education and be prepared for unforeseen situations.

CHAPTER 1

THE ROLE AND PLACE OF SOME SMART TECHNOLOGIES FOR TRAINING OF STUDENTS IN PHYSICS AND TECHNOLOGY

New digital technologies have undoubtedly entered education rapidly, forced by the events accompanying the COVID-19 pandemic. The transformations in education that they caused led to the consideration of new educational concepts. One such concept is SMART learning, seen as technologically enhanced education incorporating technological enhancements. SMART knowledge is based on electronic devices, creating new learning environments and technologies. Connecting modern technologies in a network allows them to share information or work together. SMART technologies can thus be more energy efficient and synchronized in their functions when coordinated and communicated. The collection of SMART technologies and their potential is often called the Internet of Things (IoT) (Zhu et al., 2016).

SMART technologies mean such integration of computer and telecommunication technologies, which allows automation, the adaptation of processes, and remote access to them. SMART technologies are primarily associated with artificial intelligence, augmented and virtual reality, IoT, remote experiments, and cloud technologies. SMART technologies might be media or tools for accessing educational content, applying various educational methods (exploratory, integrative, etc.), communication and collaboration, construction, expression and evaluation, and personalization of learning. Nobody can ignore their importance in the education system at all levels in the post-pandemic time.

Their knowledge by trainers and successful application in the learning process is a condition for modernization and improvement.

1.1. Artificial intelligence is a trend in STEM education (Zhelyazka Raykova, Janka Raganova)

Importance of Artificial Intelligence (AI)

The development of Information and Communications Technology (ICT) in recent years has led to the creation of AI, which is now part of our daily lives. AI is changing how we search for information, communicate, and behave. This "technology is continuously updated and widely used in various fields" (Pannu, 2015). In the development process, more and more researchers pay attention to the importance of this technology for education. In the context of the COVID-19 pandemic, all educational institutions used learning management systems (LMS) such as Moodle, Google, Microsoft Teams, etc. The number of active users of massive open courses (MOOCs) for online learning, such as Coursera.com, is getting bigger, which shows that society appreciates e- and distance learning methodologies more and more. At the same time, we observe applications of the latest advances in virtual reality (VR), augmented reality (AR), and artificial intelligence (AI) and their application in teaching and learning. Applied robots also enter practice, allowing learners to work with their teachers or colleagues (chatbots, cobots) (Chassignol et al., 2018).

The Stanford University "AI Report" for 2021 presents that in 2020, one in every five computer science students who graduated with Ph.D. degrees specialized in AI/ML (Machine Learning) in the USA, the most popular specialty in the past decade. Also, the same report shows: "An AI Index survey conducted in 2020 suggests that the world's top universities have increased their investment in AI education over the past four years. The number of courses that teach students the skills necessary to build or deploy a practical AI model on the undergraduate and graduate levels has increased by 102.9 % and 41.7 % during the last four academic years."

Most specialized AI academic offerings in the European Union are at the master's level. "Robotics and automation" is the most frequently taught course in the technical bachelor's and master's programs. At the same time, Machine Learning (ML) dominates in the specialized short courses (Index Report 2021, Artificial Intelligence Stanford University).

A 2021 report by UNESCO, which is a guide for policymakers in education, assessed the importance of AI with the statement: "Only in the last five years, due to some remarkable successes and their disruptive potential, artificial intelligence (AI) has moved out of the backwaters." of academic research to the fore in public discussions, including those at the UN level. In many countries, artificial intelligence is "pervasive in everyday life, from personal smartphone assistants to customer support chatbots, from entertainment recommendations to crime predictions, and facial recognition to medical diagnoses" (Miao, F. Holmes, W. Huang, R., Zhang, H. 2021). It is indeed evident, as noted by the United Nations Educational, Scientific and Cultural Organization (UNESCO), that "AI has permeated various sectors of society, particularly in the education sector, as discussed, for example, instruction or teaching methods, approaches, and tools" (UNESCO, 2019).

AI offers the possibility of using a vast resource of knowledge that can be adequately structured and used in the learning process. They are ways to individualize and personalize learning and can support designing and implementing curricula. AI techniques affect the following areas - deep learning, data mining, and solving complex problems. Intelligent learning systems (ITS) represent a potential integrated teaching tool for personalizing formal education using thoughtful guidance and criticism. "AI has been widely used in education and has shown significant advantages in an application that profoundly impacts the instruction process and classroom administration" (Chassignol, 2018).

The use of AI algorithms and systems in teaching and learning is growing in popularity yearly. A reference to the number of articles published on the topics "AI" and "Education" from Web of Science and Google Scholar published in 2015-2019 shows that they represent 70 % of all indexed documents (Chen et al., 2020). It is shown in the work of Guo et al., 2021, that in recent years, research on artificial intelligence (AI) applications in education (AIED) has significantly increased between 2013 and 2019. The research done is on 1173 relevant publications collected from the databases of the Web of Science Core Collection (Expanded and the Social Science Citation Index). The number of citations of AI-related articles grew exponentially from 4 in 1986 to 2,714 in 2019. The same study identifies research trends in this field (AIED). They are predominantly multidisciplinary, integrating modern achievements in computer science, education, psychology and engineering, neuroscience, and pedagogy (Guo et al., 2021). According to the study by Sharma et al. (2019), an opportunity for a sizable change in numerous facets of education exists with the employment of AI in education.

All these convince us of the relevance of the problem of the application of AI in education. AI enters the practice of the universities that participate in the ERASMUS+ project *Applying some advanced technologies in teaching and research in relation to air pollution* and defining the latest trends in educational technologies.

Definitions of AI. The authors did not find a generally accepted definition of AI in the literature. The boundaries and scope of this concept are vast and variable. The textbook "Artificial Intelligence, Human Rights, Democracy and the Rule of Law" published by the Alan Turing Institute of the United Kingdom, based on the position of the Council of Europe, Ad Hoc Committee on Artificial Intelligence (CAHAI) https://www.coe.int/en/web/artificial-intelligence/cahai) adopts the following definition: "AI systems are algorithmic models that perform cognitive or perceptual functions in the world previously reserved for human beings to think, judge, and reason." Algorithmic models called artificial intelligence (AI) systems perform cognitive or perceptual tasks in the real world that were previously performed only by thinking, judging, and reasoning human beings (Leslie et al., 2021).

A definition of AI given by UNICEF, agreed by the Organization for Economic Co-operation and Development (OECD), is as follows: "AI refers to machine-based systems that can, given a set of human-defined objectives, make predictions, recommendations, or decisions that influence real or virtual environments. AI systems interact with us and act on our environment directly or indirectly. Often, they appear to operate autonomously and can adapt their behavior by learning about the context" (OECD, 2021).

The term *"Artificial Intelligence"* was initially used at a seminar at Dartmouth College in 1956. AI researchers have been interested in two parallel approaches since AI's earliest days. The first, the so-called *"symboli"* AI approach, focuses on encoding the principles of human reasoning and the knowledge of experts, resulting in "expert systems." This approach is known as a *"rule-based"* or *"good old-fashioned AI"* (GOFAI). The second one is also based on the structure of the human brain (neural networks), which processes and draws conclusions based on large amounts of data. This approach, also called connected artificial neural network (ANN)-like, is one of several data-driven approaches (such as Support

Vector Machine (SVM), Bayesian networks (network models), and decision trees) that are known as Machine Learning (ML).

At the beginning of the 21st century, thanks to faster processors and the availability of vast amounts of data (mainly obtained from the Internet), ML became a dominant approach in AI. ML is usually associated with automatic translation between languages through translation or image recognition applications. ML is considered a subset of AI. In AI, the use of data serves to build a model, which is subsequently upgraded or not. AI uses ML data for its development. There are still many AI applications that do not use ML. (Miao et al., 2021). AI should not be seen as a combination of purely technical terms but as something constructed from complex social processes (Eynon and Young, 2021). In other words, one has considered human and technological dimensions when discussing AI.

AI is "the ability of machines to adapt to new situations, compare with emerging conditions, solve problems, answer questions, plan a device, and perform various other functions that require some level of intelligence" observed in humans (Coppin, 2021). Another definition given by Whitby (2008) sees AI as the study of the behavior and intelligence of animals and humans, and machines in an attempt to create similar behavior through computers and related technologies. According to Wang et al. 2015, "Artificial Intelligence is that activity devoted to making machines intelligent, and intelligence is that quality which enables an entity to function appropriately and predictably in its environment."

Another critical definition of this new technology presented: (Ma et al., 2014): AI is "the area of computer science devoted to solving cognitive problems often associated with human intelligence, such as learning, problem-solving, and pattern recognition." AI is "the theory and development of computer systems capable of performing tasks that would normally require a human intelligence, such as visual perception, speech recognition, decision making and translation between languages."

Chassignol et al. provide another two-pronged definition and description of AI. They define AI as a field of computer science study aiming to solve various cognitive problems commonly associated with human intelligence, such as learning, problem-solving, pattern recognition, and subsequent adaptation. The understanding of Chassignol et al. for AI is that it guides the development and use of computer systems with the capabilities of human beings "to perform tasks that require human intelligence, including visual perception, speech recognition, decision-making, and translation between languages" (Chassignol et al., 2018). Other scholars defining AI bring almost similar elements or characteristics of AI. Sharma et al. define AI as machines that can approximate human reasoning.

Pokrivcakova claims that artificial intelligence (AI) results from decades of research and development that involved the collaboration of system designers, data scientists, product designers, statisticians, linguists, cognitivists, psychologists, educational experts, and many others. This collaboration aimed to create educational systems with a certain level of intelligence and the capacity to perform various functions, including assisting teachers and learners in developing their knowledge and flexible skills for multiple careers. Also, according to her, AI uses enhanced "capabilities of programs and software, such as algorithmic machine learning, which allows machines to perform various tasks that require human intelligence and adapt to the immediate environment" (Pokrivcakova, 2019).

Therefore, AI can do more than standard computers and related functions in education. AI is replacing the conventional understanding of the various technological applications in education, web-based, online, distance, and computer-assisted teaching and learning. In agreement, Pokrivcakova noted that AI in education takes the form of intelligent systems with adaptive capabilities. These principles and characteristics of systems allow AI to perform a wide range of tasks traditionally or conventionally performed by instructors while enhancing students' learning experience by teaching students and personalizing learning according to student expectations and needs.

Wartman et al. have similar views on AI and define "artificial intelligence as the ability of computers and machines to imitate human cognition and actions." Recently, AI and machine learning have been applied to mobile devices. It is mainly related to improving the quality of computing and creating opportunities for new applications, such as facial unlocking, speech recognition, translation of some (non-machine) language, and virtual reality. The technical development of AI in mobile devices takes mobile education to a higher level, which provides convenience by aiding learning (Chen et al., 2020).

Timms postulates that Artificial Intelligence in Education (AIED) is not just computers or desktop computers and other computing applications as commonly understood. It focuses on understanding the use of AI through embedded computing systems, such as in SMART classrooms and cobots (Timms, 2016).

Chassignol et al. note that "AI in education has taken the form of computers and related technologies, such as the Internet and the World Wide Web." According to them, AI in education is moving from ordinary computers to embedded intelligent systems, such as robots or fellow robots (cobots) that work with instructors or trainers or independently to perform teacher-like functions. Chassignol et al. highlight AI's broad application in various fields, including content development, teaching methods, student assessment, and teacher-student communication. According to them, AI is useful in curriculum development and content customization, teaching and pedagogical approaches, evaluation, and communication exchange between educators and students. They also present examples of different AI platforms and applications, such as Interactive Learning Environments (ILE), which manage, and provide feedback and exchange between educators and students. Also, AI includes intelligent learning systems, such as ACTIVE Math, MATHia, Why2Atlas, Viper, and Comet. All these learning systems are used at different levels of the education system by instructors on various subjects. They are widely used in learning assessments to evaluate and improve pedagogical tools.

Sharma et al. observe in education that AI takes the form of adaptive learning systems, intelligent learning systems, and other systems that improve the quality of administrative processes, instruction, and learning.

Mikropoulos and Natsis, in their paper, describe another aspect of AI in instruction, virtual reality (VR) and three-dimensional (3-D) technology. They noted that VR offers enormous opportunities for the learning process, integrating "simulation and 3-D technology and providing learners with an option for experiential learning" (Mikropoulos & Natsis, 2011). Summarizing the definitions of artificial intelligence mentioned above, we assume that it is related to the development of computing machines that have some level of intelligence and can perform human functions such as learning, decision-making, and adapting to the environment. This feature is the crucial characteristic of AI that determines its application in education - to exhibit some levels of intelligence and carry out various tasks and capacities that call for human ability. AI is a culmination of computers related to computer technology, machines, innovation, and ICT.

AI Impact on Education (AIED). The scientific community is actively studying the impact of AI on education. According to Chassignol et al., AI finds application in educational institutions in various ways, organized into three areas: (1) automation of administrative processes and tasks, (2) activities related to teaching (curriculum and content development, instructions, etc.), and (3) activities related to learning. This team also adds that another vital AI option tied to the application of AI in education concerns overcoming the physical barriers posed by national and international borders, brought about by the fact that learning resources are on the Internet and the World Wide Web. Online learning or web-based learning platforms allows it to be accessible to every citizen of the world using the Internet. Using other aspects of AI, such as language translation tools, enables student learners to learn best within the context of their abilities and preferences (Chassignol et al., 2018).

Holmes et al. organized the connections between AI and education (AI&ED) under four headings: (1)" Learning with AI," (2) "Using AI to learn about learning," (3) "Learning about AI," and (4) "Preparing for AI" (Holmes et al., 2019). According to Miao & Holmes, the study of AI is related to two dimensions - the technological dimension of AI and human (humanitarian) modification of AI (Miao& Holmes (2021). In addition to AI-related techniques, technologies, and applications, preparing for the use of AI includes knowledge that prepares users and all citizens for the potential effects of AI on their quality of life. People must understand issues like AI's ethics, data bias, and invasion of personal space. These features define "the human dimension in AI literacy" (Holmes et al., 2022).

To describe the application of AI in education, we have to define and systematize the technical aspects of this technology. Yuskovychzhukovska et al. systemize such as following:

Cognitive services. These AI products are capable of carrying out tasks that were previously limited to humans. Computer vision, machine learning, natural language processing, language recognition, and robots are a few examples of cognitive technology. Developers have classified Microsoft's cognitive services into four groups after analyzing their collection.

C1."Vision" includes AI technologies for image and video content recognition. Examples of such application programming interfaces (APIs) are Computer Vision, Emotion, Face, Video, and Content Moderators.

C2."Speech Recognition" involves understanding and synthesizing oral speech and recognizing people by voice. Such APIs include Custom Speech, Speaker Recognition, and Bing Speech API.

C3."Natural language processing" involves understanding, word processing, and "prediction" of what a person expects. Such APIs include Bing Spell Check, Language Understanding, Linguistic Analysis, Text Analytics, and Web Language Model.

C4."Knowledge" aims to add meaning to the text and combine it with other general definitions and concepts. Such ARIs include Academic Knowledge, Entity Linking, QnA Maker, and Language Exploration.

Virtual, mixed, and Augmented Reality make the learning process more exciting. Cheaper versions of these technologies will eventually replace textbooks and move the learning process outside of the classroom, according to experts in educational technology. AI will implement these technologies, but AI will also evaluate their efficacy and maximize the advantages they may offer.

Internet of things and peripheral computing. Currently, there are more devices than humans, and researchers predict that by 2025, the number of such devices will exceed 40 billion (The Growth in Connected IoT Devices, 2019). Educational institutions already use a variety of Applications of AI. Cloud computing may not always meet the required response time requirements. IoT requires high bandwidth, minimal latency, and reliability, so peripheral computing is essential. There is no need to send data for processing to the cloud storage - data processing is even faster.

Metacognitive scaffolding aids the student only when necessary, gradually reducing or minimizing the teacher's intervention as the student's competence increases. AI in education allows for determining when and in what applicants need help. Also, AI monitors when to increase or decrease the assistance provided during the educational process. Applicants benefit from their training findings; they become the primary users of AI technologies and services, not just data subjects.

Personalization and individualization of the educational process. AI can implement personalized and individualized learning, obtaining vast amounts of data and formulating conclusions that might be useful to develop an academic trajectory that considers students' needs and abilities.

AI-assisted learning primarily includes innovative virtual learning and data analysis and prediction. Table 1 presents the main scenarios of AI applications related to supporting relevant technologies (Chen et al., 2020).

TABLE 1. AI learning scenarios and technologies (Chen et al., 2020)

Scenarios of AI in Education	Corresponding technology
Assessment of students and schools/ universities	Adaptive learning methods and methods for assessment, personalized approach, academic analytics
Grading and evaluation of papers and exams	Image recognition, computer vision, prediction systems
Personalized intelligent teaching	Data mining, mind maps, intelligent teaching system, learning analytics
SMART school	Face recognition, speech recognition, virtual labs, AR, VR, hearing, and sensing technologies
Online and mobile remote education	Edge computing, virtual personalized assistants, real-time analysis

Intelligent educational systems provide instructors and learners with timely, personalized instruction and feedback. They are designed to improve the quality and effectiveness of learning through multiple computing technologies, especially technologies related to machine learning with statistical models and cognitive learning theory (Kahraman et al., 2010).

As an educational model and subsystem of AI, machine learning (ML) mean the discovery of formed knowledge, the process of analysis based on collected data from a sample, which generates models and structures knowledge. For example, ML can help educators to create recommendations for students when choosing different disciplines or majors. Also, instructors can understand how students are learning a concept. It is essential when evaluating students in exams. ML includes techniques such as decision tree creation, inductive logic programming, clustering, Bayesian networks, and more.

According to the assessment of the application of AI in education and as outlined in the UNESCO report, AI might promote better access to learning by removing “barriers to learning, automating management and administrative functions in academic institutions, and optimizing instruction and learning.

Also, AI promotes practical or evidence-based solutions and initiatives in education." (UNESCO, 2021).

As a virtual platform, AI can create a better professional environment for instructors and learners. AI can be used as an assessment tool for assessment and exams and free up the teacher's time. Additionally, it helps students navigate the different content pathways and customize learning according to their strengths and weaknesses.

Table 2. points to the various AI functions that can work in educational scenarios of administration, instruction, and learning. Detailed findings from the application of AI in education are summarized and discussed below.

TABLE 2 The Functions AI Provides in Educational Scenarios (Chen et al., 2020)

	The work Al can do in education
Administration	• Speed up administrative procedures that take up a lot of an instructor's time, such marking tests and giving feedback. • Recognize students' preferred learning methods and styles to assist them in creating individualized lesson plans. • Help instructors with data-driven projects and decision support. • Work with students promptly and directly while providing feedback.
Instruction	• Anticipate the likelihood of a student dropping out and how well they perform above expectations on assignments and activities. • Examine the syllabus and course material to propose taylored content. • Encourage collaboration by allowing instruction to extend beyond the classroom and into higher education. • Based on the statistics, adjust the teaching strategies for each student. • Assist teachers in developing individualized learning programs for each student.
Learning	• Identify students' learning weaknesses and deal with them early in the educational process. • Customize the university course selection for students. • Predict each student's career route by collecting study data. • Detect the students' learning states and use an intelligent, adaptive intervention.

We assume that the use of AI-driven tools can be in the following three directions:

1. Using AI to *support administrative systems* (e.g., recruiting, scheduling, and training management);
2. Using AI to support teaching directly (intelligent preparation of learning materials, intelligent learning systems, dialogue-based learning systems, exploratory learning environments, automatic writing assessment, chatbots, cobots) and AI to support learners with disabilities;
3. Using AI to *support learning* is based on automation that involves analyzing data through various analytical techniques. This data track learners' learning progression and how they do so. The goal is to support students in learning and plan their future development.

Using AI for learning also includes increasing the AI knowledge and skills of learners of all ages (i.e., primary, secondary to tertiary) and their educators, covering AI techniques (e.g., ML) and AI technologies (e.g., Natural Language Processing) and others (Miao & Holmes, 2021).

AI in Educational Administration. One of the areas in education affected by AI is the performance of various administrative tasks in the educational process, such as assigning homework, reviewing papers, grading student work, and providing feedback to students. According to Sharma et al., these administrative functions of AI in education are particularly relevant in online learning, where institutional and organizational services are delivered more efficiently through AI (Sharma et al., 2019).

Specific educational platforms, PMLs, have built-in features facilitating student assessment and feedback for continuous improvement. Other programs such as Grammarly, Ecree, PaperRater, and TurnItIn also provide opportunities to perform various administrative functions, including plagiarism checking, grading, and grading, and giving feedback to students on areas for improvement. Thus, AI reduces the documentation and workload of educators in the performance of various administrative functions, thereby providing them with conditions to concentrate on teaching - selection of learning resources following the curriculum, etc. (Sharma et al., 2019). AI has improved efficiency in performing administrative tasks such as reviewing student work, grading, and providing feedback on assignments through automation using web-based platforms or computer programs.

Rus et al. said that "intelligent instructional systems (ITS) perform a wide range of functions, including assessing and providing feedback to students on their work" (Rus et al., 2013). ITS instructors (such as TurnItIn and Ecree), he says, provide guidance and instruction to help students excel in their studies.

Data mining of the learning process in the application of AI is associated with generating systematic and automated learner responses. For example, educators can analyze learner demographics and grade data from several written assignments to predict a student's future performance and warn of the possibility of dropping out. Furthermore, data mining becomes a powerful tool for improving the quality of the learning process, leading to a better understanding of learners' educational settings and even interpersonal relationships.

AI in teaching. Teaching represents another critical area where AI might be helpful. AI has made it easier to create and deploy systems that are valuable pedagogical tools. These tools have fostered an improved quality of learning.

Timms discusses another application of AI as a pedagogical tool or learning platform *(MLP)*. Simulation-based instruction involving multiple technologies, such as virtual reality, demonstrates or displays concepts to students or hands-on demonstration of materials, providing students with experiential or hands-on learning. He highlights that another critical form of application of "AI in education is the development and use of robots as assistants" to educators and colleagues (cobots/chatbots) for advanced learning, such as teaching students in word pronunciation and reading (Timms, 2016).

Gamification, i.e., the use of educational game applications related to VR and 3-D technologies, can also be considered a way of applying AI for educational purposes, significantly benefiting the quality of learning (Kiesler et al., 2011, Le et al., 2013). *Combining personalized learning* methods with gamification techniques gives a higher education rate. In particular, gamification elements such as ranking and points can help record student progress and solve the problem of balancing students' speed of understanding new academic material.

Computer Assisted Language Learning (CALL) provides students with personalized instruction, writing, and translation assistants in language learning. An example of offering foreign language training is the Duolingo app https://builtin.com/company/ Duolingo. It is a free language learning app incorporating machine learning into its technology to help language learners. Data is collected from each answer and fed into Duolingo's statistical model, which predicts how long each user will remember a particular word before needing refresher exercises. As a result, Duolingo knows when to ping that person with a suggestion to retry specific tasks. The program also includes game moments that create a sense of competition.

Amazon AWS https://builtin.com/company/amazon-web-services offers free ML services and products like Amazon SageMaker to help developers and data scientists build, train and deploy ML models. AWS also provides Amazon Rekognition, which uses machine learning to identify objects, text, people, and activities in images and videos.

Other studies approached the concept of applying elements of *Virtual Reality* as an element of AI in education. For example, Wartman and Combs highlight the use of AI in virtual reality and simulation in medical education related to conducting surgical operations, anatomy exercises, etc.

The post-pandemic time has also brought considerable development in digital technologies. Advanced technologies, such as AI, ML, neural networks, etc., have found their use in various research areas and have been continuously implemented into curricula at many university study programs.

Here we can point out some *examples* of the use of advanced technologies at the Faculty of Natural Sciences, UMB. The Department of Computer Science incorporates those technologies into educational practice. Students of Applied Informatics gain an understanding of those technologies. The students learn to develop applications of advanced technologies for training in various areas. For example, as a result of a student bachelor's thesis, a set of virtual reality applications was developed that was successfully used in treating phobias (Horváthová et al., 2016).

Such student projects usually require an interdisciplinary collaboration with researchers or faculty of the relevant science branch. The applications initially developed for research are implemented into teaching the given science topic.

Other applications are being developed directly by academic staff members. As an example, we can mention the research of A. Michalikova and M. Vagač (2015). They have developed a method to automatically detect a tire tread in provided image from a given database.

Special attention is given to the development of applications directly useable in education. We will introduce four examples of such application of advanced technologies within science education at the Faculty of Natural Sciences UMB. Three represent machine learning in various branches of chemistry; one is an example used by biology students.

Molecular modeling using the machine learning approach. Molecular modeling is a theoretical approach where computers build atomic models of the structures of chemical substances or materials. Subsequently, selected calculations are carried out for the momodeledtructures, either electronic-structural based on the Schrodinger equation or simpler and computationally much faster, based on the principle of interatomic interaction potentials (hereinafter referred to as potentials).

They are the interatomic interaction potentials that open up the space for the entry of neural networks. A characteristic feature of the potentials is that they must be parametrized for a specific chemical system (or a set of systems), described by more accurate electron-structure methods, most often by the density functional method. The Department of Chemistry uses software (see https://www.scm.com/doc/MLPotential/index.html) to parameterize potentials using machine learning. The potential generated in this way will also serve in the teaching process within the course Molecular Modelling, taught at the Department of Chemistry of UMB (Iliaš, 2022).

Identification of cannabinoids with the help of machine learning. Various ways of identification of drugs, including new synthetic cannabinoids, form a part of the curricula of the Forensic and Criminalistic Chemistry study program. Students built the neural network models as a part of the diploma thesis that can identify cannabinoids. The developed neural network can learn from the pictures of the structure of cannabinoids and non-cannabinoids and classifies the substances into those two categories. Students took the input data from the Cayman Chemicals database. The neural network has proved to be an effective tool for identifying forbidden substances among many freely available substances. For Forensic and Criminalistic Chemistry students, the developed neural network also represents a working example of how machine learning can be used in their future practice (Kotočová, 2021).

Identification of dangerous situations in chemistry labs. During the pandemic, researchers or students must work in laboratories in isolation from other staff or students. It has caused a lot of problems concerning possible safety risks. In the case of a dangerous situation in the laboratory, nobody could help the student when they worked lonely. Students developed a new application of machine learning to minimize the risk of a dangerous situation in the chemistry lab. It will learn to identify a danger from the face of a student who is in a complex case. The system will then "call for help" (Budzák, 2022).

Identification of fungi by using fuzzy interference system. During their study, biology students develop an understanding of species classification principles and apply their general theoretical knowledge to identify unknown species. The course Diversity and Phylogeny of Protists, algae, and Fungi introduces an application of advanced technologies in this area besides traditional approaches to species classification. Students get familiar with an original method of identifying fungi developed in cooperation with researchers from the Departments of Computer Science and Biology of the Faculty of Natural Sciences, UMB. The technique used a fuzzy interference system of Sugeno type. Faculty and students successfully tested this technique to determine central European Ganoderma species. (Michalíková, et al., 2021).

Incorporating Augmented Reality is also a tool to impact AI in the teaching and learning process. The next chapter is devoted to this topic.

Pokrivcakova highlights the pedagogical possibilities of integrating "AI into computer programs and the development and use of chatbots or online computer-based robots with conversational and dialogic capabilities to answer routine student inquiries" and, in some cases, distribute learning materials (Pokrivcakova, 2019).

According to Rus et al., the development of conversational and dialogic intelligent learning systems (ITS) has aided in the realization of teaching efficacy. These systems are combined with animated conversational agents in the form of chatbots or cobots.

AI provides improved course content delivery, from the curriculum development phase to the actual delivery of content or instruction, even more so in online and web-based learning platforms. Thus, there is a correspondence between the curriculum and the specific needs and abilities of the learner. This correspondence ensures the personalization of learning. Programs such as DeepTutor and AutoTutor, as discussed by Rus et al., are learner-centric programs that promote personalization and personalized content according to learner capabilities and needs, enhancing the learner experience and promoting the achievement of learning objectives. Some studies highlight the role of technology in AI to promote academic integrity, the use of plagiarism and proctoring checks, and online monitoring of student activities on platforms such as Grammarly, TurnItIn, and White Smoke, among others (Sutton, 2013).

AI in learning. Learning is an integral part of education and there are various ways in which AI has been adopted and implemented or used to enhance the quality of learning.

We believe that they relate to the following aspects:

- the customization (of the curricula and content following the needs and abilities of the learners)
- turning learning into a more engaging and experiential process and stimulating interest in learning (VR, AR, gamification, etc.)
- by providing broader access to training through online and web-based platforms.

AI in education can improve independent (personalized) learning conditions based on learner behavior data collected during the learning process. This data is then analyzed to assess how knowledge has been mastered – resulting in a "knowledge map." A relationship can also be established between learning outcomes and various factors that influence it, such as learning resources, learning content structure, teaching methods, etc. (Nunn et al., 2016). Knowing these maps of learners' knowledge allows trainers (instructors) to adapt their teaching strategies and actions, assuming that this would help to offer appropriate assistance to learners in need.

AI offers such assistance based on built-in options based on different *learning models*. The user interface allows learners to present themselves through multiple input media – voice, input, symbols, clicking and renders the processed results through text, figures, tables, etc. The advanced human-machine interface provides AI-related features such as speech interaction, recognition, and learner emotion detection.

One of the essential applications is that AI based on data mining can achieve personalized learning, where students do their knowledge at their own pace and decide on their AI-assisted *learning method*. Thus, learners can choose to study what they are interested in, and the instructors adapt the course and the teaching methods according to the student's interests.

Some platforms will encourage the personalization and customization of content and thus promote the absorption and retention of information, improving the student's learning experience. For example, an app like KNEWTON makes real-time recommendations for students based on deciphered learning style, as added by technology using machine learning algorithms, and subsequently customizes learning materials or content found on learner needs. Other platforms with similar capabilities include CEREGO, Immersive Reader, and CALL, which, together with other media, can potentially improve learners' learning experience at all levels of the education system, from early childhood education to undergraduate and graduate levels. Pokrivcakova also noted that integrating AI and using chatbots improves students' learning experience, as they use the ML algorithm and deliver content customized to their learning needs and abilities.

AI significantly impacts learning by applying and using *simulation-based learning* and intelligent training systems (ITS). Virtual Reality and simulation promote better student learning and prepare them for the coming new age of widespread application of AI in the industry (Mikropoulos & Natsis, 2011).

Another application of AI to promote learner engagement in the learning process is the use of AIWBES. This application adapts and generates learning content according to learner needs based on understanding their behavior. It adjusts accordingly by generating content appropriate to learner needs, age, physiology and psychology characteristics, and properties. In this way, students receive the most effective and accessible learning that will stimulate research ability and the ability to solve everyday problems.

Other benefits of AI and its effect on learning quality have been highlighted in other studies focusing on web-based platforms. Kahraman discusses important principles or "components of AIWBES, such as adaptive hypermedia, information filtering, class observation, and collaborative learning, among others, noting that they promote collaboration, interactions, and learning among students" (Kahraman et al., 2010).

The impact of AI on learning relates to using AI to promote *academic integrity* and improve understanding using *review and writing aids* (TurnItIn, Write-to-Learn tools). However, other studies have highlighted AI's possible harmful or adverse effects on learning. Crowe et al. noted in their research that AI might enable plagiarism and threaten academic integrity by facilitating or allowing students to use off-the-shelf resources for reports and to generate texts (Crowe et al., 2017).

In the topic of the impact of AI on learning, it is also necessary to touch on the issue of the learning of AI by students, educators, and other users. Miao &

Holmes proposes that all citizens should be encouraged and supported to achieve a certain *level of AI literacy*. They must possess the knowledge, skills, and values focused on developing, implementing, and using AI technologies. The UNESCO report recommends that the world's citizens understand "what the impact of AI might be, what AI can and cannot do, when AI is useful and when its use should be questioned, and how AI can be managed for the public good" (Miao & Holmes, 2021). Learning AI involves increasing the knowledge and skills of what AI is and how to use it in learners of all ages and their educators. Knowledge of AI techniques (e.g., ML) and AI technologies (e.g., natural language processing) is required, along with statistics and coding (Miao & Holmes, 2021).

AI learning includes the use of:

- AI-driven tools in teaching and learning, such as intelligent learning systems, dialogue-based learning systems, exploratory learning environments, automatic writing assessments, cobots, and chatbots, support learners with disabilities;
- AI for training administration, such as recruitment, scheduling, and training management;
- AI to directly support educators.

Some scholars talk about learning about AI as two kinds of *AI literacy*—one with a *technical dimension* and one with a *human dimension* (Holmes et al., 2022). Preparing to use AI includes understanding the potential impact of AI on users' lives. They need to understand issues around the ethics of using AI, workplace surveillance, and data bias. Moreover, it is necessary to ensure that all citizens are prepared for the possible impacts of AI on their lives – helping them to look beyond the noise to understand issues such as AI ethics, data bias, surveillance, and the potential impact on jobs. This step is called preparation for AI literacy with a *human dimension* (Holmes et al., 2022).

In the past three decades, most scientific research and applications of AIED have focused on what should be the learning accompanied by the AI, which is in the direction of *automating the teaching activity*, because the learners learn independently of the teacher or have their instructor (assistant) in the person of AI. This research is more about adapting pedagogic approaches and focusing on automating educational practice rather than innovation. An example is examining observations rather than using innovative ways of assessment). This AI feature having a direct impact on helping learners in areas where there are few experienced or qualified educators, such as rural areas in developing countries, can be very useful. In the context of AI aiding learners, the question that appears here is *trust*. For AI tools to become more widely used in classrooms, it is necessary to prove that AI is an educationally valuable technology and that learning will improve without harm.

"AI literacy cannot be limited to its technological components. It should include both the technical and human dimensions of AI, both how it works (techniques and technologies) and what its impact is on humans (on human cognition, privacy, agency, etc.)." (Holmes et al., 2019).

Advantages and disadvantages of using AI in education. Some advantages and disadvantages of using artificial intelligence technologies for participants in the educational process can be summarized as follows:

AI creates the conditions for personalization and individualization of training. Intelligent learning systems create a digital profile of a student that, used by the teacher, has the potential to result in the learning process.

A personalized learning environment improves the educational process's quality and enables students with health problems to learn more effectively.

AI provides students with hands-on or experiential learning experiences, mainly when used with other technologies, such as virtual reality, 3-D, gaming, and simulation, thereby enhancing student learning experiences.

By examining their learning preferences, emotional states, and levels of initiative, a well-chosen AI system can mold students' imagination and creativity while enhancing learning capacity and creativity and fostering subjective initiative.

Personalized learning also has some criticisms. Kohn, an American author and speaker, wrote, "…meaningful (and truly personal) learning never requires technology. Therefore, since personalization is presented from the outset as software or screen related, we must be extremely skeptical about who benefits" (Kohn, 2015).

All other arguments center around the notion that highly motivated students do not require a personalized learning system because they would find all the knowledge necessary for learning independently. According to Chassignol, firms looking to sell software rather than students desire to blame for the rise in popularity of personalized learning today. (Chassignol et al., 2018).

The intelligent educational environment has become a promising means of self-learning for students. Implementing AI technology provides many opportunities to develop massive open online courses (MOOCs).

The COVID-19 pandemic, quarantine, restrictive measures, and mass transfer of students to distance learning in almost all world countries have only updated the *trend:* An intellectual educational environment to become promising not only in distance learning but also in self-education, including lifelong learning.

The application of AI stimulates the continuous improvement of the *digital competence of trainers*. They must know AI's possibilities for automating several activities, learn to apply various electronic educational tools and applications, and fully use the electronic learning platforms (MLP). This competence will increase their pedagogical functionality and improve the quality of the learning process.

AI enables getting the most out of *data analysis.* Since data plays a much more critical role today than ever, its use can provide a competitive advantage to educational institutions.

AI enables the automation of repetitive learning and search processes by leveraging data. AI can automate basic actions in education, such as certification. Automating assessment processes, for example, can help trainers use their time more efficiently and focus on collaboration and professional development.

Assessment of many assignments and detection learning and teaching gaps is not a problem with implementing intelligent systems. In addition, measuring learning progress is becoming more popular and effective. Sometimes these intelligent scoring systems may miss some correct ones because the system decides based on *massive statistics*. AI-based evaluation systems cannot be accurate in every possible situation without a human mentor.

AIED collects data representing learners' responses to questions, their mood and emotional state (for example, interested or distracted), "what they click, and how they move their mouse across the screen" (Chassignol et al. 2018). A session with a child interacting with an AI or other e-learning system (such as a MOOC or serious game) can generate "about 5-10 million data points on student action each day." This data is "a learner's *digital footprint* and can be used to search and act on patterns of learner participation in a class, approve or deny learner places in institutions, and identify ways of participation" (Pardo et al. 2019).

There are numerous issues with the social and ethical importance of this: who has the right to collect these digital traces, how are they transformed into valuable knowledge, how can and how is this knowledge used, who has access to it, and who uses this knowledge and who benefits from it? The answers leave us wondering if this data will improve training or help AIED vendors and serve business intelligence.

AI-based programs provide *feedback* for both the learner and the teacher. AI systems have successfully proven themselves in online learning to monitor student performance and promptly alert instructors to existing performance issues. By introducing pertinent adjustments, these AI systems foster the circumstances for an effective improvement of the educational process.

AI tools can automate the assessment of learner knowledge, providing greater objectivity and freeing up time for trainers. It raises the question of whether AI is capable of profoundly interpreting or accurately analyzing the way a teacher can. Therefore, the understanding that the teacher does the assessment and the AI only supports this process is more realistic. There is little evidence for the claim that AI can save teachers' time.

Heads of educational institutions, using AI technologies, can more effectively manage and guide the institution's change processes. AI programs help students choose majors based on the areas in which they excel. Intelligent systems can change how educational institutions and academia use and seek information.

Another focus of AI in supporting institutions "is using chatbots to facilitate communication with learners and provide 24/7 self-service" (Leslie et al., 2021).

Institutions are also investing in analytics tools to predict *student dropout*. An example of such an application of AI is the Course Signals system at Purdue University, which initially appeared to impact learner retention positively, but controversial discussions about the results followed this. Using AI to predict dropouts is also a popular area of research, especially in MOOCs (massive open online courses), where dropout rates can reach more than 90%. The goal is to understand the factors that may influence dropout. There is currently little evidence of the effectiveness of such systems.

An objective examination of the actual effects of AI on administration, teaching, and learning requires pointing out some shortcomings/imperfections and challenges of AI (Yuskovychzhukovska et al., 2022)

In 2019, the Committee of Ministers of the Council of Europe adopted a recommendation on education for digital citizenship, in which a key focus was the application of artificial intelligence (AI) in an educational context:

"AI, like any other tool, offers many opportunities, but it also brings many threats, making it necessary to consider human rights principles in its early application design. Educators need to be aware of the strengths and weaknesses of AI in learning so that they are empowered – not overpowered – by technology in their digital citizenship educational practices. AI, through machine learning and deep learning, can enrich education... Similarly, developments in AI can profoundly affect interactions between educators and learners and citizens in general, which may undermine the very essence of education, namely the promotion of free will and independence and critical thinking through learning opportunities…."

Although the broader use of AI in learning environments seems premature, education professionals must be aware of AI and its ethical challenges in learning (Council of Europe, 2019).

Globally, AI in education is often met with enthusiasm – with many international reports and articles strongly recommending its use. However, it should not underestimate that AI cuts across the focus of the Council of Europe directorates on data protection, children's rights, and competencies for a democratic culture.

The Council of Europe's Ad Hoc Committee on Artificial Intelligence (CAHAI) has to explore the potential of AI based on broad multi-stakeholder consultation based on the Council of Europe's standards on human rights, democracy, and the rule of law. The Committee on Artificial Intelligence (CAI), which aims to identify issues and improve the relationship between AI and education, replaced CAHAI.

Indeed, recent work (e.g., Centre for Data Ethics and Innovation 2020; (Tuomi, 2018)) highlights "the technical, social, scientific, and conceptual limitations of AI in education systems" and notes "the lack of robust independent evidence" of its efficacy or success in achieving of the planned results.

Although AI brings several benefits to education, it will face some **challenges**.

1. In implementing AI in education, fairness must be ensured. With AI development, low- and middle-income countries face the risk of being left behind in education development due to their technological backwardness and limited access to the Internet. In addition, most AI algorithms come from developed countries; they do not fully consider the conditions of developing countries and cannot be applied directly.

2. Ethical and safety issues arise from data collection, use, and dissemination. The application of AI has raised many ethical questions regarding providing personalized advice to students, the collection of personal data, data privacy and ownership of responsibilities, and data submission algorithms.
3. Educators must master new digital teaching skills to use AI appropriately. In addition, AI learning product developers must understand how faculty work and create a product that applies to learning.
4. AI is changing the learning style by placing higher demands on students' autonomy and ability to learn independently. These things change learning objectives and contribute to forming independent learning skills.
5. The educators have to consider the communication between students. With the more active use of AI learning platforms, students communicate with machines as a priority, which deepens social communication skills. AI education projects should create a distance learning model emphasizing socialization (Saleh, 2021).

AI has significantly affected or impacted the education sector, particularly in its application in specific educational institutions.

After reviewing the characteristics and possibilities of AI to influence education, we can summarize that although there are no significant differences with traditional education, the application of AI brings substantial changes. However, it will not completely replace traditional education. AI is added and adapted to the conventional learning process, as with gamification, and is currently happening with VR and AR technologies. Understanding the problems that may arise when implementing AI in education will help people better prepare and improve the future application of AI in education.

The importance of AI technology in education is rising in prominence due to the profound expansion of economic and technical globalization. Furthermore, many nations view the advancement of AI technology as a national priority. The main characteristic of the innovative AI-based educational ecosystem is the precision, individualization, and adaptation of educational services and management. In building an innovative educational ecosystem, schools, teachers, and students face various challenges and problems AI poses. Teachers, students, and other stakeholders in educational institutions must collaborate to find solutions to these issues and create the ideal integration of AI technology and education.

This work contributes to existing knowledge in the field and will interest technology-enhanced learning professionals, educators, students, and people interested in the state of our education.

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1.2. "Augmented reality" technology in education (Diana Stoyanova)

Definition of the term "augmented reality."

Thomas Caudell, one of the leading engineers of the Boeing Company (Lee, 2012), introduced the term "Augmented reality" (AR) in the first half of the 1990s. The first definition of augmented reality was given in 1994 by Milgram and his associates (Milgram et al., 1994). They said that AR is a virtual and augmented reality in the context of a continuum (Fig. 1.1). At the left end of the continuum is the real environment, and at the right is the virtual, which is a completely unreal, entirely computer-generated environment. Between these two poles lies the so-called "mixed reality" (a part of which is also "augmented reality"), where we have a mixture of virtual and real objects. When moving from left to right along a continuous line, the virtual images increase, and the connection with reality decreases (Wheeler & Ivanova, 2010).

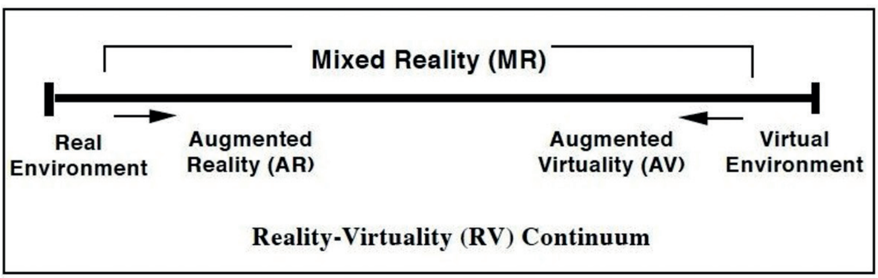

Fig. 1.1. Miligram and Kishino's Reality-Virtuality Continuum (Milgram, et al., 1994)

In 1997 Azuma gave one of the most widely accepted definitions, according to which the technology "augmented reality" is the superimposition of computer-generated 3D objects on a real environment (Azuma, 1997). Any AR system should have the following essential characteristics:

1. Combines virtual and real objects.
2. Offers real-time interactivity.
3. Provides real-time spatial alignment (positioning and orientation) of virtual objects relative to the real environment.

Although this definition implies an "extension" of only one of the human senses, like vision, "augmented reality" technology can be applied to different senses (to complement what we see, hear, etc.) (Carmigniani & Furht, 2011).

AR systems can assist or replace missing senses, such as "assisting" the vision of blind users by using additional audio information or "assisting" the hearing of deaf users by using other visual images.

Many researchers and educators believe that "augmented reality" should not be defined too restrictively. Limiting it to a particular sense or imaging technology may limit its future development (Wu et al., 2013). Therefore, based on the already mentioned definitions of Milgram and Azuma, they propose new definitions that are broader in meaning.

According to Klopfer (Klopfer, 2008), an AR system is any system that combines real and virtual information in a meaningful way. This information can be text, images, video, sound, 3D objects, and animation (Bower et al., 2014). In this case, AR creates different sensations in the user and a better perception of the environment (Graham et al., 2013; Azuma et al., 2001).

Zhou et al. (Zhou et al., 2008) provide an even broader definition, according to which AR technology allows real-time objects to be overlaid with computer-generated virtual images.

Considering the above definitions, we can describe augmented reality: as the superimposition of context-dependent virtual content (text, animation, graphics, video, 3D objects) on real things. The image generated by augmented reality software is a combination of the real environment that the user sees and a computer-generated virtual scene that alters our perception of reality and provides additional information.

Hardware components used to create augmented reality

Processors, visualization systems, and sensors are the main hardware components to develop augmented reality.

Visualization system

The visualization system lets the user see the real and virtual objects as a unified whole. These include - helmets for augmented reality, screens of personal computers or mobile devices, and video projectors.

Head-mounted display (HMD). A head-mounted display is a device worn on the head. It simultaneously positions images from the real and virtual worlds in front of the user's eyes (Fig. 1.2). The market also offers models that stimulate vision and hearing and another human sense - smell. Users can smell different aromas, which "immerse" them in a completely new way in augmented reality (Coward, 2015).

Fig. 1.2. Real object observed with HMD
(https://www.hexaengineers.us/the-revolution-that-augmented-reality-is-bringing-to-industry-4-0/)

A variety of HMD is the “smart” glasses. Google Glass is one of the first such devices, introduced in 2012. A small retinal display on one side of the glasses (Fig. 1.3) projects text and images directly into the wearer’s peripheral vision, allowing them to maintain additional contact with what they see. The glasses are connected directly to a smartphone equipped with augmented reality software, acceleration, and direction sensors, which make it possible to understand where the gaze is directed and provide additional information about the observed object (“Google Glass”, 2016).

The main criticism of Google Glass is that it violates privacy when used in public because the device can record conversations between people without their consent.

In 2022, Google presented the prototype of its new glasses for augmented reality. The test glasses will have several specific features to try out in real situations. These include using them for real-time language translation, conversation transcription, visual search, and navigation. This information is displayed on the glasses and superimposed on real objects. For now, however, the glasses themselves will not be able to take photos and video, which was the subject of criticism for the company’s first glasses - Google Glass (Antonov, 2022).

Fig. 1.3. Glasses with augmented reality Google Glass
(https://technews.bg/article-83413.html)

Screen. A computer monitor or a mobile device display can be used as a screen for viewing the image generated by augmented reality software. It's a much cheaper option than HMD devices and allows augmented reality to be viewed by multiple users simultaneously.

Video projector. Here, augmented reality is created by visualizing graphic information directly on real objects.

Sensors. The primary role of the sensors is to collect information from the surrounding environment and transmit it to the augmented reality software. The purpose of some sensors is to offer information about the user's location and orientation. These are digital cameras, GPS, accelerometers, etc. Other sensors collect information about the surrounding environment, such as illumination, pressure, temperature, etc. These include light sensors, barometers, thermometers, etc. (Craig, 2013).

Processors. Augmented reality systems require powerful processors that, in real-time, can:

- process the information received from the sensors;
- provide spatial alignment (positioning and orientation) of virtual objects relative to the real environment.

Types of augmented reality

There are several main types of augmented reality (Types of Augmented Reality applications):

Marker-based augmented reality. In the marker approach, augmented reality is created after recognizing a so-called marker. These are often square black-and-white images, similar to a 2D/QR barcode, marking a specific location or real object from the environment. After the augmented reality software reads the tag, the user can see the associated virtual content (Fig. 1.4). Currently, this approach is more widespread and easier to implement.

Fig. 1.4. Marker-based Augmented Reality
(https://medium.com/@codefluegel/5-business-use-cases-for-augmented-reality-a30e19fcd69d)

Architecture of an AR system based on marker recognition is shown in Fig. 1.5.

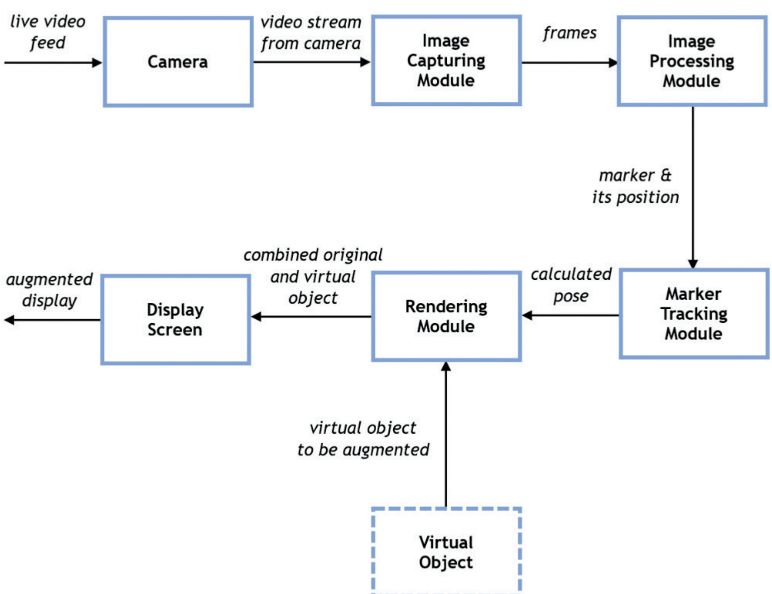

Fig. 1.5. The architecture of an augmented reality system based on marker recognition (Birje, 2013)

The main components of such a system are (Birje, 2013):

1. Camera
2. Image capturing module
3. Image processing module
4. Marker tracking module
5. Visualization module

The real-time video captured by the camera is transmitted to the image-capturing module. This module analyses each video frame and converts it into a digital image. Digital images are given to the image processing module, which is analyzed for AR marker detection. Detecting this marker is essential to determine the position where the virtual object will be superimposed. Its position is transmitted to the marker tracking module as soon as it is detected. This module, in real-time, calculates the user's perspective i.e., the position and orientation of the camera relative to the marker. These coordinates are given to the visualization module, which combines the real image from the camera with the virtual components and visualizes the augmented reality on display.

Location-based augmented reality. Here, AR is created after processing information about the user's position, detected by location sensors - GPS, digital compass, etc. (Ortman & Swedlund, 2012). Context-dependent information is visualized depending on the location (Fig. 1.6). If the user changes his location or the device's position or orientation, the virtual content changes according to his new location. AR applications using this approach are most commonly used as virtual guides.

Fig. 1.6. Augmented reality based on geolocation
(https://blog.vakoms.com/everything-you-need-to-knowto-build-location-based-ar-app/)

Projection-based augmented reality. Projection-based AR uses projectors to overlay virtual content directly onto real-world objects using projection mapping techniques and allows users to view AR content with the naked eye without needing glasses, augmented reality helmets, or mobile device screens. The most famous example of this type of AR is the so-called augmented reality sandbox (Fig. 1.7). The sandbox simulates a map in a real-time to allow users to create topography models by moving and shaping natural sand. Even virtual water can be “poured” onto the sandbox. In real-time, with the help of a simple bucket and spade, the user can “change” the landscape, creating mountains, valleys, lakes, and rivers for water to flow.

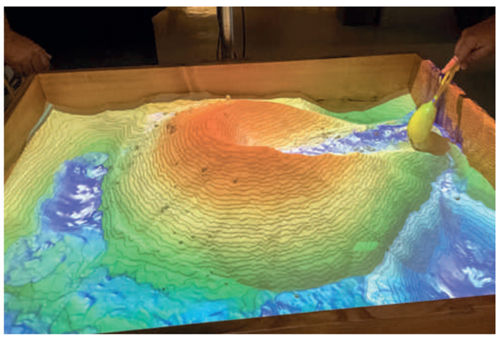

Fig. 1.7. Projection augmented reality
(https://dakotastudent.com/8748/arts-comm/augmented-reality-sandbox-puts-geography-on-the-map/)

Superimposition Augmented Reality replaces the image of the real object with digital content on the display (Fig. 1.8). The most known app based on this type of augmented reality is IKEA Place. It uses augmented reality to show how the IKEA’s furniture will look in your home (Lunden, 2017).

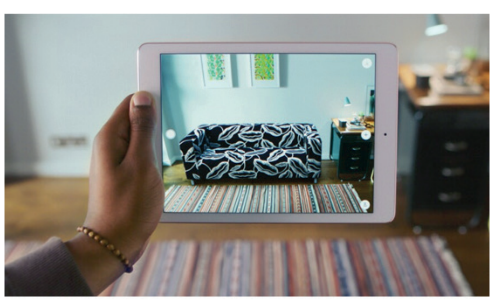

Fig. 1.8. Overlay-based Augmented Reality
(https://www.architectmagazine.com/technology/ikea-launches-augmented-reality-application)

Software packages for the development of augmented reality applications:

Vuforia Engine. Vuforia Engine (https://developer.vuforia.com/) is an augmented reality software package that is preferred by over half a million registered developers worldwide. It uses precise and efficient computer vision technology to recognize: square AR markers, 3D objects (cylinders, cubes), English words, photos, etc.

ARToolkit. Key features of ARToolkit (http://www.artoolkit.org/) include:

- recognition of AR markers in video frames;
- determining the geometry of the marker (its position and angle);
- determining the user's point of view by calculating the real position and orientation of the camera relative to the marker;
- generation of augmented reality by superimposing virtual objects on the real image captured by a camera.

Wikitude. The Wikitude AR SDK (https://www.wikitude.com/) enables the creation of applications using a marker and markerless approach to create augmented reality. The main characteristics of this software are the following:

- Ability to create augmented reality depending on the user's current location;
- Stable tracking system based on pattern recognition;
- Enables the recognition of nearly 1000 images;
- Fast and reliable online image recognition**.**

ARmedia3D. The main advantage of ARmedia3D is the ability to recognize not only planar images but also real 3D objects, regardless of their size and geometry (http://www.armedia.it/). This application is designed for Android and iOS mobile operating systems.

Google ARCore. ARCore (https://developers.google.com/ar) uses three key capabilities to integrate virtual content with the real world seen through your phone's camera:

- *Motion tracking* - ARCore can determine the position and orientation of your mobile device;
- *Environmental recognition* – recognizes the size and location of all types of surfaces;
- *Light estimation* - enables your phone to estimate the ambient light.

Apple ARKit. Apple ARKit (https://developer.apple.com/augmented-reality/) is the alternative to Google ARCore. It has almost the same capabilities as ARCore. If we compare these two platforms, we will observe that ARKit is better for image recognition. At the same time, ARCore is better for manipulating graphics and games.

Use of AR technology with mobile devices in the learning process

Until recently, augmented reality applications were mainly available for powerful personal computers making the technology significantly more expensive and hindering its widespread use. The rapid development of mobile communications in recent years has radically changed the situation. Regarding functionality and performance, modern mobile devices (smartphones, tablets, PDAs) are increasingly approaching stationary computers. Their low price, powerful processors, and the presence of a camera, GPS, accelerometer, gyroscope, etc., sensors make these devices highly suitable for creating augmented reality applications (Cvetanovski et al., 2015). This type of application in the learning process inherits the advantages, disadvantages, and features of the technologies it combines: mobile technologies and AR technology.

Use of AR technology in the learning process

Advantages:

Several researchers recognize the enormous potential that augmented reality technology has for educational purposes. According to Nunez et al. (2008), AR technology can make learning material more attractive and fun, which is essential to achieve maximum effectiveness in the learning process. Combining real and virtual objects helps to reduce the complexity of the learning material, contributes to its better perception (Shirazi & Behzadan, 2013; Behzadan & Kamat, 2012), and stimulates the imagination and creativity of students (Yuen et al., 2011; Zünd et al., 2015). It can facilitate understanding complex abstract and spatial concepts by making them more precise and understandable (Kaufmann & Schmalstieg, 2003; Kaufmann et al., 2005; Dori & Belcher, 2005). Augmented reality allows students to manipulate digital resources, further stimulating their interest (Wu et al., 2013; Lim & Jung, 2014). Using it in the learning process increases student motivation and activity in class (Di Serio et al., 2012; Li et al., 2014). Experiments have shown that learning material presented with AR technology is suitable for different learning styles (Yuen et al., 2011; Megahed, 2014). This feature helps students learn more effectively and increases the durability of acquired knowledge (Di Serio et al., 2012; Solak & Cakır, 2015).

Combining augmented reality technology with mobile devices provides additional benefits that make it particularly valuable for educational purposes. First, it facilitates access to digital learning resources. Students can access context-sensitive information anytime, anywhere - outside the school and the computer labs. Second, opportunities for collaboration among students and between students and educators are expanded (Billinghurst, 2003; Vassigh et al., 2014). Third, it does not require students to have prior training on how to work with these devices, as they have already used them in their daily lives.

Disadvantages:

The most frequently cited problem related to using augmented reality technology in the educational process is the danger of cognitive overload for students (Dunleavy & Dede, 2014; O'Shea et al., 2009). They have to perform many activities related to using AR software and viewing digital resources while simultaneously analyzing, making inferences, or making decisions as a team (Perry et al., 2008). Managing and controlling cognitive load is essential for successfully applying AR technology in learning.

Another often-cited problem is the unsuitability of the existing educational system for using AR technology. Lessons based on this technology require more time for teacher preparation and are more difficult to lead than traditional ones (Dunleavy & Dede, 2014). Children need time to become accustomed to using new technology. All this can lead to some disruption of educational distribution. Therefore, successfully implementing such lessons depends on the teacher's skills, confidence, and willingness to use new technologies (Perry et al., 2008).

Often, the use of mobile augmented reality applications based on geolocation has errors and problems arising from the inaccuracies of GPS systems (Bonsor, n.d.). GPS systems have a positioning accuracy of up to 10m and are also unsuitable for indoor navigation ("Global Positioning System," 2015). Errors can also occur with AR software using pattern recognition - for example, due to low lighting, poor marker quality, etc. (Rabbi et al., 2013). All this can prevent the normal course of the learning process and cause negative emotions in students, reducing the effect of AR technology.

The use of this technology in education is associated with additional costs. The schools have to pay for AR software and technical devices (mobile devices, augmented reality glasses, cameras, etc.), to develop digital learning resources, to maintain the Wi-Fi network in the school, and others. In the absence of precise positive results, some administrators believe that these costs are entirely unjustified.

Main directions for using AR technology in education

The following rules for using augmented reality technology in education can be distinguished (Yuen et al., 2011): augmented reality books, games, applications based on discovery learning, 3D object modeling, and learning applications aimed at acquiring specific skills.

Books with AR. Although they appeared on the market relatively recently, books with augmented reality have gained much popularity. At first glance, these books are no different from the others, but things change when we put them in front of the webcam or the mobile device's camera. The images from these books come alive through 3D graphics, video, or sound. Some books require installing special software, while others require AR glasses (Specht, 2011). The use of augmented reality books in the learning process is one possibility to tailor the learning content to the different learning styles of the students ("Augmented Books," n.d.). They stimulate children's imagination, increase their interest in learning content and make learning an interactive experience (Tomi & Rambli, 2013).

Games with AR. Games are a commonly used learning method, especially among elementary school students. It develops their ability to work in a team and helps them acquire knowledge. In this age group, creative thinking is essential to understand cause-and-effect relationships. Research shows augmented reality games reveal these connections more easily and meaningfully (Horoky, 2010).

Applications based on discovery learning. Learning through discovery is a modern pedagogical approach applied to provoke students' interest in the subject by conducting research activities. Jerome Bruner considered the main ideologist of learning through discovery, claims that in this way, students make sense of the activity while performing it and not just copy a given action (Emilov, 2015). The so-called virtual guides are among the most popular AR applications based on discovery learning. This application allows visitors to museums, galleries, and historical sites to receive additional information about the currently viewed object in text, audio, video, or graphic files (Persefoni & Tsinakos, 2015).

Modeling 3D objects. AR technology models 3D objects. Models can be moved, rotated, reduced, or enlarged, thus allowing the user to view these objects from a different angle (Ko et al., 2011).

Educational applications aimed at acquiring specific skills. Using AR technology, context-dependent learning can be provided to develop a particular skill (Raheja, 2014). The areas where this type of training application has the most significant potential are medicine and the military. The Army is a leader in using AR for training purposes. Video helmets and smart glasses are widely used to train in war games or troubleshoot. AR trains students and medical staff in medicine to perform various medical procedures or surgical operations (Botden, 2009).

AR technology is instrumental in engineering students' education. For example, 3D models visualized with the help of marker-based AR can be used by students when studying the device and the principle of operation of complex machines. Images from textbooks are used as markers.

The pandemic appeared as an opportunity to modernize education by implementing modern educational technologies, including augmented reality. This opportunity will undoubtedly remain a feature of the post-pandemic period in education systems. While many virtual apps and resources were not in high demand before the pandemic, they have become more popular. To use these technologies and tools, faculty and students must learn about and develop the skills to use them.

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1.3. Remote laboratories (Janka Raganova, Miriam Spodniakova Pfefferova, Martin Hruska, Zhelyazka Raykova)

In science education, remote experiments represent a relatively new method of experimentation where investigation plays a decisive role. This method makes "computer-based e-laboratories accessible to any user with a connection to the Internet, equipped with simple technical means" (Shauer et al., 2018).

A remote lab, by definition (Chen et al., 2022), is "an experiment conducted and controlled remotely through the Internet." The experiment uses real components or instrumentation at a different location from where they are being managed or operated. The use of remote experiments in university science education aligns with an effort to educate students using strategies compatible with society's present state. One of those strategies is "the method of e-LTR (e-learning, e-teaching, and e-research)" (Thomsen et al., 2005). The main characteristics of this method are "observations, searching for helpful information, processing and storing, organization and planning of work, data and results presentation, etc." On the Internet, a large number of actual remote e-laboratories are available. The Internet offers experiments on real-world objects, supplying the client with the view of the experiment, an interactive environment for the experiment control, and resulting data for evaluation (Schauer, 2018).

As a working example, we can introduce remote labs developed in the Faculty of Mathematics and Physics UK in Prague, Czech Republic, since 2002. Lustig, Shauer, et al. has developed a remote laboratory system with data transfer using Internet School Experimental System (ISES) as hardware and ISES WEB Control kit as software. In the beginning (in 2005), they set up and operated seven experiments, running round the clock, with more than 12 000 connections in three years (Schauer, 2018). They aimed to draw students more into practical experimental work and remove the barriers to independent laboratory work. They also intended to address positively several issues connected with laboratory work in science, technical, or engineering education. For example, remote experiments enable students to choose the optimal time and work at their most suitable speed. Access to the costly and potential safety risk experiments is feasible.

From a pedagogical point of view, remote experiments are an appropriate tool to substitute traditional experiments with research laboratories, enabling the development of an understanding of the experimental process (Schauer, 2018).

The first generation of remote experiments was built on Java applets (iSES, 2022). Since 2013 the developers of remote experiments have been moving to JavaScript. Until now, Lustig's team has built 18 remote experiments on the secondary and university levels. They are freely offered in school projects, education, and free time activities (Lustig et al., 2018).

How does the remote experiment work?

According to Lustig (2018), the "remote experiment is an application of the type server-client. On the server side, there is a computer with an investigation; on the client side, there is only a device with the latest version of the Internet browser, in which script language is supported."

The server side of the experiment means a computer connected to the Internet. A measuring apparatus is connected to the computer (e.g., ISES, LabVIEW, or another measuring system). It might include stepper motors, controllable sources, multimeters, and others. Naturally, there is also a real experiment. Systems with analog or digital control channels, such as ISES, LabVIEW, and others, allow remote building experiments of type "control." Special applications must run on the server. Firstly, it is a MeasureServer – a particular server application that communicates with hardware from measuring apparatus, e.g., with ISES sensors. Secondly, a WEB server is necessary. It enables running custom webpages written in HTML using JavaScript widgets from the new kit "iSES Remote Lab SDK" developed by Lustig and his team. Suppose an online camera view of the experiment is wished. In that case, it is necessary to run ImageServer (part of "iSES Remote Lab SDK"), which streams the view of the experiment with fast-sensing images (Lustig et al., 2018).

Experience with the use of remote experiments

If the remote laboratories are well designed, they can, according to Nedice (2013), offer students the following:

- "telepresence in the laboratory,
- to perform experiments on real equipment,
- to collaborate,
- to learn by trial and error,
- to perform analysis on real experimental data,
- but also flexibility in choosing the time and place for conducting experiments."

The study of Alkhaldi et al. (2016) suggests that remote laboratories provide several advantages, such as remote 24 /7 access, flexibility, and freedom to learn at one's own pace and reset/ retrial experiments without wasting resources in a safe environment and provide new learning opportunities. They have observed that "these labs, when incorporated with a sound pedagogical framework, learner support, and content and tutor interaction, result in higher learning outcomes and richer learning experiences."

Harward et al. (2008) stress the cost-effectiveness of remote labs compared to physical labs. The ability for numerous students to remotely share pricey equipment is one of the most significant benefits of creating remote laboratories. Lustigova and Novotna (2013) found that remote laboratories significantly improved students' data processing skills. Working on their computers and undisrupted by co-workers and the unknown laboratory territory, they focused on the problem and reached substantially better results. They also improved their conceptual thanks to fast graphical visualization and remote labs' great potential to recollect data and re-run experiments under many different settings.

What methods are used by faculty to teach STEM practical work in remote classrooms?

The increased use of educational technology creates a gap in using long-standing pedagogical theories about e-learning. Siemens (2004) claims that behaviorism, cognitivism, and constructivism theories cannot fully explain technology-assisted learning. For this aim, Siemens propose a new theory of connectivism. In 2004, trying to explain what e-learning means, Siemens emphasized one of the weaknesses of behaviorism, cognitivism, and constructivism theories: learning primarily occurs in the human mind. Through the idea of connectivism, Siemens (2004) opined that non-human devices can learn and acquire knowledge. Connectivism attempts to explain learning in communities formed by learners and devices connected through new technologies.

One of the technologies that enable people and things to form learning communities is IoT (Internet of Things). IoT is described as a network of digital devices embedded in the Internet, enabling communication between people. Connectivism, however, has been criticized for being a "new theory." Moreover, Goldie claimed that the connectivism idea is based on the old theories and the new SMART technologies can be learned (*Goldie, 2016*).

Another widely used theory in studies seeking to understand online learning is the Community of Inquiry (CoI) framework by *Garrison et al. (2000)*. The CoI consists of three components corresponding to types of presence in online classrooms. These are instructional presence (how online instruction support cognitive presence and social presence), cognitive presence (how learners make meaning in online classrooms), and social presence (the sense people have of being in a social environment or part of a group). Researchers use the three types of existence to examine how students experience online learning. Nagel and Kotzé (2010) found in their study that all three components of CoI can be measured and are related to teaching quality.

Teaching presence is believed to have a more significant impact on how one learns. Teaching through cognitive and social attendance strongly influences the training methods (DeNoyelles et al., 2014). Other scholars, such as Anderson (2011), believe CoI is only one component in an e-learning environment.

During remote laboratories, the instructors can use **methods** like practical work in a virtual environment and an environment with augmented reality, experimental work in remote laboratories, homework, use of educational robotics, project-based learning, inquiry-based learning, and problem-based learning.

What are the prospects of using remote access to laboratories for conducting practical work with students?

Following the experiences gained during the pandemic in experimental work with remote access laboratories, Chu et al. (2021) suggest using allows mobile learning (learning via mobile devices) as a possible alternative. The experiments that have been done by this collective are related to the use of smartphones by students. They conducted experiments on sound but in virtual laboratories.

Future research may focus on using phones to receive instructions and collect experimental data from real experiments in remote access laboratories. The applications for working in laboratories with remote access are improved more and more, which makes it possible to work with more diverse experimental tasks from different fields of science.

The lack of sufficient pedagogical research on the effectiveness and specifics of organizing learning in remote access laboratories is why more and more researchers are turning their attention to studies on this topic.

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1.4. Hybrid and blended learning (Zhelyazka Raykova)

There is more and more talk about the two types of training and having in mind that they are becoming a trend, it is essential to understand the difference between them.

What are the **definitions of these two types of learning**?

- Hybrid learning is an educational approach in which some students participate in the learning process in person and online. Lecturers or instructors or facilitators teach both remotely and face-to-face at the same time using technology such as video conferencing.
- In blended learning, trainers combine face-to-face learning with online activities. Learners complete some components online and others in person.

Both types of learning combine face-to-face and online learning but differ in the scenario by which they do it. In hybrid learning, those who learn face-to-face are different from those who study online. In blended learning, the students are the same. In hybrid learning, the learners are heterogeneous - some study in person, others online. In blended learning, all students learn the same way online and through face-to-face activities. According to some scientists, hybrid is parallel learning and blended sequential.

Examples of blended learning: Before discussing a problem related to using a specific sensor to measure air pollution, the educator asks students to watch a video related to this problem.

Example of hybrid learning: The teacher consults on the conduct of an exam in a particular discipline. Some of the students are in the seminar room. Others sent or are sending the questions to the teacher via chat/video link.

It is impossible to comment which of the two training approaches is better. Both have limitations and advantages.

Some limitations of hybrid versus blended learning:

Hybrid learning is more challenging because the teacher must divide his attention between groups with potentially conflicting needs. The skills a teacher must apply, for example, must be good at presenting in a face-to-face environment and at the same time working in an online environment, which is difficult and stressful. For instance, if the instructor shows attendees how to use a sensor, it excludes online learners from participating. The teacher assigns a task to research (reference) and report on some new device, which is easier for those who learn online than those who are face-to-face, who are in classrooms and do not have good Internet or do not bring their electronic laptops, with them. This fact can lead to a decrease in the quality of learning because the teacher decides to use approaches that are acceptable to both groups but do not have the same positive effect - for example, conducting a traditional lecture, which is unsuitable for both groups. Or for the teacher to prioritize the needs of one of the two groups - for example, for online students to be passive listeners and for face-to-face students to be more active, or to focus on those online students so that others decide not to come to classes.

The main disadvantage of blended learning is that sometimes the homework given by the instructor may not be done by students before the start of another component. For example, the instructor asks students to read an article and write a summary of it. Some students have prepared diligently, while others have forgotten to do so. This fact puts the teacher in a difficult situation - to spend time on repetition and clarification to stimulate everyone to do the work, or to move on, knowing that some will fall behind. In this case, the bet is on the learners themselves – they must understand and believe in the importance of each component of blended learning and be motivated to do it and complete their tasks on time.

Blended learning requires the teacher to possess two skills, hybrid. But is it so?

- The teacher must not teach both online and face-to-face at the same time. He can only focus on one thing.
- The sequential approach allows different faculty to handle the different components – one checks the online assignments, and the other conducts face-to-face training.

The benefits of hybrid and blended learning:

Blended learning makes it possible to select learning approaches and methods based on the specific situation, considering the learner's needs and the content. In the flipped classroom, learners are introduced to the new subject learning through online sources and then come together to ask questions and discuss. This example demonstrates the potential of blended learning to condense the time learners spend together.

Blended learning offers more significant opportunities to personalize learning than hybrid learning. During the face-to-face phase, the instructor considers some of the student's interests and needs or their prior knowledge, which leads to the corresponding adaptation of the content and tasks in the online phase.

Despite these advantages of blended learning, we believe that hybrid has its place in future education, hoping that technology development can make it more effective.

In the post-pandemic learning period, in which we return to face-to-face learning again, we hope to apply our positive online learning experience to a sensible choice of learning methods and approaches. When there is a need, let's conduct online training as an extension of the present one to improve the learning results.

Blended and hybrid learning are two distinct approaches, and their choice has different implications for students and the learning process.

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1.5. The flipped classroom (Zhelyazka Raykova and Galin Tsokov)

The experience of conducting training online has shown that implementing the flipped classroom as an approach has a place in the physicists' and engineers' future training.

The hybrid learner-centered learning environments that have recently emerged due to technological advancements and the flipped classroom model have caught the interest of scholars and teaching community members result of technological advances. The flipped classroom model has caught the interest of both scholars and members the interest of both scholars and members of the teaching community. (Bergmann & Sams, 2013; Chen, Wang, Kinshuk & Chen, 2014; Howitt & Pegram, 2015; Lai & Hwang, 2016). Research shows that this model can effectively stimulate learners to interact actively and form high cognitive skills (Bergmann & Sams, 2012; Chen & Chen, 2015).

Two main factors promote the implementation of a flipped classroom:

- prevalent distribution of online videos, materials, and information;
- poor learning outcomes from traditional classrooms.

These two factors influenced teachers Aaron Sams and Jonathan Bergman at Woodland Park High School in Colorado, and they began recording PowerPoint presentations for their students who missed class (Bergmann & Sams, 2013). These presentations are published online and are gaining tremendous popularity. Students use online materials/digital lectures to learn and gain knowledge before the face-to-face classes. Learners spend more time upgrading their knowledge or getting additional clarifications in face-to-face meetings. Sams and Bergman began lecturing with results from the flipped classroom method, resulting in other educators adopting the model.

What do we mean by the Flipped Classroom model?

In the classic learning model, the teacher is the central figure in classes and the primary source of information. The teacher asks questions, answers them, and organizes the students' activities and feedback accordingly. Such a way of conducting teaching can be didactically successful and meaningful depending on the trainer's professionalism. In this model (approach) of organizing the learning process, students' participation is related to activities in which they work together or independently on tasks set by the teacher. The teacher controls all discussions and is the central figure in the class.

According to Honeycutt (2014), "The flipped classroom can be described as a transition from a teacher-focused to a learner-focused learning environment." The flipped classroom represents a shift from individual to collaborative strategies. Besides, it is possible to flip a class using individual activities such as quizzes, worksheets, reflective writing prompts, and problem-solving assignments. The key is to complete these activities during the course.

Flipping a classroom involves taking energy away from the trainer, redirecting it to the learners, and using educational tools to improve the learning environment. Educational tools include but are not limited to the use of technology" (Bergmann & Sams, 2012). While videos and other technology tools can be effective in the flipped classroom, they are not required. The flipped classroom shifts the directions of communication to a student-centered constructivist model where deeper topics can be explored, and student participation can be more active and conscious. In this model, the role of modern technologies is vital, providing online access to information, recorded lectures, assignments, tests, etc., and forms to deliver the learning content to students (Hamdan, 2013).

Several researchers say this training organization can increase its effectiveness and motivation to study and promote teamwork. The flipped classroom supports learning in which the teacher presents vital points of the learning content to the learners before the class (via online texts, video lessons, and videos). Students are introduced to the learning content at home, which allows classroom learning time to develop their learning skills through discussion and debate. The constant formative feedback provided during the flipped classroom is essential and helps educators assess student achievement.

The meaning of "turning" is redirecting the focus in the learning process to the learner/student.

The most widely used description of a flipped classroom (flipped learning) is a model in which learning activities that generally occur outside the school in the form of homework or independent work assignments now happen during class. In this model, activities traditionally occur during lessons and are carried out before the face-to-face meeting. All these details mean that students pre-complete an assignment that involves watching a video, which can be a recorded lecture, a demonstration, an experimental film, etc. After arriving at face-to-face classes, students work on assignments with their peers and the instructor.

The flipped classroom is based on the constructivist approach, where learning is an active, cognitive, and social process. Learners can use their previous experience and existing knowledge to build an understanding of the new material. Using this model helps students stay in touch with the teacher for more time, doubling student access to the teacher - once with the videos at home and again in the classroom, increasing the opportunity for personalization and more precise targeting of learning.

Flipping the classroom supports learning in which the teacher shows learners before the face-to-face class "fundamental concepts, through online texts, video tutorials, videos, and activities and ensures that class time will allow learners to exercise their cognitive functions actively" (Findlay-Thompson, Mombourquette, 2014). Essential is the constant formative feedback provided during the flipped classroom that helps educators assess student achievement.

Flipped learning "focuses on meeting the student's knowledge needs through a clear set of rules that differs from established methodology. The four pillars of F-L-I-P are a flexible learning environment, learning culture, planned content, and professional trainer" (Hamdan, 2013). There are different flipped learning models, and according to the learners and their needs, the most suitable one is chosen (see 7 Unique Flipped Classroom Models – Which is Right for You?).

A standard flipped classroom. Students are assigned "homework" - watching video lectures and reading material related to the next day's lesson. During classes, students put into practice what they have learned through traditional classrooms, with educators having the opportunity to give individual attention to each of them.

Discussion-Oriented Flipped Classroom. Lecturers recommend watching lecture videos and any other videos or texts, YouTube videos, and related resources. Time is then set aside for discussion and exploration of the topic.

Demonstration Oriented Flipped Classroom. Especially for those subjects that require students to remember and repeat actions accurately - chemistry, physics, and mathematics - it is most beneficial to have a video demonstration available that can be paused, replayed, and watched many times. In this model, the instructor uses screen recording software to detail their actions, allowing learners to follow their own pace.

A "fake" flipped classroom. This idea is perfect for younger learners for whom real homework isn't quite right yet. Instead, they watch the instructional video in class, allowing them to review the material at their own pace.

Flipped classroom by groups. This model adds a new utility that encourages students to learn from each other. Learning begins similarly with instructional videos and other resources shared before class. The change occurs in the attended lectures when the task of the day must be completed in a group. This format motivates students to learn from each other and helps them explain their answers and choices.

Virtual Flipped Classroom. The need for face-to-face lectures may disappear entirely for educated adults and in specific courses. Online learning platforms are used. Individual consultation with a trainee is allowed after a pre-arranged meeting.

Role reversal. An instructional video created for the flipped classroom does not have to begin and end with the teacher. Students can also use the video to demonstrate their skills better. Assign the students tasks by engaging in various role-plays to demonstrate competence or ask them to record their videos.

A modern learning model is the combined strategy of implementing the flipped classroom and online project-based learning (FC-OPBL) to improve the quality of teaching and the effectiveness of the learning process. Flipped classroom learning design is used as an organization strategy, and OPBL as a learning method (Wen-Ling, Sh., Chun-Yen Tsai, 2017). Thus, online project-based learning (OPBL) is a popular approach that uses technology to increase the effectiveness of the educational process. Email, online forums, cloud platform tools, and databases on the Internet give students a rich and varied learning environment outside of the classroom while facilitating communication and collaboration.

Training using the FC-OPBL flipped-classroom approach to facilitating an online project-based learning model is organized as follows:

Preliminary organization:

1. Creating micro video lessons - we shoot a video explaining new learning content.

The teacher can add explanations in written or audio versions. Free educational resources from the Internet, such as Cannes Academy, Ucha.se, and e-textbooks, are used. The video created by the teacher is made available for online access to students on platforms such as YouTube, TeacherTube, Screencast.com, and Google Drive).

Variety: an online micro-lesson of 10-15 minutes explains new learning content.

1. Group organization of training
2. Differentiation of teaching through TEAMS

The instructor gives specific instructions when structuring teams. Depending on the project, the formation of homogeneous or heterogeneous groups. Teamwork and collaboration are possible in virtual space. Collaboration and individual instruction in online and offline learning (Google Classroom makes this possible).

The **technology of conducting lessons on the Flipped Classroom / Flipped Learning model** can be traced through the dynamics of the activities of the teacher and the student.

Instructor's Activities:

- In a classroom session, the instructor gives instructions and guidelines for the studied topic. He sets assignments for the students from the textbook that they must work on.
- Instructor indicates a link for meetings, or his e-mail address, through which they can communicate with the students until the next class he attends. He must be ready to answer questions posed by them.
- Instructor checks the online solutions of the assigned learning tasks in the cloud.
- The next present lesson is conducted according to the set goal. If practical skills are built in a laboratory, students are pre-acquainted with the equipment, tasks, and theoretical foundations. This thing saves the instructor a lot of time spent in the laboratories and provides an opportunity to spend more time on the task. If the classes are not practically oriented, the teacher should prepare scenarios for an upcoming discussion or discuss a case study or problems related to the studied topic. They must be willing to apply interactive methods to give access to every student to participate in discussions and to set formative assessments. Tracking progress and evaluating students' activity is very important to regulate the quality of the learning process in this model.
- During face-to-face meetings, lecturers are more like advisors or mentors who support group activities.

Student Activities:

- In the present lesson, they must understand the task set for independent work and how students should provide the expected results. Asks clarifying questions and makes comments.
- Plans working hours and performs assigned tasks by reading literature and watching video materials in the context of assigned tasks.
- Actively uses the Internet. Ask questions to the teacher online if necessary.
- Completes assigned tasks by preparing presentations, solving tasks, preparing frameworks of protocols for laboratory classes, etc.
- At the subsequent attendance lesson, they present the independent work implementation, participate in discussions, and perform a practical exercise by collecting and processing experimental data.

The "Flipped Classroom Method Study Guide in Adult Education" (2015) contains examples of flipped classroom physics lesson scenarios.

An **example** linked with the proposal is related to the study of a physics section. A textbook is chosen that the teacher traditionally works on. For example, that of Giancoli D., Physics (https://www.docdroid.net/ OFMOth4/giancoli-physics-principles-7th-ed-pdf#page=7). It is good to have ready-made online learning resources for the textbook, for example, "Mastering Physics" - https:// mlm.pearson.com/ northamerica/ masteringphysics/. Of course, together with the texts, students might receive video recordings of the teacher's lectures or practical exercises that will be solved during class.

Some **imperfections** of the Flipped Classroom model:

- The justified burden falls on the independent work of the students, and in case they do not have the skills for this, it leads to difficulties.
- Sometimes, it is possible to overload the students.
- Provided they are not well prepared, the risk of failed classes in the present phase is high. It is also possible that some students do not actively participate in the courses they attend. Some students may take the passive side in learning and expect instructions.
- The teacher must spend time preparing learning resources for students' independent work and revise the curriculum in a new way.
- Difficulties also appear in evaluating the results of the academic work.
- The teacher may find it challenging to produce quality video materials and therefore needs help from specialists, which is a kind of difficulty

Many of these challenges will be overcome if the instructor is well-trained and motivated to work this way.

Advantages:

- By video recording his lecture, the teacher can emphasize important critical ideas discussed in the present phase. It can also manage the pace of learning the particular curriculum topics.
- The recorded lectures can be watched repeatedly by the students; they can scroll through them, take breaks, and use the Google translator or its information search capabilities.
- Attended classes no longer have the character of lectures but of workshops/ seminars in which learners can ask questions about the topic, work in groups and carry out practical exercises.
- The flipped classroom changes the role of trainers, who give up their leading position in favor of active and collaborative work during the learning process.
- The flipped classroom model makes the students' responsibilities bigger and allows them to experiment more. To date, the flipped classroom has been used primarily in higher education.

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CHAPTER 2

CLOUD TECHNOLOGIES IN EDUCATION IN PANDEMIC AND POST-PANDEMIC TIME

2.1. Cloud technologies in education (Stefan Stoyanov)

Although gaining popularity before the COVID-19 pandemic, cloud technologies have become indispensable during the lockdown, especially in education. These technologies are one of the sought-after and actively developing areas of the modern IT world. Cloud technologies in education have opened great opportunities for all educational institutions, both for teachers and learners. Their use in education in 2021 reached an economic effect of 25 billion dollars (Riddle, 2022)

So what does this mean for the current and future development of education? What are the main advantages of cloud technologies in education?

Let's look at some of the **benefits**:

- ***Improved administration in educational institutions***. Cloud technologies provide easy collaboration between different administrative units and save money and time in solving problems. The service is delivered quickly and immediately through them, in other parts of the day, and from different places.
- ***Improved teaching process***. Using cloud technologies, educators have more significant opportunities to activate student learning by reaching a wider audience of students and managing their knowledge. They also make it easier for educators to prepare interactive learning content, prepare online tests, and facilitate communication with students. Grading tests, project results,

student assignments, and giving feedback have never been more accessible.

The long-term vision is to shift current teaching practices to project-based learning and create opportunities for more interactivity, stimulating students to conduct their research, analyze data, and come to meaningful conclusions independently. For implementing this model, the role of cloud technologies is leading.

Plovdiv City (Bulgaria) is recognized as a role model for its efforts to fully digitize the educational process by multiple organizations, including Google and the Innovation in Politics Institute. It is the winner of the Smart 50 Award 2021.

Since 2018, several Plovdiv schools have applied the **"1:1" model** in their education. This model shows how to organize the learning process when each student and teacher have their electronic device and a personal profile connected to it. The model considers digital technologies as a resource and a platform, not as an end in itself. The "1:1" model assumes that teachers and students can access all the Internet content in the classroom and anywhere. Students do not use notebooks or other paper information carriers in this model.

Some of the features of this model that apply to students and teachers are as follows:

- have a personal portable computer and permanent access to the Internet;
- the study, work, and communicate in groups, both inside and outside the classroom;
- create products that use their knowledge and skills from different subjects;
- spend their time in front of the screen in a meaningful way and master the latest digital tools;
- are in a secure environment, physically and online;
- plan lessons together.

The "1:1" model significantly increases students' motivation to learn and active participation in lessons, positively impacting their grades and overall performance. It allows for a better emphasis on competency-based education, where students become designers of learning resources and create new content themselves. Currently (the academic year 2022-23), there are over 100 classes in the city where students work only with personal laptops, and the entire learning process is digitized. As of October 2022, the municipal education system has over 40,500 active accounts, with nearly 14,000 virtual classrooms. The conducted research on the quality of this model showed that most of the teachers (80 %)

believe this model is thriving and will continue to implement it in Bulgarian schools. The experience of the municipal schools in the Municipality of Plovdiv shows that the introduction of cloud platforms has become the basis for both the creation of new and the development of already existing innovative practices in school management, educational activities, and the academic environment in general. Cloud technologies also create better conditions for teamwork between educators and students, and school management. They have realized thanks to the following capabilities of cloud technologies:

- ***Quick and easy access to information***. By using cloud technologies in the classroom or the self-training of students, the Internet is available 99.9 % of the time, which is very convenient for all participants in the educational process.

  This thing leads to the following *consequences*:

  - Both students and educators can implement learning opportunities virtually at any time, resulting in substantial time savings. Permanent access to course materials removes barriers to accessing information for students who are physically unable to attend classes in person.
  - Sharing notes has never been easier than using cloud technologies - the user can share or receive notes from any area covered by an Internet connection and at any time.
  - Data safety is no longer a problem as it is all collected and stored in the cloud, and there is no need to worry about it being kept on the computer or carried around on a flash drive that can be forgotten or lost.
- ***Online education courses***. The rapid development of online educational courses in recent years is a consequence of the introduction of cloud technologies in education.

With cloud technology, every student can access online courses offered on Coursera or those associated with some educational institution - school, college, or university. When we talk about **Coursera**, we mean that it is the largest project in online education, developed in 2012. By 2017, the service was used by more than 24 million users. The project includes physics, engineering disciplines, humanities and arts, medicine, biology, mathematics, computer science, economics, and business courses. **Coursera** runs on *the Nginx web server on Linux machines leased from Amazon Web Services.* The data is stored in Amazon S3, and the site is searched using Amazon CloudSearch.

A similar platform that offers online courses for teachers to the European Commission is the **European Schoolnet Academy** (European Schoolnet Academy, 2022).

- ***Competitiveness.*** Nowadays, learning using cloud technologies can compete with the traditional educational process. Cloud technologies make high-quality self-learning possible. Increasingly, employers are accepting potential employees who prefer e-learning to face-to-face.
- ***No need for expensive hardware and expensive software***. Since the core concept of cloud technology means connecting to cloud-based applications, neither students nor educators need specific devices to access course resources. Every device can use cloud programs without any issues. Even a low-cost smartphone allows you to connect with related academic applications.

The **SaaS model** is considered one of the most significant advantages of cloud-based computing. The acronym SaaS (software as a service) stands for software as a service. It is defined as a method of licensing and delivering software where the software is available online rather than installed on a device. It is common for these software applications to be open to students for free or at a meager cost, making learning accessible to most students.

- ***Saving money on expensive textbooks***. College-level textbooks are known to be a costly indulgence, so more students are refraining from buying them. Cloud textbooks are the only solution to this problem. Digital books are generally less expensive and allow lower-income students also to be able to access high-quality learning. By utilizing cloud technology, financial inequity is eliminated, putting all students in the same learning environment.

2.2. Advantages and disadvantages of using Moodle as a learning management system in teaching activities (Ion Buligiu, Cristian Marius Etegan)

During the pandemic, the teaching activity had to focus on methods and tools of distance work, online and offline, so that faculty could provide students with study materials and the teaching process through online video communication sessions. We will emphasize both the advantages and disadvantages of using online learning technologies and tools from the perspective of instructors and students to highlight the positive aspects and delimit the negative ones. We want to identify the elements that will successfully use in the post-pandemic period.

The experience gained in using these technologies helps us adopt more efficient teaching methods in the future by combining classical and digital learning mechanisms to create helpful content for students in an attractive and easy-to-understand format that can be accessed from anywhere, anytime.

Current education tends to make more and more use of the tools, resources, and services offered by the various online platforms. These platforms allow online content to be published and easily accessed, systematizing learning content into an attractive form for the student, providing fast and automatic evaluation mechanisms, and a wide variety of modules for video conferencing.

The Moodle learning management system gives an example of using such a platform. The authors want to highlight the advantages and disadvantages of the pandemic period, considering the experience of working with it over more than two years. The instructor needs to identify an effective solution in the organization of the teaching process. Moodle provides the best possible interaction between students and instructors to achieve a performance in transmitting to students the information needed to be assimilated by students, structuring them in an accessible and easy-to-follow form, and evaluating the learning outcomes.

Moodle offers a multitude of modules and tools for online learning management. Despite this advantage, there are issues related to Moodle's complexity. Faculty face a real challenge in choosing the right tools for teaching activities. Students face problems associated with the standardization of content for different disciplines (each teacher will select their tools for structuring the subject they will teach).

The working interface for a student is becoming increasingly complex, as the resources offered are very varied (files of different types, media feeds, links, slideshow presentations, automatic assessment modules, poll tools, etc.). Faculty and students interact through online video meetings, email, and instant or phone messages using a variety of applications (Zoom, Google Meet, Microsoft Teams, Webex, and Skype are just a few). This variety leads to a decrease in the student's ability to choose the appropriate format for communication, as well as the difficulty in selecting the most appropriate solution to share or transmit the results of his study.

Thus, educators and students must have additional skills in using so many communication tools to achieve an effective educational process. In contrast, educational institutions must have hardware equipment (network infrastructure, routers, switches, servers, computers).

During the pandemic period, the education system adapts to restrictive conditions. Still, these measures created opportunities that favoured the emergence of new innovative teaching and learning methods based on new technologies, one of which was e-learning platforms. The study focus will be on the capabilities of the Moodle platform.

Following the experience gained during the pandemic, we can appreciate that students' involvement is diminished during online teaching sessions. The instructors said they encountered numerous situations when students closed their video cameras or invoked technical reasons. In this context, the instructor no longer has visual feedback on the audience. It is not clear if the student is attentive during the teaching process. The student-teacher visual connection must be well established because it allows the teacher to assess students' understanding of the concepts taught, regardless of whether the teaching is done online or in class.

The Moodle online platform has automatic mechanisms to record the students' participation in courses. The instructor can set the platform to record student participation in classes throughout the activities by validating the actions of response to quick quizzes or poll tests, as long as they have gone through the tutorials provided and listened to them in full. The instructor may restrict access to the next module if the student has not fully completed the current stage.

A partial solution to these drawbacks would be to evaluate quickly by asking short poll questions to students at specific intervals using online platforms. All these things lead students to answer correctly to the teacher's questions. The instructor can assess how many students were attentive and understood the taught content. The instructor can apply some corrections during the course by clarifying the unclear elements and discussing what students who did not answer the poll questions correctly did not understand.

Students' active participation in classroom activities can be monitored by handshake systems to ask for clarification or to answer the teacher's questions, assimilated by choosing the correct answer from several options.

Creating groups at the platform level is also very useful because they develop teamwork skills; the teacher can interact more easily with groups of students and adapt teaching materials to the student's skills.

In the post-pandemic period, considering all these experiences, hybrid teaching solutions will use. During teaching in the classroom, students can use the resources offered by online learning platforms. They will find there the course content structured in modules, divided according to the schedule of teaching activities. Students can access valuable components such as video sequences to explain the different notions and Wiki sections. Students can complete the content, and at each activity, students can find on the online platform assessment through quiz sessions. These online questionnaires reflect student satisfaction and more.

We will see what teaching methods and techniques will be adopted in the post-pandemic period. This decision will be based on instructors' experience during the pandemic. Each instructor highlights the most appropriate components that have proven to be effective during the teaching and learning process. Their insertion in the current educational process, which will undoubtedly be a hybrid one, will combine classical teaching methods with those that use new technologies.

Our approach uses the SAMR (Substitution, Augmentation, Modification, Redefinition) model. We highlight further the microlearning method. It means learning in small segments, easy to assimilate, with rich content of visual components, and summarizing the main course's essential elements.

To better explain these teaching methods, we will first explain the SAMR model, which applies strategies for implementing new educational technologies structured on four levels (Fig. 2.1.)

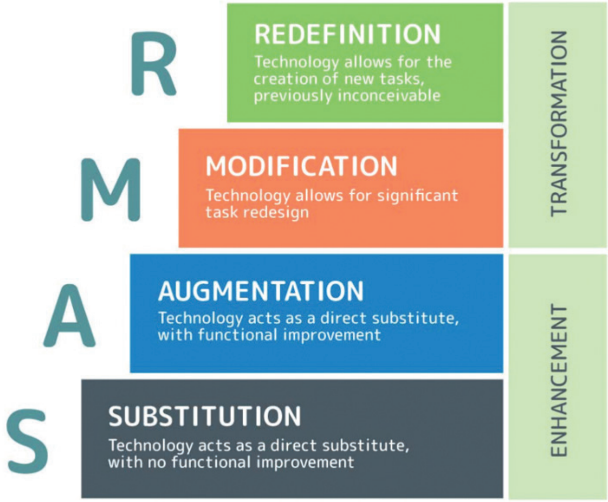


Figure 2.1. Implementation levels of the SAMR model

The first two levels, *substitution,* and *augmentation,* are based on activities through which technology is used as a direct substitute in teaching methods to improve the educational process. The level of *modification* will allow a redesign of tasks assigned to students to achieve better results. Then, new tasks will be created by redefining, which improves the previous components through a transformation process.

We will further explain the implementation mechanism of each level within the SAMR model to highlight the opportunities created in the teaching and learning process.

The *substitution level* contains the first phase in which technology is used as a substitute for traditional handwriting teaching methods, with electronic documents appearing instead that can be easily written, modified, and distributed online. Students and educators become familiar with new technologies during this phase. As homework, students can edit in Word or create PowerPoint presentations. They can use spreadsheets to make different calculations, convert documents to portable PDF format, and complete online questionnaires. The instructor evaluates students' feedback. Finally, students upload these resources to online learning platforms such as Moodle.

The *level of augmentation* means that technology allows students to understand more complex content using additional media elements during the course, such as video tutorials that explain current notions or links to documentation resources related to the content explained, PowerPoint presentations that summarize the essentials of the teaching activity and contain suggestive diagrams or even short explanatory videos. The teaching activity is complemented by media elements of this type that segment the complex content into smaller components with explanations, thus transforming the course into accessible and easy-to-assimilate content.

The *modification level* brings in the teaching process interactive tasks for students, which involve the creation of documents shared by several participants, allowing the development of teamwork skills in a collaborative environment such as Moodle. Video chat rooms can be set up for brainstorming sessions where students can discuss common topics of discussion or a specific topic or solve tasks jointly. Another interesting form of knowledge presentation is the production of video podcasts in which students can present a particular case, which can then be accessed by other students and instructors for exciting and constructive discussions.

Redefining is the most complex stage of the SAMR model, through which completely new opportunities in learning activities are designed by instructors. It will allow the student to maximize their potential by creating authentic research content and developing skills to adapt to new developments in the field. Students will be connected with students with academic and research backgrounds from other universities in the country and worldwide, encouraging students to publish their research in online journals and attend conferences. Moodle also offers multiple possibilities to insert in the course section the materials developed by students and their discussion, the use of forums containing discussion topics with question-and-answer sessions, e-voting systems, podcasts, pages Wiki, workshops sessions, and so on.

In the literature (Hug T., 2005), *microlearning* as a teaching method is characterized by the following elements: segmentation of learning time into shorter periods, which does not require the student to a prolonged assimilation effort; dividing the complex course content into smaller and easier-to-understand components; synthesizing important notions from the course; encouraging an atomic structure of the course; creating coherent and autonomous content; the use of media elements and interactive components in the form of the taught material; providing support for different ways of learning.

The emergence of microlearning as a teaching method is based on the principle that students are subject to very high cognitive demands when they have to assimilate complex and large course content. This overload reduces the student's learning performance and the risk of the student becoming tired and not fulfilling all the tasks imposed by the teacher, thus leading to gaps in the education process. Suppose the total learning effort is divided into smaller segments, atomizing the course into simpler and smaller components with a clear structure and easy to assimilate. In that case, we will get a better performance from the student in the learning process.

Specifically, the solution can be implemented on the Moodle platform by structuring a challenging course in the form of micro-content media components, such as inserting PowerPoint presentations or Prezi explaining the course segments into subchapters or placing YouTube video content that to describe a specific topic, allowing the student to access them directly from the platform and to assimilate them at their own pace.

Indeed, better results will be obtained from students in their learning process, along with an increase in their efficiency and performance, if the effective course content is divided and has an extended presentation time into well-organized subcomponents on smaller segments, rich in visual content and much easier for students to assimilate. All these features will contribute to a transition from classic, formal course content to a modular structure that can sometimes have an informal, pleasant way of presenting, attracting students in discussions with the teacher or between them, combining the advantages offered by the online platform.

On the *Moodle* online platform, the user can use quick assessment components in the form of quizzes or the completion of short online survey questionnaires. So, the teacher can get immediate feedback on how students assimilate knowledge and can proceed to provide additional explanations or discuss vague notions to students. At the same time, this system allows the teacher to interact better with students, including the placement of homework associated with each course segment, as a challenge for students, as they can upload the solved topics in the Moodle module. These can be quickly evaluated and rewarded by the teacher.

The microlearning method can achieve several positive results, such as better student assimilation of the concepts presented in the course and greater interactivity in the teaching activities. Students will have increased motivation, developed the ability to learn and collaborative research, and increased student performance and learning ability.

It must be said that there are opinions (Jomah O. et al, 2016) that microlearning method would not be suitable for the acquisition of complex skills or in the case of intensive teaching courses, where the student must perform complex tasks and assimilate notions with a high degree of difficulty at a relatively short time. As a result, further research is certainly needed in the absence of useful empirical information, along with impact assessments on applying these methods.

2.3. Using the Google Classroom platform in teaching activities during the pandemic time (Silviu Constantin Sararu)

At UCv the COVID-19 pandemic "began" on March 12, 2020, when the Administrative Council of UCv decided to suspend direct teaching activities ("face to face"), as well as all related activities (scientific conferences, student/school competitions, cultural, artistic and sports events, debates, other meetings or public events etc.) until March 31, 2020. According to the same document, during the period 13-31.03.2020, teaching activities will be carried out online using the EvStud platform or e-learning platforms (Moodle, **Google Classroom**), and faculty and students benefiting from the necessary support in the field. According to the legislation in force, e-learning platforms (but not Google Classroom) were used in the UCv for reduced frequency and distance study programs. UCv students could use a web module of the EvStud platform, which at that time offered the possibility of accessing different information (grades, curricula, thesis/ dissertation, etc.). Faculty also used this platform. For students, access to this platform is achieved through a PIN and a password. At the time of the suspension of teaching activities, students did not have an e-mail address for the *ucv.ro* domain (the UCv domain). Faculty could use an e-mail address for the *ucv.ro* domain, but the majority did not use such an e-mail address.

In the days immediately following the suspension of direct teaching activities, the IT and Communications Service of UCv generated email addresses for the *ucv.ro* domain for academic staff and all students (*name.firstname.cod@student.ucv.ro* and respectively *firstname.name@edu.ucv.ro*), the EvStud platform has been modified to allow the transmission of course and seminar notes and support materials for laboratory activities to students. Through these e-mail addresses, students and faculty could also access the *Google Workspace for Education* e-learning platform, which allowed the use of **Google Classroom**.

Google Classroom allows an approach to education that combines the possibility of posting materials online by faculty and students with the opportunity of online interaction between faculty and students with traditional teaching methods. This is possible since Google Classroom integrates various applications developed by Google (Google Drive, Google Meet, Gmail, Google Docs, Google Sheets, Google Slides, Google Forms, and Google Calendar).

Figure 2.2. Google Suite Application

Starting in 2020, Google Classroom was integrated with Google Meet to cover the needs of conducting online video direct teaching activities.

How to use Google Classroom - brief presentation

The first step for using Google Classroom is to log in to the www.classroom.google.com web page. The "teacher" or "student" status is selected at the first login. This is a significant step, because if you choose "*student*" you are not allowed to create a class.

Once logged in and identified as a teacher, the next step is creating a class. For this, press the button with the "+" symbol.

Figure 2.3. Creating (or joining) a class options

Two options, "Join class" and "Create class" appear. Select the desired option. If the second option is selected (to create a class), a menu opens where different information about the class is requested. The only mandatory information to enter is "Class name," the others being optional.

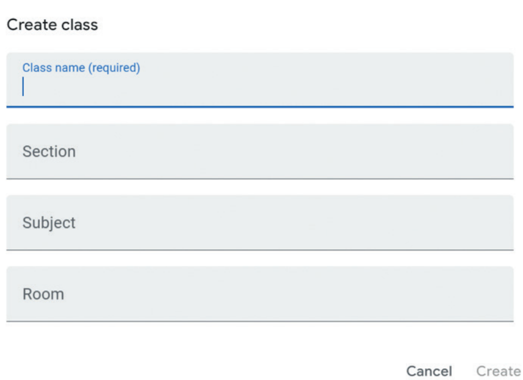


Figure 2.4. Completing class details

In the beginning, the class will look like in Figure 2.5 and can be customized by pressing the "Customize" button.

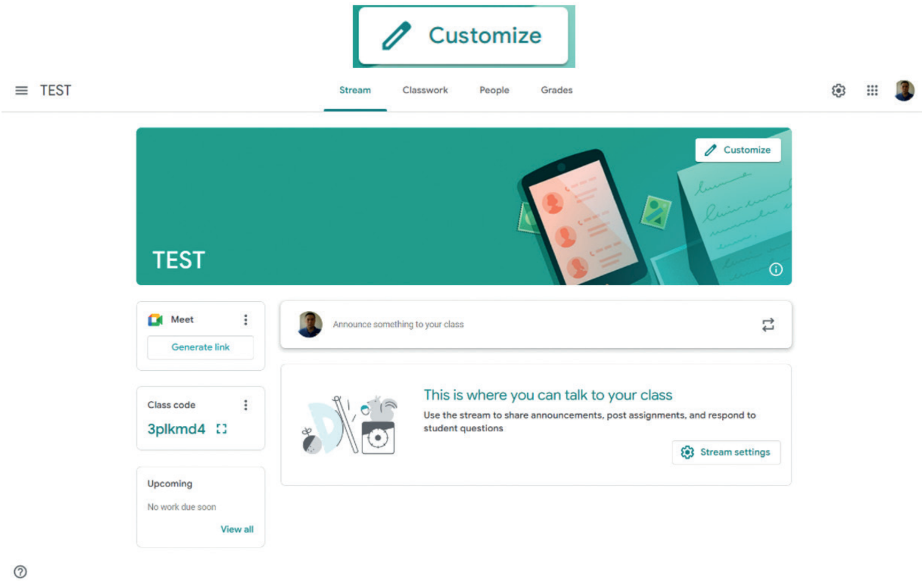
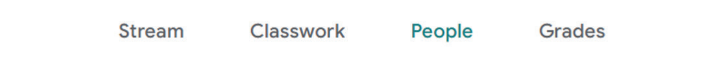
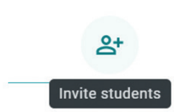


Figure 2.5. Customize a class

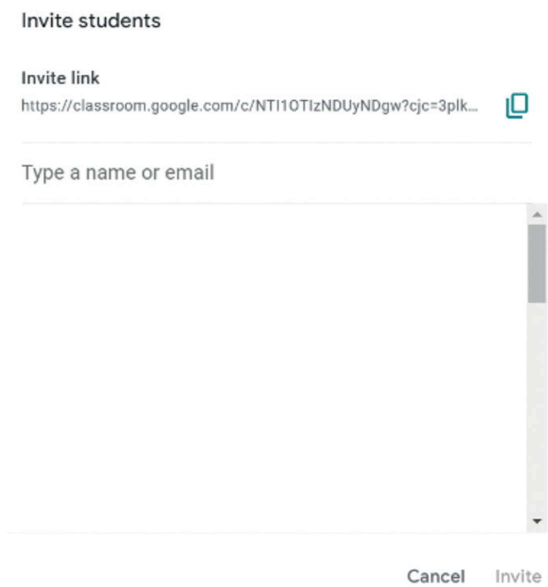
"Class code" (in our case, this is *3plkmd4*, it differs from one class to another and can be reset) displayed on the left side represents the alphanumeric code of the class. There are several possibilities to invite students to join the class. One of them is transmitting the class code to the students (for example, via email), and the students enter the class code when they press the " Join " button. If you have a list of email addresses of the students you want to invite to the class, proceed as follows. At the top of the screen is a menu that contains the following buttons "Stream," "Classroom," "People," and "Grades."



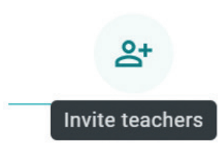
Press "People" in the new tab that opens press the button to add students.



and in the open menu



fill in the students' email addresses and press "Invite" from the bottom of the menu. Students will receive an email with the invitation to join the class. To invite another instructor to the class, proceed similarly with the observation that the "Invite teachers" button will be pressed.



Pressing the "Stream" button opens a page where all the information about the activities in the class appears, announcements can be sent, and comments can be written by the other class members (including students).

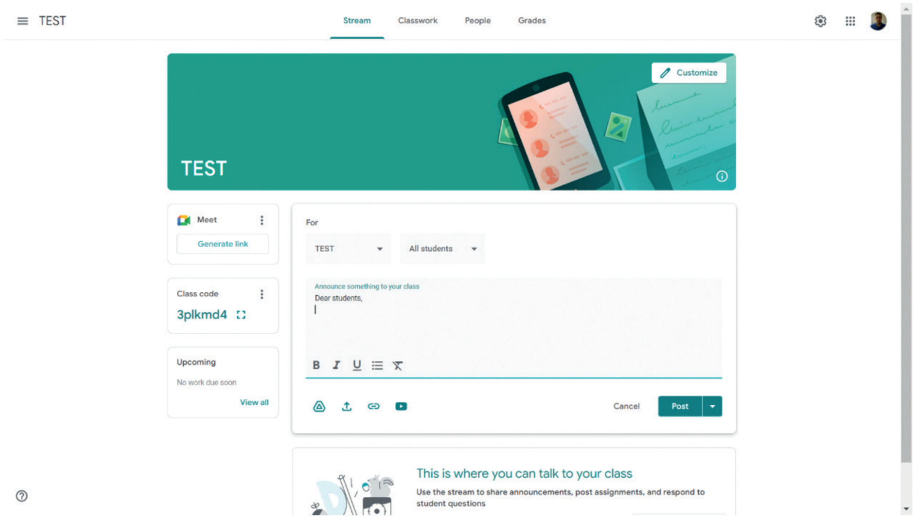
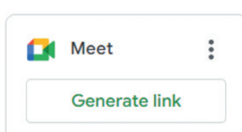


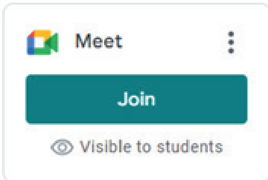
Figure 2.6. Class stream customization

The announcement may contain only text or may constitute other materials (files, links, etc.). Materials are uploaded from the computer of the person making the announcement or from Google Drive, which is integrated with Google Classroom. Google Classroom is also integrated with the YouTube platform (youtube.com). This feature allows video files posted on youtube.com to be added to the ad.

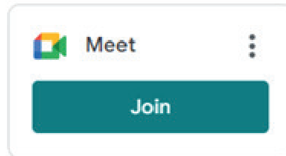
The application Google Meet can be used for live online video activities with the students in the class. Google Classroom is integrated with Google Meet. The instructor initially generates a link and pushes the "Generate link" button in the "Stream" tab.



This thing will allow students to participate in live online video activities by pressing the "Join" button on the "Stream" tab



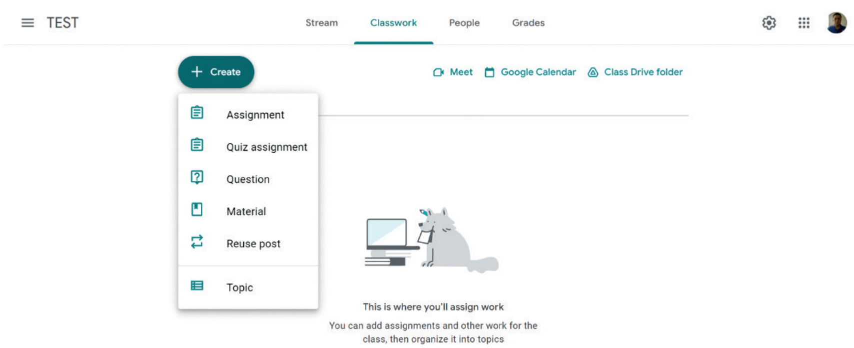
Teacher view



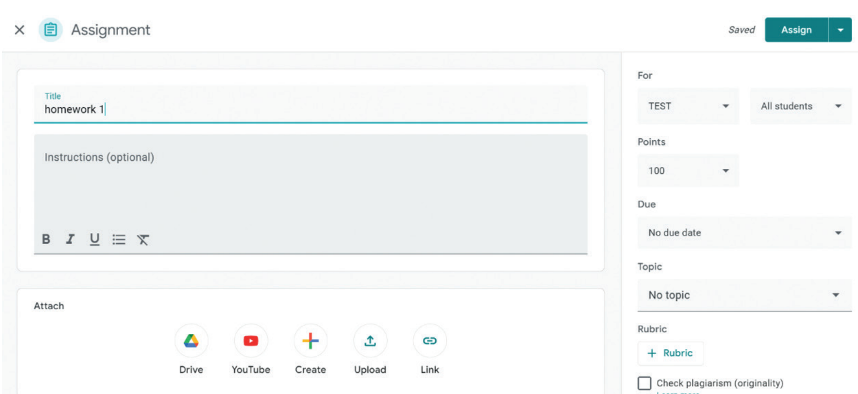
Student view

The teacher initiates the live online video activity, and students participate in the meeting.

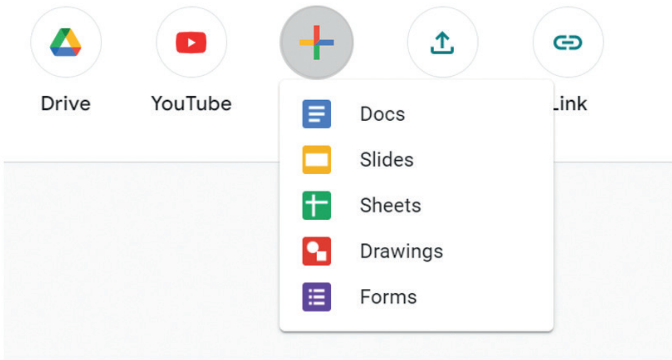
Pressing the "Classwork" button opens a tab that allows the assignment of different tasks (assignment, quiz assignment, question) to students or the transmission of materials (video files, books, course, and seminar notes, or support materials for laboratory activities).



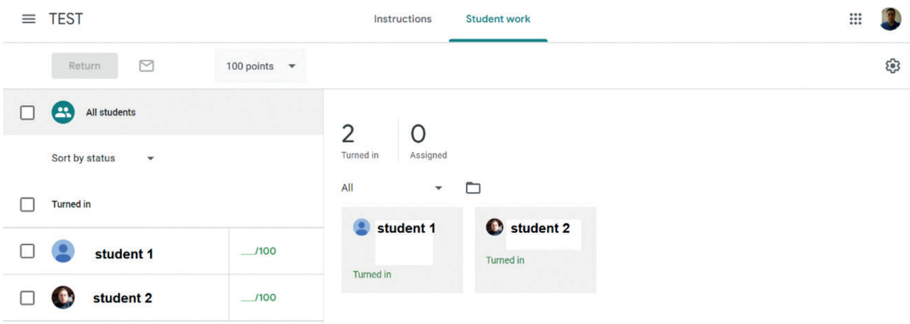
To assign a task/homework, press "Assignment" and a new tab will open.



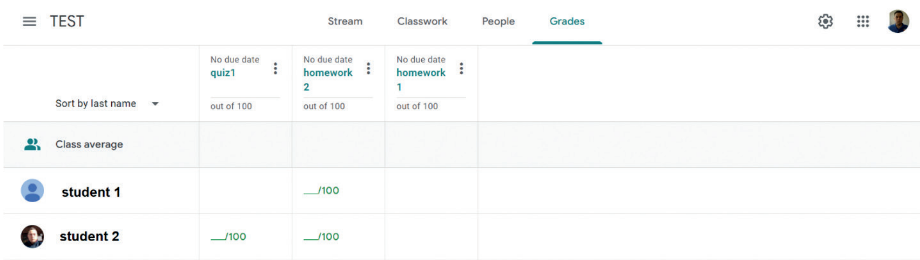
Fill in the fields (the "Title" field is mandatory) with the necessary information. Attach related materials if they have already been created or create them by pressing the "Create" button. After pressing the "Create" button, a menu opens.



This menu allows the creation of materials using Google Docs, Google Sheets, Google Slides, and Google Forms, the files being automatically saved in Google Drive. To check an assignment, click on it; in the open menu, select "Turned in" and open a tab from which "Student work" is selected.



By pressing the "Grades" button, the Teacher has access to the situation regarding the performance of tasks by the student, scores obtained for homework, etc.



Before March 2020, e-learning platforms were characteristic of reduced frequency and/or distance learning study programs. After the students returned to the classrooms and laboratories, some faculty continued to use different modules of the Google Classroom platform. The distribution to students of course and seminar notes and supporting materials for laboratory activities is one example that does not involve financial resources for the multiplication of these materials. Using the infrastructure acquired during the pandemic for video recording of courses and distribution to students (and possibly other teaching staff) contributes to improving student preparation and course content, considering that students can provide feedback through the platform. Before the pandemic, solving course and lab activities assignments were made on paper. The management and organization of the assignments by faculty require an essential time resource. Using the Google Classroom platform, students can send the materials directly to the professor, and he no longer wastes time organizing the documents, this being done automatically by the platform. Thus, using Google Classroom allows a better organization of teaching activities, saves time and material resources, and offers the possibility of quick feedback from students.

2.4. Zoom – video conferencing platform – another tool in education during the pandemic crisis (Iulian Petrisor, Mihaela Tinca Udristioiu)

Why Zoom? Along with other platforms such as *Google Meet*, *Teams*, or *Webex*, the *Zoom* platform was a solution for education in a crisis such as the Covid-19 pandemic. Among the advantages of *Zoom* compared to other platforms is that it is installed and used very quickly, connects people from anywhere, is interactive, and allows the viewing of files by meeting participants. That is why we used *Zoom* initially to organize conferences from European projects that could not be postponed. Starting with April 2020 and until March 2022, *Zoom* was used in online activities at UCv (Romania). Initially, *Zoom* was used only for Faculty meetings, and very quickly, it was implemented to communicate with students and then carry out teaching activities for students.

It is imperative to state that the only training received by faculty consisted of a few files aout how to use these platforms. The Department for Teaching Staff Training (within the University of Craiova) was not ready to contribute to the faculty's training (to obtain digital skills specific to online teaching activities). The UCv management did not pay subscriptions for *Zoom*, its recommendation was to use *Google Meet* and *Google Classroom,* which were free for education. During the pandemic, most of the UCv Faculty used the free version, a simplified version with limited usage time (40 minutes).

Even if COVID-19 restrictions were lifted in March 2022, some hybrid activities required the continued use of the *Zoom* application. Indeed, education will never be like before the Covid-19 pandemic, and it should identify and embrace the advantages of online education. It is currently running a form of transition of hybrid teaching, and we must prepare to optimize and improve it.

Why *Zoom*? At the pandemic's beginning, Faculty had online discussions with students and decided that *all online platforms* were useful. Indeed, it was impressive how quickly the idea was accepted and embraced by the students, which shows that this generation is ready for digitalization. The main reason Zoom was preferred was that some students did not have enough technical means to support large data transmissions (video), or the Internet connection was insufficient to use video transmissions. Also, UCv has students who live in isolated localities/villages (our students are mainly from the Oltenia region, Romania). It was obvious that they needed a bit of help to participate in the didactic and extra-didactic activities, both from the undergraduate study programs and master's degrees. Students' participation in teaching activities increased suddenly at the beginning of Covid 19 pandemic. Students' number online was higher than before the pandemic (when all activities were only face-to-face). Some explanations might be the impossibility of leaving their homes and students' desire to socialize. Students were in the position to leave their houses only in exceptional cases (due to restrictions). For this reason, students needed to use the apparent additional time (unprecedented situation until then).

Short description of the application. Therefore, of the need to communicate effectively and come to the support of students, we started using the *Zoom* application, which is compatible with *Windows*, *Linux*, *iOS* and/or Android. Thus, anyone could connect to (*Zoom* meetings) with any device: phone, tablet, laptop, or PC, with any operating system. The advantage was that it allowed even students from disadvantaged areas to connect from their phones or computer. The University offered computers, tablets, phones, and internet cards to students from underprivileged areas. Even before the pandemic, at the UCv, video cameras allowed quality recordings. All these things helped students from disadvantaged areas with the possibility to connect. It also allowed students who live in other localities or who worked at that moment to secure.

We appreciate that *Zoom's* appeal lies in its simplicity. It has a straightforward interface and is super intuitive, especially for someone who has used *Google Meet* or *Skype* in the past. Skype did not allow "share" at that moment; only a few people could connect using Skype. Skype will enable us to send documents, and it has a chat.

A significant advantage of the *Zoom* application is that it can be used with minimal installation on the device (phone or laptop) without an existing account. If the user needs to use different functions, the application is installed under the appropriate operating system and uses an account associated with a functional email. Activating the application requires association with an email account or any active email. Using the account, the facilities offered increased significantly. From the moment of the existence of an account, one could use one of the following existing subscriptions (plans/modes of use), made available by *Zoom*, as follows:

- Zoom Basic – a practically free "subscription" in which one-to-one video conferences can be held for an unlimited time and limited to 40 minutes; if the number of participants is greater than 3, the session will expire;
- Zoom Pro – a paid subscription, $14.00/month or $140.00/year. This affordable subscription allows 100 simultaneous users, 24 hours of endless meetings, and 1 GB of cloud recording (per license). It offers the possibility of Breakrooms that make the application more interactive; the participants can be divided into smaller groups, working in teams on different projects/themes. It also contains Pool, a tool that allows launching questions in real-time with immediate feedback;
- Zoom Business – adapted to medium-sized companies that use up to 10 hosts. It includes a dedicated user interface and other features, such as auto-generated transcription;

- Zoom Enterprise is a solution for large companies and institutions. This version allows until 100 hosts and has other benefits (e.g. the possibility of real-time translation).
- Zoom Rooms - $49.00/month/room;
- Room Connector - $49.00/month/port
- Video Webinar - $40.00/month/host (attendees 100 people).

How we used Zoom? Faculty and students used the *Zoom Basic* version at the beginning. It looks very intuitive, like in the following images. The first step is connecting to Zoom and choosing what you want to do.

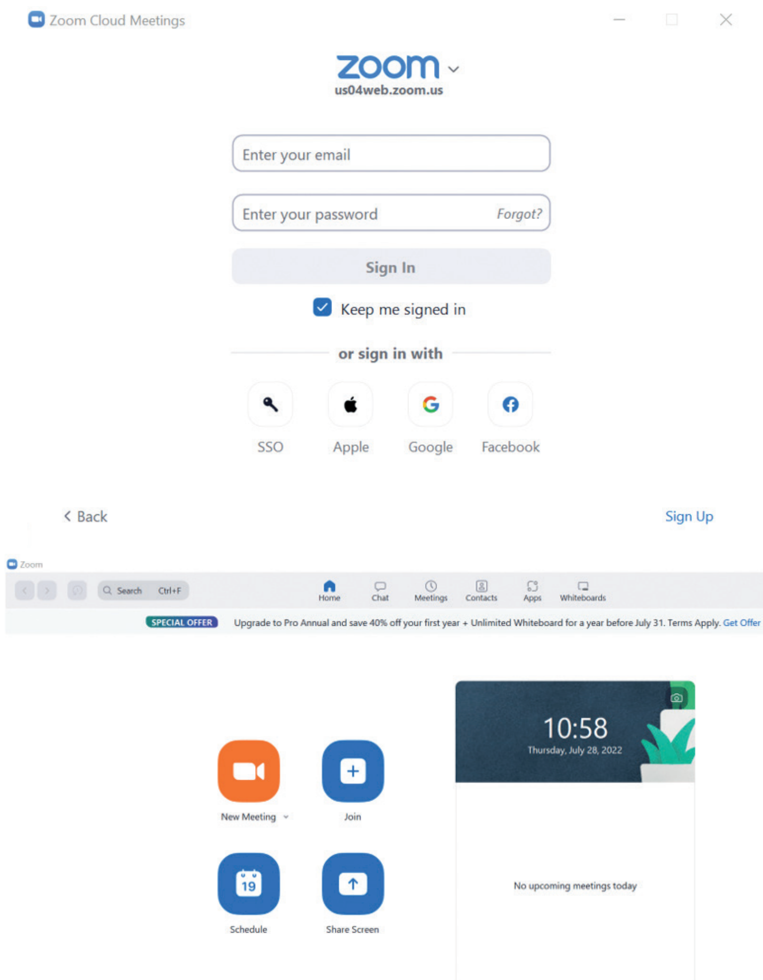


Figure 2.7. Print screens related to connection to Zoom

If it is pushed the button "Schedule", it will be scheduled a meeting with a duration of a maximum of 40 minutes in Zoom Basic and unlimited in Zoom Pro. It is possible to establish a recurring meeting, especially when you do not want to change the link for a whole semester or academic year. When someone schedules a meeting, a link is generated and will be sent to the participants by email, Google Classroom, WhatsApp, etc. At the scheduled time, the initiator of that meeting will push the button Start.

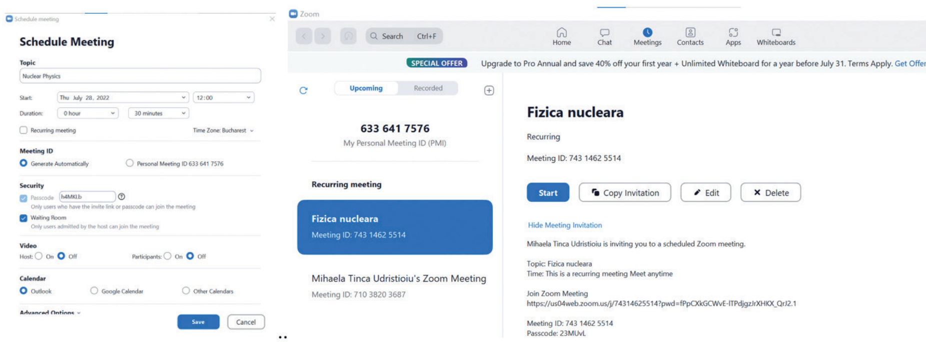


Figure 2.8. Print screens related to the schedule meeting and starts it

At the beginning of the academic year 2020-2021, each department or faculty of the University of Craiova purchased several *Zoom Pro* accounts/subscriptions. One hundred simultaneous participants were enough to carry out online activities with students from small branches of each Faculty, with one year or study program each. Zoom was very practical for carrying out online teaching activities using *Zoom*.

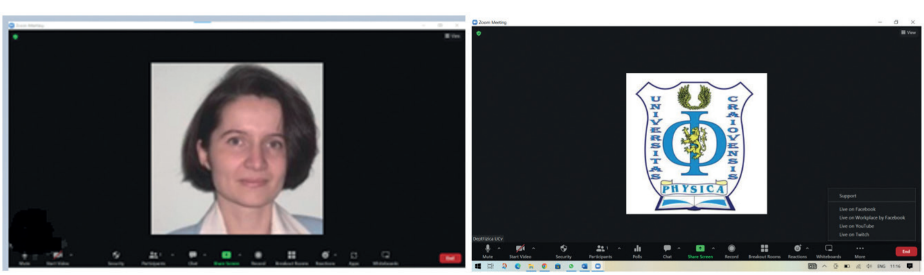


Figure 2.9. Differences between how is looking the screen in Basic (1) and Pro Zoom (2)

Also, the seminar classes were relatively easy to do with the graphic tablets acquired by the Faculty from their resources. The *Zoom* whiteboard was not easy to use, especially when some complex formulas and equations needed to be written or to make some drawings. Things are improved significantly if the whiteboard is combined with a graphics tablet.

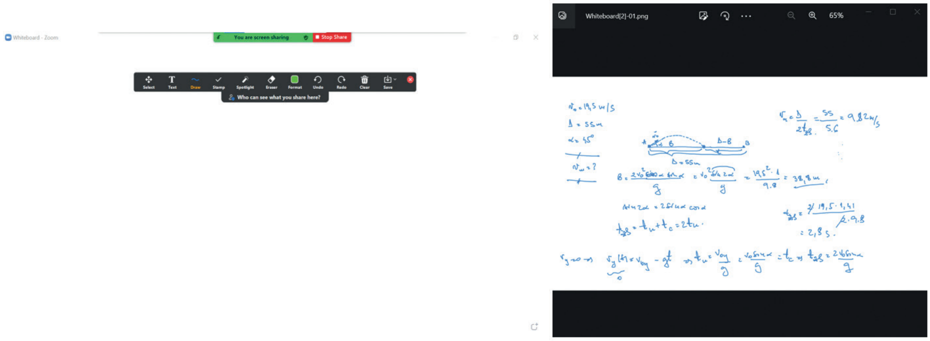


Figure 2.10. The whiteboard without and with graphics tablet

Students did not interact so well with faculty during the seminar as if they were face to face. From this point of view, the seminars were not easy to organize. Also, laboratory activities were challenging to sustain. Recordings were made in the laboratory (videos) with the installation of the equipment, the making of measurements, calculation of errors. Laboratory works in digital format. The instructors used some simulations (e.g., PhET Interactive Simulations), simulators, and *YouTube* videos, making the instructor's interaction with students outstanding. A real disadvantage was that students did not gain technical skills when they watched films or used simulations, a fact emphasized even by employers. A limited number of "open source" resources were made available by various universities.

Another essential aspect relative to the seminars and laboratories is that *Zoom* allows interactive engagement applications like *Jamboard*. Students work on different projects as a team under the instructor's guidance; they can also express other viewpoints. Also, menti.com allowed obtaining feedback from students relative to understanding a problem (for the *Zoom* basic version, menti.com replaced *Pool* from *Zoom*). *Padlet* might play the role of *Google Classroom* for *Zoom* users, allowing the instructor to organize the information for students. *Zoom* allows the use of other applications such as *Lumen5* (for making short videos) or for making posters (canva.com) and other advertising materials, which is so important in communication. There is a free version of all these applications. The paid one is much more complex.

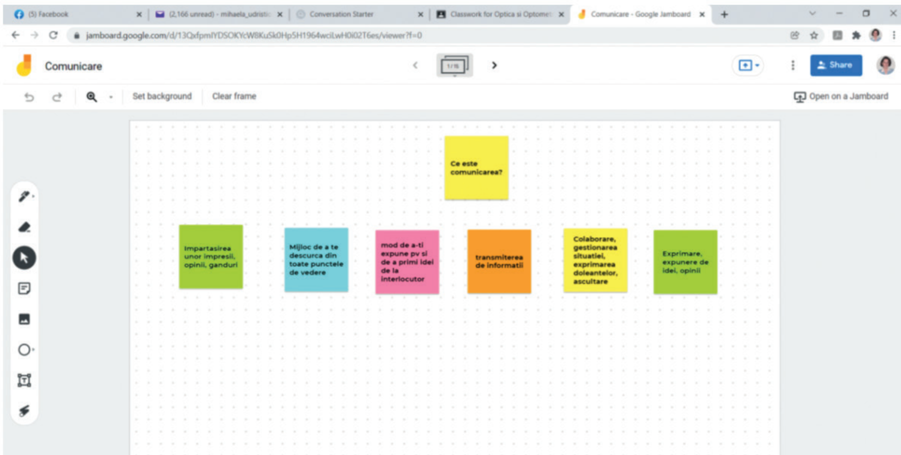


Figure 2.11. Example of print screen with using Jamboard application with Zoom

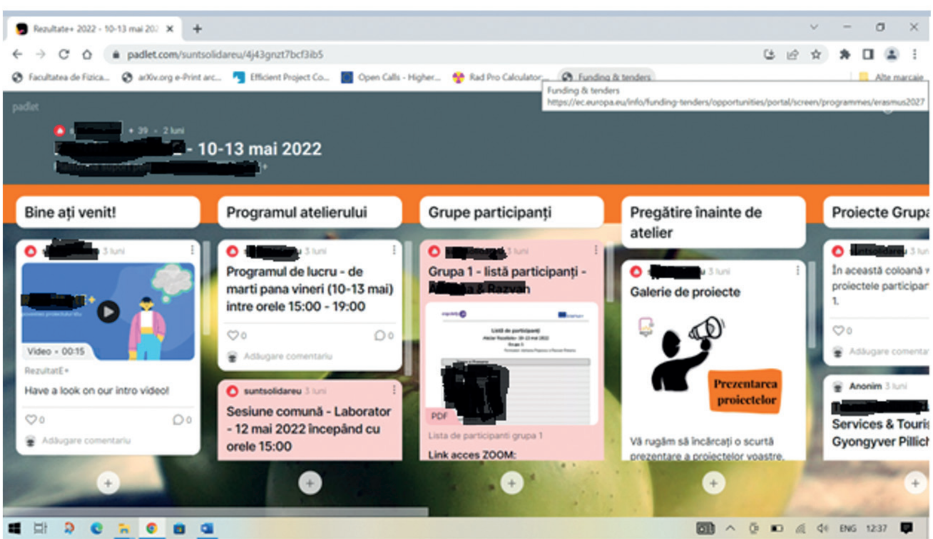


Figure 2.12. Example of print screen using Padlet application, complementary with Zoom

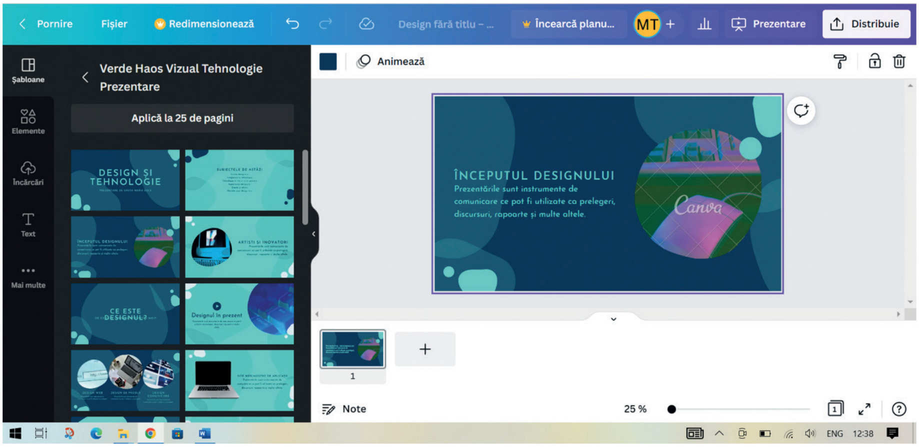


Figure 2.13. Example of print screen using Canva application to design different posters

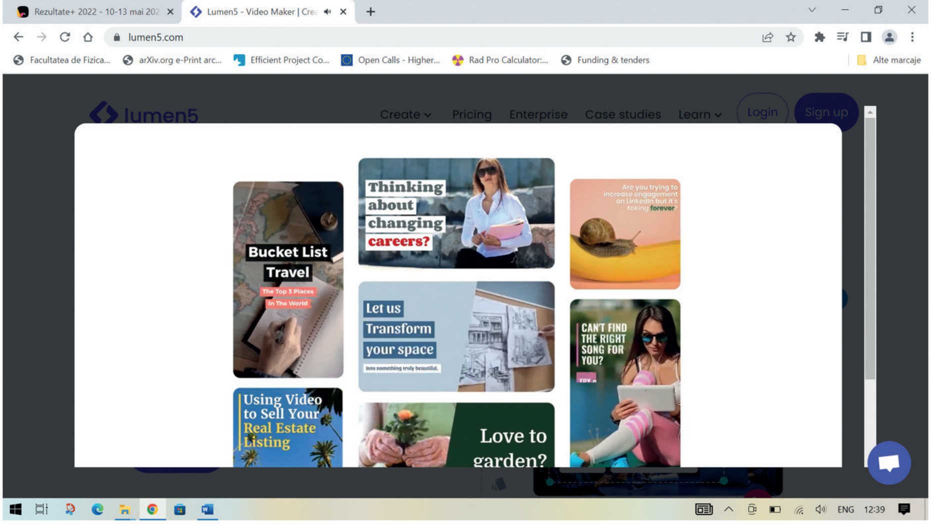


Figure 2.14. Example of print screen using Lumen5 application, especially for short videos

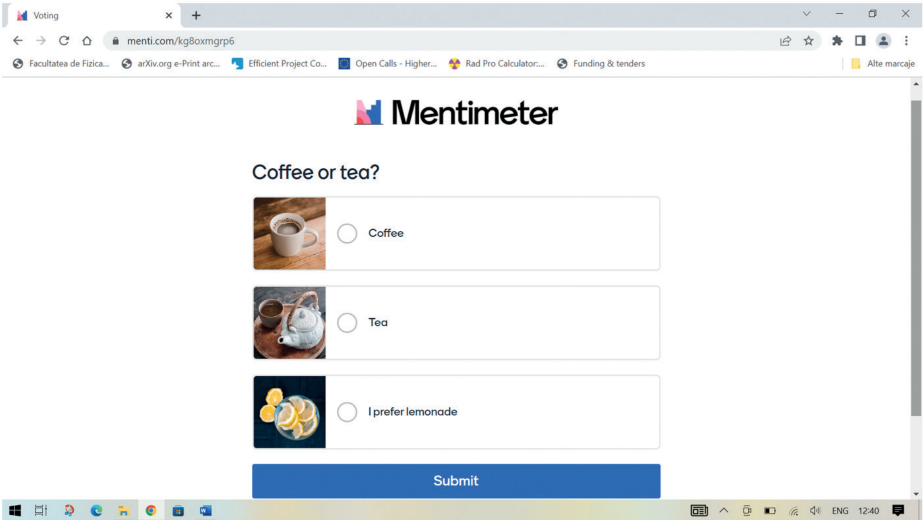


Figure 2.15. Example of print screen using Lumen5 application for interactivity

Indeed, nobody was ready for the impact of Covid19 crisis. Even though the UCv had *Webex* before the pandemic, this application was used only to organize senates, management meetings, and online events (e.g., Faculty of Science Day, Researchers' Night). Faculty did not use Webex for teaching activities, especially for financial reasons.

Sciences and Engineering Faculties involve carrying out laboratories or doing experiments to fix the notions and concepts developed in the courses or seminars. At the beginning of the pandemic, laboratory activities were affected or carried out partially or only demonstratively, without so much impact for the preparation of students, especially those in the first year of the bachelor's degree. After the beginning of the academic year 2020/2021, Faculty acquired some graphic tablets to replace the physical blackboard, and the professors who had classes, as a rule, used helpful graphic tablets. After the partial relaxation of the initial harsh conditions imposed by the COVID-19 pandemic, Faculty were able to arrive at the University (at the office/lecture hall/seminar/laboratory). Some instructors, using laptops and high-resolution external cameras, have started online teaching (demonstration lessons) from their lecture hall/seminar/laboratory. Even so, in the case of experimental subjects, students did not take measurements during the experiment. They only analyzed collected data by instructors, which did not solve the fundamental problem of acquiring technical skills for students. Students did not use the equipment to understand the equipment setup and functions for collecting experimental data, errors, etc.

Progressively, and at the same time as the direct didactic activities carried out online, were also related to Zoom application activities such as:

- Tutoring and/or counseling activities;
- Additional or remedial actions for students who could not participate in various activities;
- Consultations on the disciplines taught;
- Department meetings;
- Working sessions for different activities;
- Activities from projects with/for students, such as internship projects, projects to reduce dropout among students, volunteer projects with the involvement of teaching staff, students, and some companies or partners, etc.;
- Local or national students' competitions;
- Events generated with or by employers;
- Taking the final exams of study programs (license, dissertation, and postgraduate programs) in 2020 and 2021;
- Special events, such as graduation from the study program;
- Accreditation of study programs (even institutional accreditation) coordinated by the University of Craiova, with external evaluators, a process that involved to organize multiple, separate/disjoint online meetings with students, Faculty, and potential employers, in one or more languages;
- School competitions for students from high schools (e.g., school Olympiads, national contests);
- A summer school, for disadvantaged students from high schools, with a duration of 2 weeks, in 2021;
- Courses for middle school and secondary education teachers;
- Conference for Physics teachers from middle schools and secondary education;
- Promotion of two volunteering projects or the educational offer of the Department of Physics and the Faculty of Science (advertising carried out in secondary education).
- International conferences.

Benefits, strengths, weaknesses. The advantage of *Zoom* was that we discovered an effective way of communication when the direct interaction between people (in the current case, the educational sphere) moved to the online environment, with the total elimination of physical participation.

People were connected, no matter how far they were, with some pluses and minuses for the education process. Indeed, we thus had at our disposal a very efficient tool that allowed everyone to connect, regardless of device or operating system.

The Faculty's ability to use *Zoom* tools might increase if some departments of UCv were more involved in training human resources during the pandemic (Continuing Education Department or Teacher Training Department). Even now, there are still many functions unknown to some teaching staff. One of the pandemic's lessons is that human resource needs continuous training.

Some teaching activities (courses, seminars, or laboratories) were recorded by instructors through the *Zoom* application and saved as a movie (e.g., in .mp4 format). These resources are valuable and available now. Students can access them when they have time. The pandemic has led to digital resources that might be useful in other emergencies. It is vital to store these resources and use them further. The pandemic proves that it is necessary to have teaching materials in a digital format. Even before the pandemic, some universities (such as Duke University) taught online to students worldwide.

It was possible to transmit some activities organized on Zoom on Facebook or YouTube. The *Zoom* application has an interconnection facility with other applications. These features increase the visibility of those activities in the online environment, contributing to a much better promotion/visibility of those activities.

In *Zoom* meetings, it is effortless to share information through screen-sharing; during a course or seminar, the instructor can share, successively, the screen of the device from several participants.

Using *Chat*, the instructor can transfer files to the participants. The participants have two ways of communication in a group (visible for every participant) or private. There could be private conversations on the chat, which not everyone could see. The transmitted files can be accessed (saved) only by the participants in the meeting. Through *Breakout rooms,* the instructor can separate a meeting into groups so that the participants from disjoint groups can communicate separately.

A significant advantage of *Zoom* is that it has allowed students and faculty to connect to conferences where the fees were usually high. From this point of view, students' involvement in research could increase. Also, prestigious universities (e.g., Oxford, Duke) organized a series of free courses (or with little money) during the pandemic.

There are disadvantages too. For example, during the pandemic, sometimes the professors connected to several meetings simultaneously because the programming was faulty. It was a lot of work involving much more hours than usual, the degree of exhaustion being significant. All projects had to demonstrate the performance of the activity through *Zoom*. Sometimes, while carrying out the teaching activity, the Faculty could easily forget to release screenshots, which could cause problems later (e.g., to prove on different projects that some activities were organized).

Another disadvantage is that the connection link could reach people from outside who entered the meeting and disturbed or could use the board. In other words, *Zoom* had some security issues, solved along the way. Zoom gave solutions to the instructors: the intruders could be set to "mute" to stop them from transmitting images or even being kicked out of the meeting.

Sometimes, *Zoom* customer service responded late, even if it was a paid Zoom warranty. Any delay in the meeting (related to connection problems) could lead to the non-connection of impatient participants.

Another *Zoom* advantage is that it allowed quite a good service on poor quality connections. Thus, it made our work more flexible and adapted to students' needs. It brought us closer to the students. Students' participation in physical activities after the physical start of classes was not at the same level as during the pandemic. The hybrid version of the lessons proved challenging to achieve because it is difficult to achieve the transmission of information to the video projector simultaneously with the *Zoom* transmission. There were critical sound problems for those online when the instructor used a video projector for those in the hall. Even this issue is solved now.

Hybrid versions of some conferences are more challenging to organize. The advantage is they reduce the costs of participating in conferences, giving students and researchers worldwide a chance to participate.

Why will we use Zoom post-pandemic? In the presented context, according to the new post-pandemic reality, the form of frequent education will allow the didactic and/or research activities to take place combined and successively, both in the university space and through resources/information technologies specific to synchronous online education, in a mixed organizational mode.

The hybrid mode involves learning, teaching, and research activities "face to face" inside the university and using IT and communication resources outside the university space. In the projection and programming of the activities, the observance of the principles of student-centered learning and teaching is considered with the capitalization of the outstanding progress in information technologies to develop innovative learning resources, methods, and environments.

Learning resources can thus be more diverse, accessible, and enriched regarding how to approach the contents and the form of presentation, available at any time to students on IT platforms. Students can also participate in face-to-face activities and benefit from support from teaching staff without moving to the university premises, thus increasing the flexibility of their academic journey and improving participation in tertiary education.

For the individual study, students have permanent access to a secure IT platform, which allows access to the content of the course/seminar, in whole or by study units, in digital format. Thus, students have various resources, such as pre-recorded video courses, course notes in digital format, bibliography with digital access, specific databases, online documentation facilities, simulations, open educational resources (ORE), etc.

National/international competitions were organized free of charge using online platforms. Also, meetings with employers, entrepreneurs, and graduates can occur online on the Zoom platform. The organizers streamed some of these events on YouTube or Facebook and had better visibility.

2.5. The use of the Microsoft Teams platform in education (Miriam Spodniakova Pfefferova, Martin Hruska)

Microsoft (MS) Teams is another platform – next to Zoom, Webex, Google Classroom, etc. –used more frequently during the COVID-19 pandemic. In the time before the pandemic, MS Teams was used to a much lesser extent than it is now, despite providing many possibilities to make teaching more efficient and attractive. Just LMS Moodle was a much more used system.

Although Moodle provides maximum support for distance learning – sufficient space for sharing materials, various information sources, and preparation of tools for obtaining feedback, at a time of many restrictions during the pandemic, it was necessary to start using a suitable tool for online teaching. Several programs were already mentioned in previous parts of this book. At the beginning of the pandemic time, faculty and students of UMB tried many of these programs. Finally, MS Teams was chosen as the only platform where the support of the university IT center was provided (solving various problems, updates, etc.). One of the main reasons was that MS Teams was part of the MS Office software package, a standard part of the software package for working computers at UMB, and there was no need to deal with the purchase of additional software.

Short description of the application. MS Teams is a cloud-based application that combines the apps, conversations, meetings, and files in one LMS. Additionally, the usage of MS Teams has enhanced the teaching-learning process, the faculty's capacity to grade and keep track of the students' activities and assignments, classroom management, and teacher-student interaction. Courses using Teams can be 100 % online, hybrid, or face-to-face. This tool enables a broader range of teacher and student interactions and allows regular, substantive interaction in online courses (Poston, Apostel & Richardson, 2019). One feature of MS Teams is represented by chats. Some group features are known as "teams" with two types of channels: "general and private, assignments, class notebooks, files, tests, and meetings (a feature that is similar to video calling but in bigger groups)" (Juanis, 2020).

Most of the application's activity focuses on working in "teams." By team, we mean a logical grouping of users determined by their social role in the organization (at school). Teams comprise employees, company management, students from a specific class/course, project participants, students, and faculty in the interest group. It is, therefore, a logical (virtual) grouping of people with a common interest or position in the school environment (Microsoft Teams, 2022).

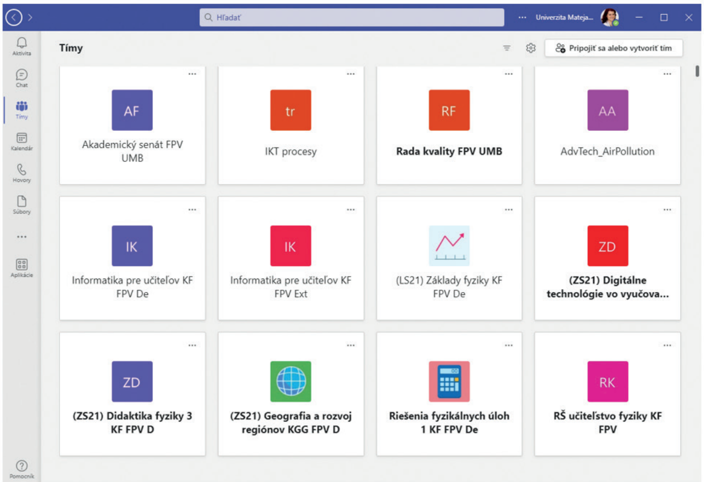


Figure 2.17. A sample of MS Teams desktop app with various teams (teams for educational courses, a team for online communication with university IT support, a communication canal for project team, etc.)

Teams can be established by users with sufficient rights set up for this action in the network from the owner, the network administrator. Within the teams, the own communication takes place in the so-called channels. A channel is an association of a topic-related conversation with other related activities, such as file sharing, OneNote notebooks, Planner timelines, Forms, or other applications that can be added to the channel as additional cards.

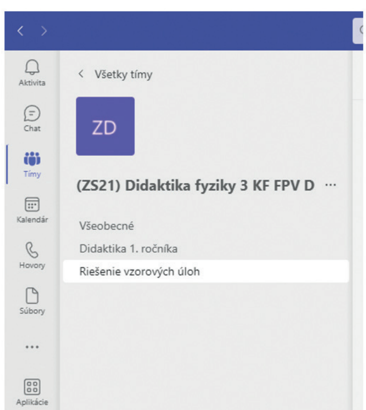


Figure 2.18. A sample of more channels for the different topics of conversation

The Teams application is available for various operating system platforms (Windows, iOS, MacOS, Android) or as a web application. The developers try to maintain the same consistency of control and layout of the application controls on most platforms. Only the mobile version of the application and the desktop version differ significantly from each other (Šindlerová, 2018)

MS Teams for school practice. MS Teams can be used for various purposes, but we will focus on its use in teaching. MS Teams has many functions and additional applications which are interesting just for education (Meet Microsoft Teams, 2022):

- manage learning using conversation or input functions;
- in the "point a finger" conversation - mention a specific user or group of users with the @ sign;
- send private messages to users;
- conduct video calls with individuals or groups (suitable for distance learning);
- easily share files with other users;
- edit one file by multiple users in real-time;
- give pupils "assignments" – tasks that are then quickly submitted and evaluated by the teacher;
- use either a point scale or a verbal assessment or an assessment using criteria to assess students;
- create custom applications based on the PowerApps platform tailored to the school's needs and integrate them into the Teams environment.

The pandemic has taught us to use many tools, such as MS Teams, which were previously overlooked or unimportant. After two years (2020, 2021) of online teaching, we can state, based on the different results of the conducted surveys, that MS Teams has a positive impact on education (Khidir, Sa'ari, Mohammad, 2021) (Juanis, 2020):

- helping interaction between students or between students and teachers,
- increasing learning motivation,
- assisting in learning more effectively, etc.

Like everything, using MS Teams has advantages and disadvantages (e.g., not very user-friendly environment for the first used, limited functions of applications integrated into MS Teams). Despite the disadvantages, using MS Teams brings many positive effects, so it is reasonable to think that MS Teams will remain part of the teaching process even during face-to-face teaching.

2.6. DIPSEIL system at Plovdiv University (Diana Stoyanova)

Distributed Internet-based Performance Support Environment for Individualized Learning (DIPSEIL) is a learning management system (LMS) developed by a team of PU "Paisii Hilendarski." The learning content in DIPSEIL is based on learning tasks. Learning tasks are aimed at solving specific problems. In their solving, the student acquires the necessary knowledge and skills in the relevant discipline [1]. For each learning task, the teacher provides the following:

- Task description (Task description) - contains an explanation of what the student must complete and in what time frame.
- Specific theoretical material (Task-specific training) - contains the critical theory the student must learn to complete the task.
- Reference information (Reference information) - technical diagrams, reference materials, books, WEB links, etc.
- Instructions for performance (Instructions on how to perform) - guidelines for task performance.
- Expert advice - information about possible problems, symptoms, and solutions for all critical situations.

Students perform the learning tasks throughout the semester and collect points for each learning task performance.

DIPSEIL consists of two modules:

1. DIPSEIL Teacher Area - an environment where the instructors can create a new course, add new modules and learning tasks, edit courses, modules, and learning tasks, and access students' solutions (Fig. 2.19).

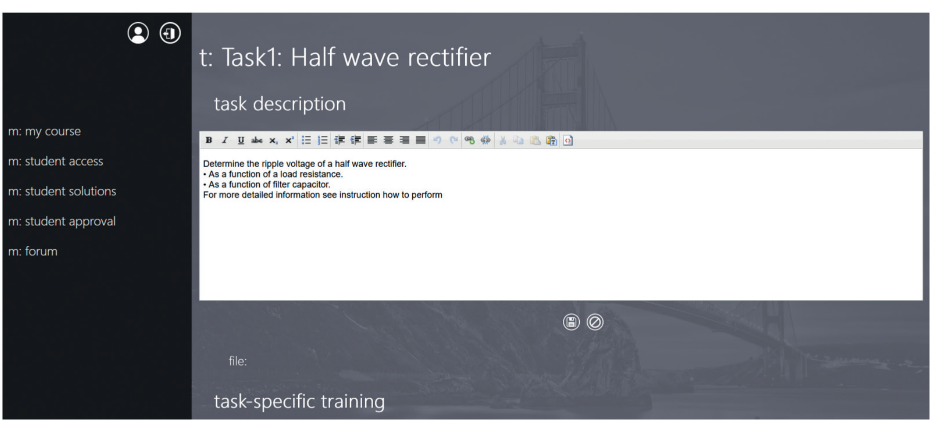


Figure 2.19. Editing a learning task in DIPSEIL Teacher Area

2. DIPSEIL Student Area –environment where the learner can perform the learning tasks and submit their solutions (Fig. 2.20)

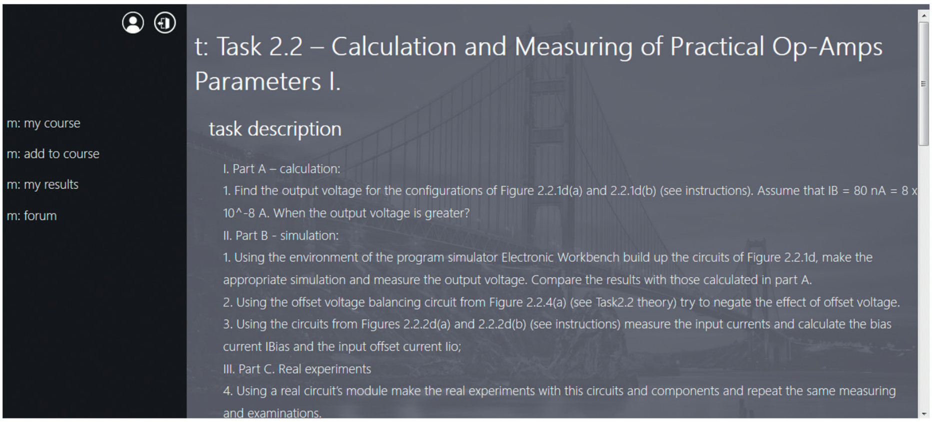


Figure 2.20. Access to learning tasks description in DIPSEIL Student Area

The module Forum in DIPSEIL enables asynchronous communication between students and faculty. The discussion in the forum is at the learning task level. Our long-term experience using DIPSEIL shows that a performance support learning environment is extremely suitable in engineering education because through it, students acquire theoretical knowledge and learn to solve real-life problems.

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CHAPTER 3

THE ROLE OF INTEGRATIVE APPROACH IN THE TEACHING AND LEARNING OF STUDENTS IN STEM SPECIALTIES AT THE UNIVERSITIES

In recent decades, the integration processes in science and social practice increasingly actively influence the development trends in the field of the educational process. The global problems of modernity have an integrating effect on humanity, which is aware of interrelationships and interdependence, the community of nature and social phenomena. Integrative trends are increasingly singled out as specific ways to improve the structuring of learning content to help future scientists and engineers make a more holistic sense of the studied objects and phenomena and differentiated conceptual structures.

The nature of engineering education implies a high level of fundamental training and specialized knowledge and experience consistent with the requirements of professional guilds. Thus, the dynamics in the learning goals of natural sciences and engineering are provoked by the objective processes of professional practices and reflect different levels of integration. This integration is a consequence of the globalization of production and the diversity of products and goods. As a result of studies in natural sciences and engineering, students must have developed creative thinking in interdisciplinary contexts and be able to conduct adequate communication on a range of scientific, technical, and technological issues in line with the increasing complexity of technical systems and new, constantly developing markets.

The International Society for Engineering Pedagogy (IGIP) defines the development of engineering education in the following directions:

- Improvement of teaching methods depending on the development of new SMART technologies;
- Development of practically oriented programs corresponding to the needs of students and employers;
- Integration of language and humanitarian education;
- Acquisition of new communication skills, teamwork, and ethical and inter-cultural competencies.

Addressing the issue of an integrative approach to STEM education in universities is essential, broad enough, and suitable for serious research. Here, we aim only to present the experience of a few universities (UCv, ATU, PU, UMB) related to this topic.

The main goal of integration in education is building a comprehensive picture of the world, developing students' worldviews in intensive correlation with the environment, quality professional training, and strengthening emotional experiences (Andreev, 1986).

In the pedagogical aspect, the integration of education has its foundations in the paradigm of holism. In it, the reality is seen as an integrated whole and not as a collection of disparate elements and fragments. The integration helps to avoid the expansion of the learning content and solve the problem of learning overload to some extent.

While in the middle of the 20th century, ideas of integration are manifested as intersubjective connections, in modern science, integration is at the level of synergy. A transdisciplinary scientific theory of self-organization and organization of complex dynamic processes leads to a vision of the universality of the world. It ensures the dialogue between natural sciences and humanitarian culture. The systematic approach to scientific knowledge is always carried out in interconnected processes of differentiation and integration related to a mathematical unity of the world.

Integrative learning is a realization of the integrative approach, which represents the way to implement integration. On this basis, training is organized and viewed as a system and a process of establishing integrative connections.

3.1. Forms of integration and ways to implement the integrative approach in education (Zhelyazka Raykova)

There are different **forms of integration**:

- organizational, which shapes and strengthens the creation of learning complexes, educational networks, etc.), as a unity of education;
- the educational content, which is related to the integration of the content of various academic subjects in the context of solving life problems;
- of concepts, technologies, and teaching methods Gritsenko L.I. (2012).

Structural and functional integrative tendencies are distinguished.

Structural tendencies are related to the nature of scientific knowledge and the degree of generality and abstractness, associated with integrated (interdisciplinary) courses. Functional integration is centering learning content around an important principle, idea, or theme. The topic-oriented approach is the most frequently presented for qualitative integration and includes work on projects (diploma theses), including knowledge from different subjects and areas.

In pedagogy, two more types of integration are distinguished - horizontal and vertical *according to the continuity* of educational knowledge. Vertical integration ensures continuity between studies at different educational levels –secondary education, bachelor's degree, and master's degree.

One of the most applied ways to implement integration is the implementation of **interdisciplinary training.** Interdisciplinary learning develops as a deliberate attempt to simultaneously apply knowledge, principles, and/or values of more than one academic discipline. A major theme, question, problem, or practice may link academic disciplines.

Learning process is organized around common themes for several sciences and academic disciplines in interdisciplinary integration. Teaching begins with formulating a real-world problem, focusing on multidisciplinary content, and forming general curricular skills (e.g., critical thinking and problem-solving). Thus, the concepts and skills of individual disciplines become interconnected and interdependent, and the boundaries between the disciplines begin to blur. Students are encouraged to realize the application of the disciplines and the significant role of social interactions in analyzing problems. The structure of interdisciplinary learning is consistent with the main characteristics of deep learning, where the learner should participate actively in the process.

Effective interdisciplinary learning can be *individual, within project assignments, or in longer integrated courses of study*, and must meet the following requirements:

- have planned goals;
- to be based on experience and learning outcomes in different learning areas;
- to provide progress in skills, knowledge, and understanding;
- to provide learning opportunities at different levels in different areas, integrated into the set learning tasks [IGIP].

What are the **training methods** for implementing the integrative approach in training?

Since integrative trends are dynamic and functional, combined with excellent mobility of didactic phenomena, they also imply a great variety of methods with the help of which training is realized.

Many **traditional methods** have the potential to meet the requirements of this approach if they meet the condition of contributing to the full expression and realization of integrative trends in education. They are related to the activation of the overall participation of learners in the learning process.

Modern methods take on a stylish appearance with the widespread entry of information technologies into life, attract more and more followers among educators and researchers. Some of them play a leading role in implementing the integrative approach.

The tasks of integrative learning are solved most successfully when the learning is implemented along the path of discovery, i.e., using the **research method**. This method is an essential part of inquiry-based learning that builds new knowledge.

The application of the project method and its variety, **project-based learning** is a method that acquires a modern appearance by applying information technologies. The project activity aims at the united achievement of a clearly set goal. The main elements of any project are – activity, integration, and purpose. The projects are related to the student's life interests, and applying this method makes the knowledge whole, unified, and integral (Andreev, 1986). The boundaries between individual subjects are crossed, and learning integration occurs.

The integrative approach is also related to applying the **problem-oriented method** (problem-based learning). It is based on inductive or deductive evidence and requires processing the learned information to obtain new information and solve the problem. The integrative trends here are contained not only in the subject knowledge and skills but also in the general academic skills that are important for the student's personal growth.

With the methods listed above, it is essential to emphasize that they are predominantly **practical in orientation**. This orientation allows students to conduct experimental work, work in the field, analyze collected data, and explain and predict.

Realizing integrative tendencies requires implementing **cooperative (joint) learning** structured through **teamwork**. Working together, students receive informal training in social skills and become convinced that human knowledge is produced by many scientists from different fields through joint activity and collaboration.

All these methods are designed on constructivist ideas, and each has different opportunities and limitations in integrating learning. Teaching methods are dynamic and constantly repeated following the development of society and technology, and therefore it is not appropriate to seek and justify any correlation between them.

What are **the reasons** for implementing the integrated approach in STEM education in higher schools?

- Need for integrated training for the fronts of science.
- The growth of world interconnectedness (globalization), global problems, and our obligations to find the right solutions require a direct connection of education with global issues.
- Environmental issues, which are gaining increasing global importance and have a solid social resonance, have their place in the education of science and engineering specialties. As a result of this integration and on its basis, the work on the project "Applying some advanced technologies in teaching and research, in relation to air pollution" was organized.
- Students can choose subjects relevant to their interests. The number of academic disciplines at each teaching stage is reduced. The boundaries of the various academic disciplines in the field of STEM are changing, and new ones are emerging. The integrative approach in science increases the transformation of teaching, i.e., students more easily notice the internal relationship between

concepts, principles, and concepts because the idea is followed that the structure of knowledge reflects the design of the individual science.

- The integrative approach enables different scientists to plan and teach together, increases cooperation, and strengthens the connection between knowledge obtained in life and higher education Raikova, Zh. (2019).

The following can be mentioned as **basic ideas** in STEM education that provides integrated learning:

- Training should have a *strong character*. The process of studying STEM subjects should not only be a preparation for life, future realization, or profession but a whole experience for every student.
- Education in physics and engineering specialties should be *active.* Integrative trends in physics education should be seen in the context of constructivist ideas. The central premise of constructivism is that the integration of knowledge is not passively accepted but develops as students construct their knowledge. Learning through activities is a significant component of constructivist theory. The spontaneous activity must be leading and not determined by external prompts and stimuli. The idea of activity is related to *self-study and group work*. The activity of the students has an accurate and educational result only if they are busy solving their problems and satisfying their interests.

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Actualization of Integrated STEM Degree Programs: A Model to Inform, Catalyze, and Shape Inter- and Trans-Disciplinary University Education APEC Human Resources Development Working Group September 2021

3.2. Integrative trends in the education of STEM students at the four universities participating in the project (Zhelyazka Raykova, Mihaela Tinca Udristioiu, Ece Yilmaz, Janka Raganova, Yunus Çelik, Hasan Yildizhan)

The experience of the four universities participating in the project is systematized in the following aspects:

- **Formal integration:**
  - The inclusion in the curricula of study disciplines that allow integrative learning and the formation of modern competencies.
  - Conducting classes with specialists from fields not specific to the student's professional training.
  - Carrying out joint initiatives with different specialists from different fields.
- **Content integration:**
  - Inclusion of the learning content of some specific professionally-oriented learning disciplines, knowledge from another science, or another scientific field.
  - Work on integrative projects.

FORMAL INTEGRATION

- ***Inclusion in the curricula of disciplines that allow integration***

At the **UCv**, **Department of Physics**, the facultative subjects in Bachelor programs (Computational Physics and Medical Physics) are History of Physics, Programming concepts for physicists, Foreign language (French and English), Oscillations and waves, Data acquisition and processing systems, Astrophysics and cosmology, Transmission of information through optical fiber, Biochemistry. In master programs, there are no facultative subjects in the curriculum.

Foreign languages are essential for students because both master programs (Theoretical Physics, Applied Physics) are in English. The most critical part of scientific literature is in English, so students should improve their skills in foreign languages. Romania is a francophone country, so many students want a study experience in France. Also, there are international events for students in English (summer schools, conferences, seminars). They should be able to communicate in a foreign language because comprehension and communication are essential. Another aspect is that each university needs internationalization, relations with other universities, exchange of experience and good practices, and project research. In the framework of the Erasmus+ cooperation, there are mobilities for students and faculty and projects conducted in foreign languages.

Programming concepts for physicists, Data acquisition, and processing systems are important for students to handle data provided by measurements during lab activities and to program sensors developed on Arduino or Raspberry PI during Electronics laboratories.

In the Oltenia region, a company (Prysmian Group) focuses on producing optical fiber, so there is a course in this field. They need graduates who understand how can be made quality assurance for optical fiber. In Craiova, 25 companies and firms are activated in ICT, requiring highly skilled programming graduates. At the request of the companies were added subjects in this field.

History of Physics is necessary for students to understand how evolved knowledge in Physics, which is the role of theory and experiment in knowledge, to understand nature from the physical point of view.

The course "Oscillations and Waves" aims to help students understand how an oscillation propagates in a free space or a material environment. Students should understand the features of waves. Medical physics graduates might work in an environment with ionizing radiation and need to understand wave-particle duality for X and gamma radiation, electrons, protons, etc. Also, there is a postgraduate course in Acoustic and Audiology that helps students find jobs in another niche field, audiology.

There is a successful course in Celestial Mechanics for Physics and Mathematics students in the third year of the bachelor program. It is a good combination of knowledge for both programs. At UCV, there are telescopes and a planetarium for practical activities.

At **ATU, Department of Engineering,** the facultative subjects in the Bachelor programs are Tourism Geography of Turkey, Introduction to Economics, World Economy, Introduction to MatLab for Engineers, Organizational Behaviour, English for Academic Purposes, Mining History, Environmental Problems, History of Science, Strategic Management, Management, and Organization. In master's programs, there are no facultative subjects in the curriculum.

The British Council has designated the university as one of five pilot universities in Turkey for the "Program for Improving the Quality of English Education in Higher Education" established for higher education institutions.

Furthermore, it offers an English education accredited by "Pearson Assured," ensuring excellence. Except for a few disciplines, ATU offers a completely English-based education. As a result, many departments have international faculty members.

As a result, English instruction is critical for ATU students. Furthermore, because the programs are given in English, many students are interested in participating in international exchange programs. In addition, other English activities are carried out by student clubs at the university. Members of the club, for example, plan speaking club activities. Various organizations are also held with the participation of Erasmus students. Such exercises are highly beneficial to students' foreign language development. Student and academic mobilities from the Erasmus+ programs are critical and helpful now.

The history of science and programming such as MatLab, is significant for engineering students. In addition, the fact that there are courses in social sciences in the curriculum gives students a multidisciplinary perspective. It provides beneficial information for engineers who will take on managerial positions in the future. In addition, providing an academic English course is very important in improving the student's academic English level. Thus, if students want to advance in the educational field in the future, they will have formed their foundations. The history of science is necessary for students. They have to understand how knowledge develops, the role of theory and experimentation, and how science evolved from the past to the present.

The need for people who know to program in today's conditions has been a pioneer in adding Matlab to the university curriculum as a course. Since Matlab is an essential programming type in all engineering departments, it is seen as a sought-after skill in today's employment.

In the **Faculty of Physics and Technology (FPT) of PU**, students study optional subjects, which, according to the requirements of the National Accreditation Agency of Bulgaria, must be 4 % of the total number of subjects (about 90 hours). Students choose and study three of the optional subjects during their undergraduate studies. These academic disciplines must be different in content from those closely related to vocational training.

The ones for the physics majors (Engineering Physics, Eco-energy Technologies, Medical Physics, and Technologies in Telecommunications) are Specialized English Language, Foreign Language - Russian, German, Economics, Business Communications, Human Resource Management, Creativity, Responsibility and Leadership, Technical Safety, Economics of Technical Change, Innovation and Entrepreneurship, Biomedical Ethics, Psychology, Technical Documentation with AutoCad.

For the engineering majors (Information and Computer Engineering, Telecommunications and Information Technologies, Telecommunications with Management), the optional disciplines are Specialized English, Foreign Language, Business Communications, Economics of Technical Change, Innovations, and Entrepreneurship, Marketing Studies, The New Times in Europe: scientific, applied and social ideas, Sociology of science and technology, Sociology of traditional and modern societies, Contemporary risk societies: a sociological analysis, Introduction to psychoanalysis, Technical English, Presentation and communication skills, Technical safety.

Learning foreign languages is vital for future specialists who graduate from the faculty. A good command of the English language provides them with opportunities to continue their education in master's programs in English, both at FPT and around the world. Their potential opportunities for participation in Erasmus international student exchange programs also require a good command of the language and the formation of technical and scientific documentation (articles, participation in international conferences, etc.). Finding a job in the specialty of the many multinational companies in Bulgaria is also a motivating factor to learn foreign languages.

Including economic disciplines (Economics, Business Communications, Human Resource Management, Creativity, Responsibility and Leadership, Technical Safety, Economics of Technical Change, Innovation, and Entrepreneurship) in the curriculum allows students to gain knowledge. It will expand their training for the actual conditions in both industry and business.

The economic, financial, and managerial literacy of students, future physicists, and engineers is a condition for forming key competencies such as "Civil and public competence," "Initiative, and entrepreneurship." The other academic disciplines are directly related to the personal growth of the students - "Independence and responsibility," "Personal and social competences and learning competence", and "Presentation and communication skills." The inclusion of disciplines with social content such as "The New Time in Europe: Scientific, Applied and Social Ideas", "Sociology of Science and Technology," "Sociology of Traditional and Modern

Societies", "Contemporary Risk Societies: Sociological Analysis," complement the general educational preparation of students and create the integrative nature of learning.

The Faculty of Natural Sciences, UMB, provides two kinds of study programs. First, it has a long tradition of training teachers for primary and secondary schools in natural sciences (Biology, Chemistry, Physics, Geography), Technology, Mathematics, and Computer Science. The faculty also offers non-teaching study programs, for example, Environmental Biology, Forensic and Criminalistic Chemistry, Applied Computer Science and Software Development, Geopotential of Regions, Mathematics of Data Analysis and Finance, Applied Geosciences, Geochemistry (Ph.D. study program), etc. The integrative approaches are applied in both kinds (teacher training and non-teaching) study programs.

First, the character of some of the programs themselves is integrative. For example, Environmental Biology integrates knowledge and methods of environmental science and biology. Therefore, this study program is provided by the Department of Biology and Ecology and the Department of Environmental Management. Geochemistry integrates two fields of nature study: geology and chemistry. Another example is the Data analysis and Finance study programme that integrates knowledge of one of the STEM branches with economics studies.

Although the system of science teacher training follows a separate way of teaching sciences (Biology, Chemistry, Physics) at primary and secondary schools in Slovakia, integrative approaches can also be found in the teacher training programs. Physics is considered the basis of all other natural sciences; thus, physics lessons form a part of the curricula of Biology and Chemistry study programs. And vice versa: physics students can gain knowledge of chemistry within a particular course arranged just for them.

In addition, all Faculty of Natural Sciences students have an opportunity to profile themselves by selecting courses provided by any department within the faculty or even within the University. The Department of Physical Education and Sports of the Faculty of Arts undoubtedly provides the most popular courses. Thus, the University supports students' intellectual and physical development and outlines the importance of physical activities to students of all branches.

Moreover, the Faculty of Natural Sciences provides a set of optional courses for students at all study levels (bachelor, master, Ph.D.) that aim to develop students' general knowledge, soft skills, and life competencies. At the bachelor level, such courses include, for example, courses dedicated to developing students' mathematical or English language skills, developing their financial literacy, management, and communication skills, etc. Special attention is given to developing student skills to use digital technologies first as practical tools in the learning process and later as a tool supporting research. Several optional courses are focused on environmental issues: Global environmental problems, Biodiversity – news in its protection, Earth's ecological system and its present changes, etc. Students can also gain knowledge of rational nutrition, first aid, and the prevention of drug addiction. A significant group of optional courses consists of courses that aim to educate students – future researchers and STEM specialists – in the methods of gaining and processing experimental data and to develop the skills necessary to conduct independent research projects: Elementary statistics and probability, Algorithms, and programming for non-computer specialists, Selected methods of measurement and analysis data in the natural sciences (FPV UMB, 2022).

The last-mentioned course was included in the set of optional courses provided by the Faculty of Natural Sciences UMB as a result of the international Erasmus+ project AdvTech_AirPollution. This intensive course is an introduction to how to collect data with the use of sensors based on microcontrollers. Students can participate in the summer school organized by UCv, gain practical skills and experience in designing, building and programming the sensors, and gain insight into how to process the data given by sensors (Udristioiu, 2022).

The optional courses offered to students at magister level enable students to gain knowledge and skills either in a specific scientific area or in a general topic important to students of all study programmes, such as statistics, ethics, research methodology, etc. (FPV UMB, 2022). Some courses focus on using advanced technologies in science – Virtual technologies in Geography, microcontrollers in education, Molecular modeling, and others.

As examples of voluntary magister courses that are built upon integrative approaches, we can mention three courses. The first is a top-rated course, "Myths and superstitions in natural sciences" that aims to develop students' critical thinking in connection with typical myths, superstitions, hoaxes, and misconceptions in the natural sciences. The course intends to increase students' ability to apply critical thinking and knowledge of natural sciences to everyday life. Thanks to a series of interactive lectures focused on discussing selected myths in the field of natural sciences, students can identify reliable sources of information, test the presented solutions critically, and argue to support their positions and attitudes. The discussed themes and topics include research failures (thalidomide and others), homeopathy, vitamin C, miracle drugs without a prescription, natural = safe, and glutamate. Students also work with exciting myths of the Internet environment, such as "healthy" nutrition, miracle diet, etc. (Budzák, 2022).

Another popular optional course among Physics, Chemistry, and Biology students is Integrated science through experiments. This course was incorporated into study plans at the Faculty of Natural Sciences as a result of an effort to encourage applying a more integrated approach to the sciences and to provide physics, biology, and chemistry students with a greater understanding of natural phenomena. The teaching and learning materials used within the course include the integration of science curricula in two meanings: an integration of knowledge and methodology of physics, chemistry, and biology, as well as an integration of various real and virtual computerized methods of experiments. Students learn investigative activities, in which they can study life science processes using computerized data-logging tools. The themes were chosen to illustrate the integration of natural processes and cover topics such as the Origin and development of the universe, the ordered universe, Energy, Colours of nature and color vision, Imaging technologies, Chemical bonding, Carbon in non-living and living nature, Life, molecules of life, Cells, nature, and diversity of cells, Classical and modern genetics, Earth and other planets, solar system, evolution, Earth dynamics and earth cycles, Ecosystems, radiation in everyday life, thermoregulation in living organisms, environmental measurements, etc. (Holec et al., 2004).

An integrative course, Advanced Technologies to process big data in Science, was incorporated into curricula at the Faculty of Natural Sciences in 2022/2023 due to the international cooperation of four partner countries within the AdvTech_AirPollution Project. The course enables students to obtain a comprehensive overview of data analysis methods and approaches and the field of big data. After completing the course, the student can choose and use the right tools for processing a data analysis, interpret the achieved results and evaluate their reliability (Duda, 2022). The students are trained to process the data using data sets from sensors monitoring air pollution. Therefore, besides digital skills, students will also develop green and STEM competencies required by the research and industry (Udristioiu, 2021).

- ***Conducting classes with specialists from areas that are not specific to the professional training of students***

Once or twice per month, each department of the **UCv** organizes meetings, inviting graduates and professional models in their careers. These meetings represent a bridge between generations that makes the exchange of experience between students and graduates easier. Each department organizes debates and presentations on topics like green energy (nuclear fusion and fission, solar and wind energy), laser applications, plasma, refractive issues, colour, and electronics. Experts from Optometry give lectures and presentations, Optometry being a niche field where our students can find easier a job. Specialists from Radiotherapy and Nuclear Medicine give presentations to Medical Physics students or teach different subjects to the students from the postgraduate course in Radiotherapy for Medical Physicists. Practice in Optometry and Radiotherapy is done only with specialists from these fields. Associate researchers from climate change, weather, and environment help students understand why climate change adaptation and mitigation are crucial for each community. The purpose of these meetings is to help students to find out fields where they might work after graduation and to help them to think "out of the box". Their exposure to different ideas and concepts contributes to developing their multidisciplinary and open thinking.

Also, there are organized meetings with employers where trainers, PR specialists, engineers, and experts in different fields from different companies and firms (in Optometry, Radiotherapy, Nuclear Medicine, Medical Imaging, and ICT) can participate. Students can find out truthful information about potential jobs, employers' expectations, internships, and projects that will be developed at companies in the following years. Students visit local companies to appreciate if they want to work or have trained there. It is part of their orientation program.

Students' scientific communication sessions are organized annually, and students can present their fields of interest. At these sessions, students from all faculties can participate. Science Faculty students participate in the sessions organized by environment branches from Engineering or Horticulture and Agriculture.

Moreover, the UCv has a research infrastructure in Applied Sciences, and bachelor and master students can apply for scholarships. Some Ph.D. students work there, taking measurements and analyzing data in those modern research laboratories. Incesa hub is well connected to the needs of the local companies, developing together some research projects. Bachelor and master students visit this infrastructure once or twice during their academic program.

At **ATU,** academicians from other faculties who are experts in their fields or people with specific experiences in the sector are selected to give elective courses to our students. At this point, the selection criterion is that the individual is competent in his field. Professional knowledge and experience are considered. It is for preferring qualified people and transferring healthier and more helpful information to students. People with expertise in the subject area for many years have sufficient knowledge to deal with the relevant subject at many points. In addition, students can visit and use the laboratories of other departments if needed. In addition, the career center of our university regularly hosts important names from the sector and organizes seminars every week. This seminar is held on Instagram and aims to broaden the perspective of students from all departments by participating in such activities. In addition, various training is organized by inviting people from the sector to the university, and students who wish can participate in these activities by announcing each faculty.

Organizing such activities is very important for the development of students toward business life. Students can get answers to the information they have learned theoretically and to which degree they are used in the sector. It is beneficial in terms of knowing what awaits them in the industry after graduation. In addition, at these events, authorized persons explain their companies' job and internship opportunities. Some students do their internships through these events. Based on this, it can be stated that these activities provide positive results for students in many respects.

Events related to some of the university's nine faculties are held almost every day at the PU, in which all university students have the right to participate. In the auditoriums of the university, many and varied meetings are held with famous personalities of the day - from ambassadors to prominent scientists, authors of books or notable athletes, artists, etc. Given the location of the Faculty of Physics and Technology (FPT), whose laboratories and classrooms are in the central building of the university, information about these events is available to our students, and they benefit from this convenience.

The dean's management of the FPT has organized meetings with representatives of large companies that deal with human resources and finding a job. Training is also scheduled for students on the requirements for conducting job interviews or preparing documents, etc., taking advantage of the practical experience of specialists in this field.

The classes of some of the disciplines of the specialty "Medical Physics" are held at the Medical University in Plovdiv. Students conduct practical classes in operating imaging laboratories together with future doctors. Communicating with specialists from this field is extremely useful for their professional training. Taking them out of university classrooms and laboratories, where classes are traditionally held, increases students' interest in their major, allows them to compare with students from other higher education institutions, and motivates them to study more consciously.

At **UMB**, we believe that understanding interrelationships and interactions in different fields stimulates student personality development. It is also essential to provide students a chance to think in broader contexts, not leave them to live in a "bubble," far away from real society.

Therefore we encourage students to visit lectures and workshops given by specialists from various fields outside the Faculty of Natural Sciences, such as economists, technical experts, specialists in pedagogy, etc. These specialists often come from other regions in Slovakia, the Slovak Academy of Sciences, or foreign universities.

We also organize excursions for our students to various organizations where they could work after their studies, such as the Slovak Environment Agency, Slovak Academy of Sciences, different private companies and NGOs, Townhall, Slovak Hydrometeorological Institute, Banská Bystrica Astronomical Observatory, etc.

- ***Conducting joint initiatives with different specialists from different fields***

During the pandemic, some conferences were online and without taxes, giving students a chance to participate. It was an opportunity for those students interested in research to collaborate and publish with their mentors. Students made measurements, collected data in our labs with specialists, and analyzed them. Such students become independent and learn how to write a paper.

At the **UCv** have collaborated on Medical Physics with students from the Medicine and Pharmacy University and on Environment with students and academic staff from Horticulture, Agriculture, and Electric Engineering Faculties. Moreover, students were invited to participate in conferences, workshops, and summer schools organized by professional associations (SEENET-MTP, EFOMP, CFMR). It is a chance for students to know students from different countries, cultures, and faculties. These experiences make students more flexible, develop their communication in foreign languages, and listen to or work with international specialists.

Many seminars and conferences are organized within the **ATU, Turkey**. The Career Centre unit, responsible for such activities, organizes many different and comprehensive conferences and workshops for students in many fields, announces these events throughout the university, and offers all students the opportunity to participate. The events held during the pandemic period were held online through platforms such as Instagram, Zoom, and Google Meets. It aims to reach students from every department, especially by trying to realize it through Instagram. After the pandemic, online training and conferences continue, and many face-to-face events have begun to be organized. In addition, students or academics from many different fields can find the opportunity to be involved in projects or research carried out at ATU. Students from various departments are sent to the Erasmus projects carried out. In addition, academicians from the faculty of engineering, faculty of business, and foreign languages are involved in current projects.

Students of the **Faculty of Natural Sciences UMB** have an opportunity to work in specialized laboratories of important business companies, such as Continental Slovensko, IBM, and the metal factory in Podbrezova, etc. A very important is also international cooperation with universities under the Erasmus+ program. Students from the Department of Computer Science visit, for example, specialized laboratories of Oulu University of Applied Sciences in Finland. Ph.D. students conduct their research also in labs at the Slovak Academy of Science and visit partner universities, for example, in France.

Faculty of Natural Sciences UMB students have a chance to participate in research projects conducted by researchers and faculty departments financed by national grant agencies. Students are also encouraged to join at a student scientific conference that we co-organize with our partner Constantine the Philosopher University in Nitra. Students present their research work results and compete for the best student research project. Such student conferences are organized internationally with partner universities in the Czech Republic in some science fields. Students can also present their results at scientific conferences in Slovakia and abroad, such as Didinfo (http://www.didinfo.net/), Informatics (https://

informatics.kpi.fei. tuke.sk/), Information and Digital Technologies (https://idt.fri.uniza.sk/) or Conference for young hydrologists organized by Slovak Hydrometeorological Institute.

CONTENT INTEGRATION

- ***Inclusion of the curriculum of some specific professionally oriented courses, knowledge from another science, or another scientific field***

In the Physics curriculum, Bachelor Program at **UCV,** there are courses in Mathematics given by lectures from the Mathematics department, Anatomy given by lectures from Medicine and Pharmacy University, Chemistry provided by lectures from the Chemistry Department, Programming and working with databases given by specialists from the Computer Science department. The language of sciences is mathematics, and it is normal to have such a collaboration. Medical Physicists need to know to read and understand computed tomography, and a partnership in a bachelor program with faculty from Medicine is mandatory. Also, there are courses in Physics in engineering programs. As a tendency, the number of practical applications and laboratory classes decreased significantly during the last ten years. The explanation is to reduce faculty costs in Romania's finance per capita framework.

In the Electrical and Electronical curriculum, Bachelor Program at **ATU**, there are courses in Mathematics given by lectures from the Materials Engineering department and Environmental Problems provided by lectures from the Bioengineering department. In the mechanical engineering department, Mining History is presented by Mining and Mineral Processing Engineering lectures. In the industrial engineering department, there are courses in introduction to economics and world economy given by academics in the business administration department.

In the curricula of the physics and engineering majors of the **Faculty of Physics and Technology of the PU**, study disciplines are included, the content of which has an interdisciplinary nature. The knowledge that is obtained in mathematics courses is the language in which the physical phenomena and regularities and the theoretical foundations of telecommunication technologies are taught.

Many of our engineering majors also require knowledge of chemistry, which, apart from being a separate study discipline, is included in the content of specific disciplines. This thing applies in full force to the "Eco-energy technologies" specialty. The content of most fields in the Medical Physics major is closely related to knowledge of human biology, anatomy, and physiology. This knowledge and some practical skills are formed in the laboratories of the Faculty of Biology by qualified persons in the biological and medical sciences field.

Teaching some academic disciplines related to the student's training from Telecommunications with Management" specialty is carried out in the context of some social sciences such as - management, business communication, labor law, and the basics of human relations (public relations). The faculty are qualified persons from the university's Faculty of History and Social Sciences. Some of these classes are co-taught with students from their majors, allowing our students to interact with them and discuss common topics.

- ***Work on integrative projects***

UCv has a few integrative research projects where students from Ph.D. programs are included. Ph.D. students from Chemistry and Physics collaborate frequently. Students must cooperate because they will listen to other opinions and notice the same issue from many angles. These shared experiences might become the basis of future research connexions and the key to multidisciplinary projects.

There are collaborations with Engineering Faculties and Chemistry Departments, and bachelor students from these faculties use Physics laboratories and mutual. Another type of integrative project developed at the UCv is represented by volunteering, sponsored by different local companies. For example, students from Physics, Journalism, and Medicine developed campaigns in mass media about the importance of clean air for the population's health or how vital ophthalmologic screening is in detecting vision issues at early ages and preventing early school leaving. Moreover, students become more responsible and active in their communities.

Summer schools from this Erasmus+ project might be an opportunity to involve international students from Science, Computer Science, and Engineering in a joint effort to understand how is made and working a sensor for air quality monitoring. Students will practice under academic staff supervision, making such a sensor, programming, connecting the sensor to a European independent network of sensors, data collecting, processing, and analyzing data. Simultaneously, during these summer schools, students meet specialists from different fields connected with environmental protection.

ATU has several integrative research projects in which students from different faculties find space to work together. Students from computer engineering, software engineering, and electrical and electronic engineering departments often collaborate. Collaboration of students is very beneficial. Because students from different departments come together and participate in the same project, giving a different perspective. Such collaborations can be the foundation of future research and essential to multidisciplinary projects. In addition, there may be projects in which mechanical engineering and energy systems engineering students participate jointly. In addition, students from different faculties can participate in a joint project with companies the university has contracted through applied training.

The summer school in this Erasmus+ project is a significant opportunity to involve students from different departments of the Engineering faculty in a joint project to understand how a sensor works. Students can present their ideas on how sensors work from many perspectives, offering different views.

PU has conditions that stimulate the integrative nature of scientific projects that apply for university funding. There is also a certain quota for funding student projects only. FPT students have won competitions for this funding many times. Such projects are: "Bio polyelectrolyte nanoparticles for immobilization and controlled release of curcumin," "Building a laboratory for simulation and experimental research in electrical engineering," "Design, Analysis, and Fabrication of CNC Router Rotary Table Realizing Fourth and Fifth Axis," "Building a system of educational Internet resources in physics and evaluating its didactic value."

Every year, university-wide scientific research projects receive special funding, in which the condition is that specialists from more than one faculty participate and, accordingly, there is a reserved quota for the participation of students and doctoral students. In recent years, one such project was the "Bio design and Bio-economy" project for the "University Projects - Green Technologies" competition. In this project, the participants are from 7 faculties of PU.

The joint work of scientists and students on an interdisciplinary project is an example of an activity of an integral nature. Solving separate tasks that combine topics from several scientific fields allows students to get a broad overview of the areas of application of their professional training and form their vision of the integral nature of modern science and technology.

Faculty of Natural Sciences UMB students are invited to participate in interdisciplinary projects in collaboration with several faculty departments. A partnership between the Department of Computer Science and the Departments of Chemistry and Biology is the most common and fruitful. Some of its results were introduced in Chapter 1.

Some options for future development of integrability in the four universities

The level of integration will be improved during the following years. International courses for students and academic staff, exposure to diverse approaches, and exchange of good practices are real chances to intensify this process.

In the framework of this Erasmus+ project (code 2021-1-RO01-KA220-HED-000030286, Applying some advanced technologies in teaching and research in relation to air pollution) will be organized **three international courses** for academic staff in "*The capabilities of the technology of augmented reality on mobile devices within the process of data acquisition,*" "*Introduction in AI and statistics with practical examples*" and "*An introduction in ML and a practical demonstration about how can be used ML technology for the modeling of radiation emitted by green sources of energy*."These courses will represent an opportunity for researchers to work together, exchange ideas, and find new things regarding advanced technologies that might help them in their research. Faculty will visit other university facilities to find solutions to apply together on other projects or to develop different research studies.

„If our small minds, for some convenience, divide this glass of wine, this universe, into parts — physics, biology, geology, astronomy, psychology, and so on — remember that nature does not know it!" [Source: https://quotepark.com/quotes/1921667-richard-feynman-if-our-small-minds-for-some-convenience-divide-t/]. We agree that if we want to understand nature, we have to start thinking in an integrative way.

ATU will be able to integrate students from other departments and universities in the following years. This integration is made possible by the current project. For example, organizing foreign courses and summer schools for students and academic staff as part of the initiative improves integration.

In **Bulgaria**, the National Accreditation Agency's requirements for modernizing the educational process are directly related to introducing the competence approach. The formation of the critical competencies and those associated with the professional direction should be the result of the studies in the bachelor's degree. This thing necessitates a new look at the curricula and their related educational content, which will lead to strengthening their integral character. Any modernization of the educational content in physics and engineering specialties is related to the latest achievements in science and technology, which are predominantly integrative in nature.

The rules of the project activity at the **PU** will continue to tolerate a project of an integrative nature with students' participation, which will ensure sustainability in the trend for the integral character in the education of future physicists and engineers.

Both formal and content integrations have been applied in newly accredited study programs at the **Faculty of Natural Sciences, UMB.** Several study programs have been introduced that are integrative by their nature. Students at all study levels can choose from a wide range of integrative courses that aim to develop their general knowledge, soft skills, and life competencies, such as mathematical or English language skills, financial literacy, management and communication skills, green competencies, competencies to use digital and other advanced technologies, etc. Creating study groups of students of various specializations has brought a valuable exchange of views and ideas and contributed to developing student critical thinking. Integration approaches have contributed to the training and education of "integrative" personalities that will contribute to society's future development.

The articles in the literature also describe negative results from applying the integrative approach, such as the lack of systematicity that characterizes scientific knowledge and the superficiality of training since theoretical thinking is not formed in sufficient completeness. It is believed that interactivity is challenging to combine with the consistency and orderly logic of scientific knowledge in the subject (Thibaut L. et al., 2018, Lamanauskas & Vilkoniene, 2008, Lamanauskas, 2009).

The world experience in applying the integrative approach in education is diverse, rich, and specific for each country. There is no country whose experience in integrating education has been highly effective or completely ineffective. Borrowing from the experience of other countries needs in-depth analysis and skillful adaptation to our educational traditions and opportunities.

The opportunities for integration into learning are significantly enriched after the educational changes related to online learning. Faculty and students were in a situation that allowed them to become familiar with the various educational resources offered on the Internet and to appreciate the potential for communication and information exchange that social networks provide. This thing represents an opportunity for new cooperation and influences the level of integration between different educational institutions and individual faculty.

The integrative approach is unique in science and engineering students' education, both pre-pandemic and after. The new learning conditions caused by SMART technologies reinforce the importance of integration in the organization and conduct of a modern learning process. The effectiveness of the implementation of an integrative approach in education mainly depends on the professional competencies of the educators, as well as on their conscious motivation to apply it.

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CHAPTER 4

STUDENTS' INVOLVEMENT IN RESEARCH

4.1. Always an up-to-date approach to training future engineers and scientists (Ece Yilmaz, Hasan Yildizhan, Zhelyazka Raykova)

Modern engineering constantly deals with uncertainty, missing data, and competing demands from customers, governments, environmental groups, and the general public. It demands both interpersonal and technical abilities. Today's engineers must deal with constant technological and organizational change in the workplace while also attempting to include more "human" capabilities into their knowledge bases and professional practices. They also have to cope with the business realities of modern industrial training and the legal implications of every professional decision they make. Despite these obstacles, the prevailing style of engineering education is still the same as in the 1950s. Chalk and talk, big classrooms, and single-disciplinary lecture-based presentations were the norms, particularly in the early years of study. Advances in student-centered learning, such as problem-based and project-based learning, have had little influence on general engineering teaching thus far (Mills & Treagust, 2003).

The most crucial aspect of engineering education is determining the graduates' knowledge level. Engineering education programs can produce qualified graduates if applied programs include some basic principles and quality control is conducted regularly. Engineering education is aimed at improving design abilities and solving design challenges. Engineering should be viewed as solving societal problems by moving from analysis to synthesis.

The following are the essential problems to address in engineering education:

- To help students discover analytical solutions and alternatives to situations they will face.
- To provide general design concepts that can be used in various situations.
- In laboratory lessons, emphasize the exploration of experimental methodologies.
- To enable graduates to solve technical challenges by combining their practical and analytical skills.
- To learn how to design using existing materials and systems while researching and developing alternative technologies.
- To prepare graduates for postgraduate studies (Gençoğlu & Cebeci, 1999).

The inquiry approach (learning by inquiry, learning by discovery, IBSE, research approach) is essential in science and engineering teaching. It is based on constructivist ideas in learning, according to which each learner should follow his own path of constructing and organizing his knowledge, which involves students exploring topics and using data as evidence to answer the questions posed (Crawford, 2000). The inquiry approach can be applied to all academic disciplines, but the most extensive research and application are in the study of sciences and engineering. Student research can be small or large in scale, including the entire cycle of scientific knowledge or only some of its elements. These may involve using digital resources or appropriate equipment, conducted in real-world settings or online, or a combination of both.

This approach has a leading role in implementing integrated learning in education. Integrative trends in education are directly related to methods that strongly activate the activity of students for researching complex problems from reality and to those that individualize instruction. In this sense, the research approach is most suitable for organizing a learning process of an integrative nature.

Learning by inquiry can be viewed in three ways:

1. *as an element of the curriculum that explains how science works*. Here it is helpful to include academic disciplines that are content-oriented to methodological knowledge, philosophy of science, history of science, those related to how to do a diploma thesis, master's thesis, etc. These conceptions of research reflect the philosophical nature of scientific knowledge. In this sense, the courses in scientometrics also apply here.

Learning through inquiry is an approach that provides a deep contextual understanding of the learning content but also considers the research process as an element of the learning content. In applying this approach, students understand how science is done and how scientists work.

2. *such as carrying out scientific research by the students in the learning process.* Abilities to do scientific research include formulating and asking questions, planning and designing experiments, collecting and processing data, using data, and linking data into evidence in constructing explanations. Instruction organized through inquiry-based learning involves engaging students in the practice of science.
3. *as a pedagogical approach or as the ability of educators to use inquiry-based learning in the classroom to uncover the essence of fundamental scientific principles and concepts.*

In inquiry learning, knowledge discovery is foregrounded, and everything else as a learning task, assessments, resources, learning environments, and instructional strategies are designed to support learning through inquiry and discovery.

No clear and unmistakable recommendations or strictly defined teaching strategies characterize this approach. Nevertheless, some characteristic starting points and marks are typical for it and make it recognizable: appropriately formulated questions, problems, or scientific research scenarios, often developed by the students conducting research in scientific laboratories or the field, as well as of different types of research projects.

The main characteristics of inquiry-based learning can be summarized in the following statements:

- The learning process is organized as research and study of answers to questions or solutions to problems, which is carried out in cooperation with other students and with the help of ICT;
- Principles and regularities of scientific research are applied;
- It can be related to questions and problems, the answer and solution of which are open-ended;
- Knowledge is obtained based on student activity, critical and creative thinking;
- A new meaning is given to what has been learned, and the level of depth of knowledge is raised;

- Practical skills are built, and knowledge about the methods of scientific knowledge is formed;
- Social skills are built for sharing research results with peers and with a broader audience, working in a group, and conducting reflection;
- It is key to the formation of motivation for learning (Millar, 1997).

According to Reece & Walker (2007), learning by inquiry can be seen as a variant of active learning that includes problem-based learning. Expected achievements of students when applying this approach in the education of sciences and engineering can be grouped as follows:

- Gaining knowledge about facts, evidence, theories, and explanations;
- Formation and development of practical and research skills;
- Construction of the so-called "soft skills."

In 2009, technology faculties were added to the list of engineering schools alongside regular engineering faculty in Turkey. Students who graduate from technology faculties are awarded the engineering title, just like those who graduate from engineering faculties, and there is no difference in authority. The most significant difference between technology and engineering faculties is that technology faculties place a greater emphasis on practical training. The fact that the seventh semester of the last year of technological faculties is entirely dedicated to **internship education** clearly indicates how important practice is. The one-semester internship training provided last year was a critical chance for engineering candidate students to put their theoretical knowledge into reality. Because they have established their practical expertise and foresee the business climate in the industry after they graduate, students who walk into a form of business life during internship training will have little difficulty finding a job and adapting to the work they have started (Akgül, Uçar, Öztürk & Ekşi, 2013).

The world is undergoing dramatic changes and is being influenced by rapid transformations, which engineering education cannot resist. Furthermore, the nature of engineering practice is evolving, impacting engineering education (Ribeiro & Mizukami 2005). It is stated that the teaching of students by active researchers and their direct involvement in the research process is a beneficial form of learning. Therefore, integrating research and education has been a significant concern for both governments and academics on a global scale (Healey, Jordan, Pell & Short, 2010).

The form of research–learning integration can be specific, broad, or indirect. For instance, when academic staff members' research pursuits are interwoven into their teaching activities in some way. On the other hand, the research–learning relationship is frequently ambiguous. Academics provide a more general perspective on the subject, the process of knowledge creation, and the teaching situation rather than specific methodologies, discoveries, and experiences linked with particular research endeavors. Furthermore, research may be included in instructional activities in a weak or strong manner. The first case may be observed when academic staff members' research is used as teaching material in classrooms. In contrast, where research is more completely incorporated, students' learning activities are consciously shaped by it. Academic staff members' research and scientific activity become a structural aspect of the learning process for students rather than just a piece of knowledge (Griffiths, 2004).

A study on students' awareness, experiences, and perceptions of research has shown that students realized the benefits of staff research in terms of their learning, such as being taught by motivated faculty, increased staff legitimacy, and the reflected glory of being conducted by well-known researchers. Students recognized that their understanding of research and developing research skills increased the most when they were actively involved in research projects. Some students believed that participating in research activities would help them find work in the future (Healey et al., 2010). Active learning affects and improves students' exam grades. One study shows that active learning increases exam performance, raising average grades by half a letter. In addition, the study shows that failure rates in traditional lectures increase by 55% compared to the rates observed under active learning (Freeman et al., 2014).

Twelve days after March 11, 2020, when the first case was seen in Turkey, many institutions started online distance education on March 23, 2020, upon the recommendation of YÖK (Higher Education Board in Turkey). When the pandemic period training given in higher education institutions is examined, it is seen that the institutions continue on their way with the existing distance education systems and transfer face-to-face training to this system (Durak, Çankaya, and İzmirli, 2020).

Distance education is a process in which synchronous (live lectures, webinars, online chats, etc.) and asynchronous (recorded videos, reading texts, events, discussion forums, etc.) activities are created for a goal. Although nowadays mainly designed with online processes, offline activities, and learning materials are part of distance education. Therefore, the elements and dimensions that make up the distance education ecosystem should be considered in the instructional design processes, and designs that will allow for meaningful learning experiences should be made instead of pure technology or purely synchronous activity-oriented applications (Bozkurt, 2020).

A study (Ceviz, Tektaş, Basmacı, Tektaş, 2020) provides opinions on the efficiency of distance education and its applicability in Turkey after the pandemic. This study was carried out with an online questionnaire with 997 students from various universities in Turkey. According to the study results, the students stated that they were not the most satisfied with the homework in distance education. 758 students (22.7%) did not want to be given assignments; 689 students (20.63%) wanted homework not to be difficult, 568 students (17.01%) stated that they wasted a lot of time doing homework, 483 students (14.47%) wanted to use tools for distance education and a device (mobile phone, computer, tablet, laptop) to access the Internet at home and they had to do their homework by phone, 345 students (10.33%) stated that the classroom environment was not suitable at home, 259 students (7.76%) indicated that they had Internet interruptions, and 237 students (7.1%) stated that there was no Internet at all.

With the significant decrease in the impact of the pandemic on Turkey today, changes have occurred in education and training practices. Many universities have adopted the distance education techniques they have been applying due to the pandemic in their educational processes. For example, after the pandemic, some courses continued to be given online at ATU. Standard compulsory courses such as Turkish Language, Atatürk's Principles, and Revolution History, called YÖK courses, are offered to students online.

It is possible to quickly put into action by eliminating some infrastructure deficiencies in the implementation of distance education in Turkey. In addition, many students can be provided with educational opportunities, and individuals who cannot reach education due to various impossibilities are given a chance. A significant opportunity will be created for willing students who have to work or live far from Universities and cannot go to the Campus for various reasons (Kılıç, 2020).

Cooperation with institutions in the field of distance education is also available for individuals who want to keep up with current advances in the field of STEM. Through the existing virtual platforms, every institution can offer educational content on STEM areas such as the latest technology, engineering, and scientific advancement. As a result of distance education, STEM education expands its reach and reaches an ever-increasing number of people (Poyraz, 2018).

Distance education applications, widely used during the pandemic, can also be integrated with STEM applications to train future engineers and scientists. Robotic-Based STEM Activities in Distance Education, Virtual Laboratory Applications Used within the Framework of Simultaneous Distance Education Model and STEM Education Activities Supported by Web 2.0 Tools, and Augmented Reality Applications in the Distance Education Process applications are highly applicable education methods with distance education for engineering students. In this way, students will be able to develop independently of the concept of time and space and become highly qualified scientists in the future (Yılmaz, Akyol & Aydede, 2021).

An online education platform called BTK Academy can set an example for STEM distance STEM applications in Turkey. BTK Academy aims to raise the awareness of all segments of society, especially young people and children, by removing the barriers to accessing information in science and technology following the changing educational methods and methods with the technological developments of the current century. It is a training center that aims to contribute to producing the quality workforce needed by the public and private sectors and to transfer the current knowledge of the technology world to the public with a constantly renewing education approach with the online training certificate programs it organizes (https://www.btkakademi.gov.tr/).

For students to improve themselves in the field they study practically, the Presidential Human Resources Office in Turkey started the Internship Mobilization application in 2020. Within the scope of this application, many students can use the theoretical knowledge they have acquired about the field they are studying in practice. Thus, students can participate in many projects and research in the private or public sector.

In 2021, 172 people applied to this program from **ATU**. More than half of the applicant students have completed internships in private and public sectors. Thanks to this program, which offers internship opportunities in public institutions, many engineering candidate students studying at ATU have had the chance to do internships in institutions such as "The Turkish Aerospace Industry," "TR Ministry of Industry And Technology," "Space Technologies Research Institute," etc. It allows students to participate in research, projects, and applications in various engineering fields (https://www.kariyerkapisi.cbiko.gov.tr/).

The formation and development of research skills of students, future scientists, and engineers at the **Faculty of Physics and Technology, PU,** in the pandemic and post-pandemic study period is carried out by setting assignments that must be completed independently or in a group of students. To solve some of these assignments, students must conduct partial studies, as during the pandemic period, they were predominantly theoretical. In the post-pandemic period, the selection of projects also includes experimental ones, focusing on the relevant educational or scientific laboratory.

A sure way for students to be involved in research is to have them work on a thesis to complete their degree. Motivated students usually choose a thesis as a way to graduate. The change brought about by using online learning also affected the conduct of research by students. Their extended stay on the Internet and their work with educational platforms made them more confident in the search for information on the researched topic and in the possibility of more intensive and frequent contact with the instructors. Online consultations are increasingly preferred, which can take place at the time and social media chosen by both parties.

Our experience has shown that the implementation of experimental research work in the relevant environment is accepted willingly by the students, given the impossibility of this happening two years ago.

Another possibility for conducting more practical work is the participation of our students in the National Project "Student Practices" (https://praktiki.mon.bg/), which is already functioning in its second phase. This project envisages the organization and financing of practical training for students in the natural environment of various companies and research laboratories. Their interest in the program after the pandemic lockdown has dramatically increased, and the number of participants has increased by 35% compared to before 2020.

Conducting active learning is closely related to the application of inquiry learning. Engaging students, future engineers, and scientists in learning through research is an indispensable way for them to be well-prepared for the successful practice of their profession. The difficulties imposed by the pandemic period led to a rethinking of the meaning of this teaching approach in the direction of evaluating its significance and its connection with new technologies. In the partner universities participating in the project, the implementation of introductory training in the post-pandemic period is connected with several initiatives related to the practice and internships of students. Changes are also noted in how inquiry training is conducted - more and more engagement with social networks, new technologies, and positive emotions in experimental work.

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CONCLUSIONS

Over the past decade, how we understand the learning process has undergone enormous changes. They are caused mainly by technological progress and the rapid development of digitization. The COVID-19 pandemic caused changes in learning processes by orienting them to the use of new approaches and methods related to online communication. Faculty and students had to adapt to this new situation quickly, requiring specific digital skills and didactic knowledge. Science and engineering educators faced the additional challenge of conducting experimental classes in an online environment.

Experience has shown that the implementation of online learning made it possible to continue learning in the extreme conditions of the COVID-19 pandemic with varying degrees of success, depending on the level of preparation of the educators and the availability of learning resources.

Faculty had to reorient their curricula and learning content to become experts in working with learning management systems by skilfully using existing technologies and being ready to learn new ones. Thus, this situation has caused faculty to enrich their teaching skills by developing digital competencies related to the educational process. It is also essential for them to navigate the new opportunities offered by technology and the corresponding teaching methods and approaches to gain self-confidence and successfully carry out their educational activities.

Training conditions during the COVID-19 pandemic imposed forms of organization such as mixed and hybrid. Blended and hybrid learning are different approaches, and their choice has other implications for students and the learning process. Educators must know their characteristics and didactic possibilities described in the book to choose teaching approaches and methods based on the specific situation, considering the needs of the learner and the nature of the educational content.

We believe that hybrid and blended learning have their own place in future education as they can be made more and more effective as technology advances.

The experience of conducting blended and hybrid learning has shown that implementing the flipped classroom as an approach has a place in the future education of scientists and engineers. The characteristics of this approach, its advantages and disadvantages described in the book, can serve the educators to implement an effective learning model that is highly student-oriented and stimulates them to interact actively and form the necessary professional competencies.

The possibilities of artificial intelligence (AI) to influence education explored in this book convinced us that, while its application brings significant changes, it has a place in both online and traditional learning. Understanding the characteristics of AI and the problems that may arise in its use will help educators better prepare for the future application of AI in education. More and more countries are considering the development of AI technology as a national priority, and the place of this technology in education is becoming increasingly significant.

Augmented reality has been evaluated as a relatively new technology with educational potential. With the help of "augmented reality" technology, context-sensitive learning can be provided to acquire skills essential to students in the sciences, medicine, engineering, and military. Various 3D models visualized using marker-based augmented reality have a place in modern education as they are used in studying the device and principle of operation of complex machines and apparatus.

The remote experiments represent a new technology of great importance to higher education in science and engineering students. This method of experimentation plays a crucial role in online learning to form the practical skills necessary for these students. This method is based on computer and electronic laboratories available to any user with an Internet connection. Thus, students can conduct and control experiments with real components remotely. The research shows that applications for working in remote laboratories are becoming more and more advanced, which enables working with more diverse experimental tasks from different fields of science. Enriching and modernizing the teaching experience of scientists in universities requires them to focus on the possibilities of this technology to make attempts to organize learning in remote access laboratories.

Although gaining popularity before the COVID-19 pandemic, cloud technologies have become indispensable during the lockdown, especially in education. These technologies are one of the sought-after and actively developed emerging areas of the modern IT world. The use of cloud technologies in higher education has provided great learning opportunities that the contemporary educator must be aware of. They provide easy collaboration between different administrative units, faculty and students, educators and educators, and students, and save money and time in the problem-solving process. The service is provided quickly and immediately through them, at different parts of the day, and from other locations. In the experience shared in the book with the use of some educational platforms and applications in recent years (Zoom, Google Classroom, Microsoft Teams, DIEPSEL), some of their didactic characteristics are described, and an assessment of their advantages and disadvantages is made. This thing will help Faculty navigate and enrich their digital skills to adapt their activities in the best possible way to online learning conditions.

The integrative trends in the education of future physicists and physics engineers discussed in the book are supported by examples from the educational practice of four universities and partners in the project "New challenges in the education of STEM university students in the post-pandemic period." The opportunities for integrating learning emerged after the post-pandemic educational changes related to online learning are described and systematized. Faculty and students collaborate in a new way and use many different learning resources, which greatly influenced the level of integration in all directions - organizationally and content-wise.

The application of the research approach in the training of future STEM specialists is not new to educational systems. The changes caused by the rapid introduction of new technologies in the future engineers' and physicists' training created additional interest in this educational approach. This approach includes problem- and project-based learning and plays a leading role in organizing an integrative learning process. Research-based learning is a variant of active learning in which students carry out scientific research and thus form the necessary professional competencies. The good practices of some of the project partners, "Applying some advanced technologies in teaching and research, in relation to air pollution," described in the book, can provoke new ideas in the readers and make them appreciate the power and importance of the research approach in education.

We have witnessed numerous educational challenges posed by the pandemic that require attention. By addressing them, we seek ways to explore and overcome them in the context of our experience and interest as educators of future engineers and scientists.

We share ideas that STEM education in universities faces several issues, such as:

- How to organize better the learning process through an effective combination of hybrid and mixed forms?
- How to most successfully integrate the new learning methods associated with SMART technologies with traditions in the training of STEM students?
- How to meet the social and emotional needs of Faculty and students from communication in an online environment?
- How to ensure objectivity and reliability in assessment in an online learning environment?
- How should the learning process react to unforeseen situations, which we hope will not be many and frequent?
- How can new technologies support the formation of experimental skills of future engineers and scientists?
- and others.

We believe that not simply restoring the educational process to its pre-pandemic levels of functioning is a solution to these challenges. Still, rather than the redirection to new forms of organization, applying new approaches strongly related to new technologies defines the image of modern post-pandemic education.