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Strategies used in blended and learning and virtual laboratories for STEAM education

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Abstract. This paper explores the development of online learning practices in engineering education at "Gh. Asachi" Technical University in Iaşi (TUIaşi) from 1994 to present, including the Covid-19 pandemic period. It highlights ways in which blended teaching and learning (BTL), including virtual laboratories, gradually replaced the traditional face-to-face teaching style. By 2020 advances in Internet technology and the latter's widespread use had already enabled the emergence of hybrid classes. The author present his contribution to the development of online learning practices at the above public higher education institution, which boasts being the oldest in engineering education in Romania. At present, this university uses Moodle to manage its online learning programme. The paper looks into the following topics: use of the Internet and of educational platforms at the Departments of Teacher Training at Al. I. Cuza University (UAIC, Iaşi) and TUIaşi; implementation of innovative teaching practices, such as e-pedagogy; transition to blended learning as the dominant student-centred teaching style; contribution of digital technology to greater learner engagement and satisfaction; collaboration with universities from Romania, the Republic of Moldova, Egypt, and other European countries.

Keywords: e-Pedagogy, STEAM Education, Blended Teaching and Learning (BTL), Virtual Laboratories, Electromagnetic Compatibility.

1. Introduction

This paper highlights the progress made by "Gh. Asachi" Technical University and the Iaşi University Centre regarding the introduction and development of Computer Aided Training (CAT) in the fields of Science, Technology, Engineering, Arts, and Mathematics (STEAM).
The contribution of the Iaşi Academic University School to Blended Teaching and Learning (BTL) in the context of introducing Information and Communication Technologies (ICT) in the educational process is also emphasised.

The effective use of the Internet and of Learning Content Management Systems (LCMS) at all educational levels has been a primary concern of the teaching staff across higher education institutions in Iaşi.
Since STEAM (Science, Technology, Engineering, Arts, Mathematics) Education also involves conducting lab experiments and simulations, the implementation of virtual experiments is showcased as well.

2. Contextualization

TUIaşi's efforts to introduce the Standards of Engineering Pedagogy and Computer Aided Training into Engineering Education began as early as January 1990. At that time, it received strong support from the General Association of Engineers in Romania (AGIR) and from the UNESCO European Centre for Higher Education (CEPES) in Bucharest. A milestone in the further development of TUIaşi was the collaboration with prestigious partners, such as the European Society for Engineering Education (SEFI), International Society for Engineering Pedagogy (IGIP), International Association for Continuing Engineering Education (IACEE), and the EU TEMPUS programme (1991).
The educational journal Iaşi Polytechnic Magazine, Book and Software Reviews (IPM), published by the International Centre for Engineering Education (ICEE), encouraged publications exchanges with engineering organizations (IEEE- Institute of Electrical and Electronics Engineers, ASME- American Society of Mechanical Engineers, IEE- Institution of Electrical Engineers UK, ASEE- American Society for Engineering Education, etc.) and technical universities in technologically advanced countries.
Thanks to these partnerships, teachers and students at TUIaşi got access to a plethora of valuable research necessary for the further development of engineering education in the country.

3. Learning from International Good Practices: SEFI and IGIP Vision of Engineering Education

With regard to engineering education, the European Society for Engineering Education (SEFI) and the International Society for Engineering Education (IGIP) share a common vision:

- to improve teaching methods in technical subjects;
- to develop practice-oriented curricula that correspond to the needs of students and employers;
- to encourage the use of new media in technical teaching;
- to integrate languages and the humanities into engineering education;
- to support the development of engineering education in developing countries.

The following pedagogic and organizational principles were used as guiding principles for the Curriculum Engineering Education Model, also applied at TUIaşi:

- a steady workload is better than learning to absorb an overload of information for tests;
- frequent and adequate feedback helps students adjust learning;
- a variety in teaching methods keeps students engaged;
- community helps students help each other;
- ambitions must be clear and high, yet realistic; and
- teachers work best in teams, with minimal regulation.

For example, the International Engineering Educator *ING.PAED.IGIP Curriculum* (Rüütmann, T., et al.2023) includes a chapter, called *Fundamental principles of educational technology*, where ICT, media and e-learning are discussed. Technical devices, equipment and systems used to support instruction, the operation of these media and e-learning, their sensible use and integration into the instructional process are the main issues dealt with in this curriculum unit.

4. The EPFL-TUIaşi Strategy to Introduce CAI

TUIaşi launched its Computer Assisted Training, Tutoring and Instruction (CAI) in 1993, following a co-operation agreement with the École Polytechnique Fédérale de Lausanne (EPFL) in the field of educational technologies. The following Romanian institutions were involved: the Institute of Theoretical Computer Science of the Romanian Academy (the Iaşi Branch), and the Faculty of Electrical Engineering of TUIaşi. On behalf of EPFL, the Département d'Électricité, Département d'informatique, Laboratoire d'enseignement assisté par ordinateur (LEAO), and Laboratoire de Réseaux Électriques participated in joint activities. As part of this co-operation, a TUIaşi teacher completed a training stage at LEAO/EPFL with the following study objectives:

- to get acquainted with the organization of EPFL and its Department of Electrical Engineering;
- to examine the curriculum design of the Electrical Section (Electrical Engineering Department) at EPFL;
- to study the organization, mission and functioning of EPFL's Computer-Assisted Teaching Laboratory;
- to explore several tutorials (teaching software) developed at EPFL;
- to participate in the special one-week course "Interactive and Multimedia Educational Technologies", organised by the LEAO in the framework of the European COMETT/FORMITT (Training in Media, Information and Telecommunication Technologies) programme;
- to prepare a preliminary draft thesis plan on the use of Computer Aided Learning in the field of electrical engineering, to be accepted by TUIaşi and to benefit from support from EPFL;
- to collect important information and documentation for the continuation of their work.

EPFL donated 12 of the present LEAO PCs (complete 286 Philips with 45 MB HD, mathematical coprocessor, mouse and VGA color monitor) to "Gh. Asachi"

Technical University. This equipment was placed under the responsibility of the trained teacher and installed for the benefit of both students and teachers.
In this paper on teaching innovations in engineering education, the authors underline the most important results: a PhD thesis on Computer Aided Engineering Education (CAEE), a Computer-Aided Training handbook, an e-Didactics manual, an Electromagnetic Compatibility Courseware, and participation in two important European Union Projects: EMC (Electromagnetic Compatibility) European Leonardo da Vinci pilot Project, and For-EMC European Project.

5. Implementation of innovative teaching practices: as a result of a doctoral thesis

The PhD thesis completed under the supervision of TUIaşi and EPFL (Adăscăliței 2001) is divided into five chapters, preceded by an introduction and three annexes containing: virtual campus web sites and an online EMC course, a list of courseware citations, and the list of representative applications written in HTML code.
Chapter 1, *Current State of the Art (history of e-pedagogy and learning technology)* is an overview of the training process and issues of fundamental theories on planning the training.
Chapter 2, *Training Information System (hardware tools, network, and multimedia)* presents the multimedia pedagogic tools used by the teacher.
In Chapter 3, *Synthesis and Research*, the author's vision on pedagogy of teaching and learning computer engineering disciplines (structuring a course) is detailed; "e-Pedagogy of teaching engineering disciplines using Information Technology" is introduced as a new concept. The chapter highlights the contribution of the thesis to Instructional Design using e-pedagogy, the latter's main application areas, and open research directions to be developed in the future.
Chapter 4, entitled *Presentation of the IT structure known as Virtual Campus (VIR-TU-IS). Presentation of the Electromagnetic Compatibility Online Course*, introduces the two applications that form the backbone of the thesis: the EMC (electromagnetic compatibility) online course [Fig. 1.] and the Virtual Campus project of the "Gh. Asachi Technical University.
Chapter 5 presents the *author's main contributions*: (i) e-pedagogy systematization issues, the conclusions proposing original solutions to the design of student-computer interfaces; (ii) systematization of the EMC course-related information material and educational components (lesson, the dynamic illustration of phenomena, simulation ,testing, virtual lab work, design elements for the electrical equipment, interactive exercises); (iii) creation of a virtual library for the EMC course by highlighting the connections with the bibliographic sources provided by various educational websites around the world; (iv) design and implementation of the Virtual Campus as a distributed software system, enabling web operations corresponding to teaching and learning activities; and last but not least (v)

integration of the EMC course components into the Virtual Campus structure, facilitating the implementation of the teaching-learning process.

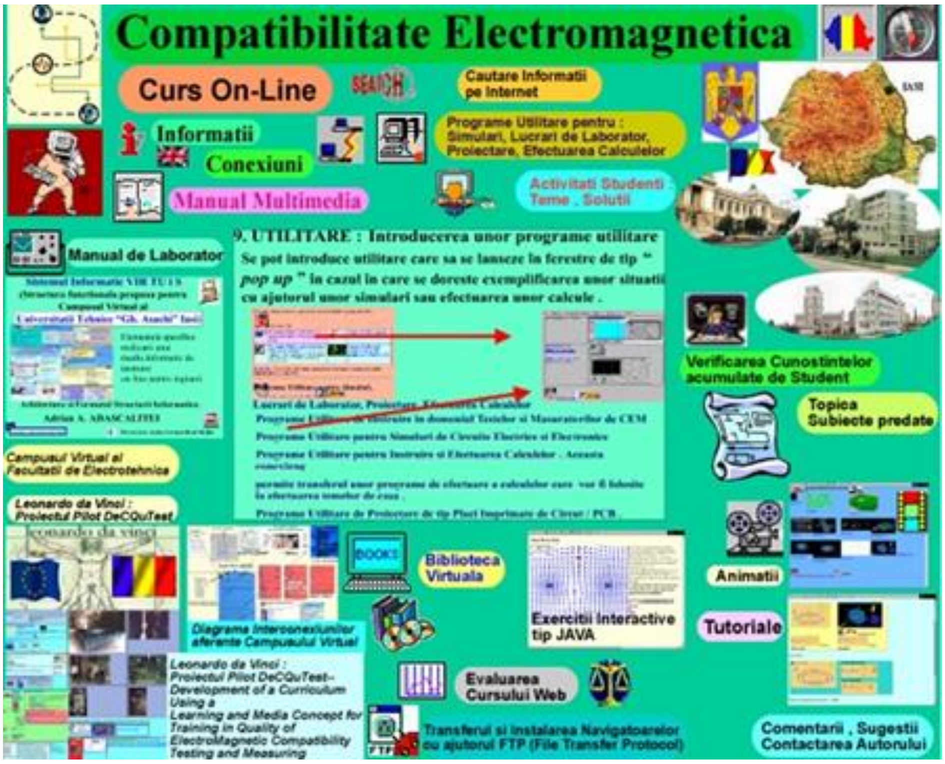

Fig. 1. Electromagnetic Compatibility Courseware.

6. Computer-Aided Training – e-Didactics Manual

The "Computer-aided training. e-Learning Pedagogy" (Adăscăliței, 2007) was published by Polirom Publishing House in 2007 [Fig. 2.]. The manual is used in Computer Assisted Training (CAT) and associated disciplines by the Departments for Teacher Education at both ”Al. I. Cuza” University (UAIC), and TUIași”. The Computer Aided Learning (CAL) Manual is a development of the doctoral thesis completed in December 2000 and defended in January 2001. To underscore the added value of the thesis, the Romanian Ministry of Education recommended this manual to be used for final and grade exams of teachers in pre-university education.

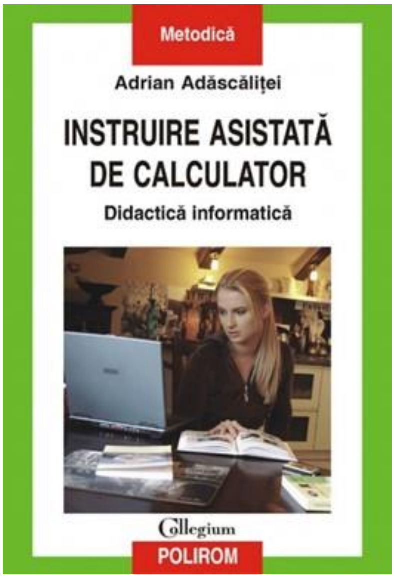

Fig. 2. Computer Aided Instruction Manual published by Polirom Publishing House.

Computer-assisted training (CAT) is a didactic method that capitalizes on the principles of modelling and cybernetic analysis of training in the context of new information and communication technologies. The synthesis between the pedagogical resources of the programmed training and the technological availability of the computer (information processing system) provides this educational method with important features regarding the computerization of the teaching-learning-evaluation activity; improved training through management-documentation-interrogation actions and interactive automated simulation of knowledge and skills acquired in the educational process, in accordance with the established curriculum requirements.
The manual is structured into the following chapters: CAI (Computer-Aided Instruction), e-learning, and instructional technology; Fundamental theories of instructional design; Classification of computer-aided training programs; Didactic Scenarios for conducting computer-aided training; the Role and functions of the tutor in CAI; Development of study materials on CAI; Methodology for designing and implementing computer-aided training programs; Interactions; Computer-mediated communications (CMC); a CAI education centre model (online, e-learning); Elements of design and standardization of e-learning resources.

7. Preparing STEAM Teachers and Students to Use BTL Environments

The preparation of Teachers and Students in STEAM education to use BTL online should contain specific chapters that are presented below (Adãscãliţei et al. 2021). These chapters can be completed either sequentially, in a pre-established order, or as stand-alone resources. They are an example of good practice and have been used in the courses offered to students. A detailed presentation of the chapters follows.

1. The chapter ***Instructional Design Models and Theories of Learning*** presents a wide range of Learning theories (from behaviourism, cognitivism, constructivism and connectivism) identified in relation to common instructional design models, such as: ***ADDIE*** (Analysis, Design, Development, Implementation, Evaluation); ***Gagne's Nine Events of Instruction*** (Gain attention; Inform learners of objectives; Stimulate recall of prior learning; Present the content; Provide "learning guidance"; Elicit performance /practice; Provide feedback; Assess performance; Enhance retention and transfer to the job); ***ARCS*** (Attention, Relevance, Confidence, Satisfaction) and ***Backward Design*** (Identify the results desired / big ideas and skills; Determine acceptable levels of evidence that support that the desired results have occurred/culminating with assessment tasks; Design activities that will make desired results happen / learning events).

2. The ***Online Course Development*** chapter analyses the following subjects: Planning to Teach Online [The Importance of Planning; Process of Online Course Development (Institutional Procedures and Resources; Instructional Design Team Members' Roles); Lesson Plan / storyboard (Purpose; Main Elements)]; Designing blended engineering courses using the CDIO (Conceive—Design—Implement—Operate) approach.

Typical BTL Engineering Course components are: *Educational Materials and Assessments*: Lecture Notes; Lecture Presentations; Additional Reading Materials; Virtual Laboratories (Labs); Assignments; Online Quizzes and Tests; Video/Audio Clips of material; Video Conference material; Webcast Lectures; *Educational Support*: Announcements of course-related matters; E-mail; Discussions Groups; Student/faculty interaction.

Course Management: Course registration and *Face-to-Face (F2F) Components*: *Educational Materials and Assessments*: Lab Sessions; Supplemental Tutorial Sessions (if needed); Project implementations; Semester-end Examinations; Workshop Component of a Course (if any), and *Educational Support*: Physical meeting with advisers

The participants in this chapter should be able to: Explain the importance of the course planning process; Explain the stages in online course development; Identify roles and responsibilities of different team members in online course development; Develop a lesson plan (storyboard) for one chapter (week, unit) of their future online course.

3. The chapter ***Online Teaching Skills*** has the following Agenda (Topics and Subtopics): Teaching online vs. teaching face-to-face (similarities and differences); Online teaching skills (Pedagogical; Technical; Administrative); Self-assessment activity. The Pedagogical Techniques for BTL in Engineering Education dealt with are the following: *Most Used Pedagogical Techniques:* Group problem-solving and collaborative tasks; Problem-based learning; Discussion; Case-based strategies; Simulations or role play; Student-generated content; Coaching or mentoring; Guided learning; Exploratory or discovery; Lecturing or teacher-directed activities; Modelling of the solution process; *Future Pedagogical Techniques:* Authentic cases and scenario learning; Simulations or gaming; Virtual team collaboration;

Problem-based learning; Coaching or mentoring; Guided learning; Self-paced learning; Exploration or discovery; Modelling of the solution process; Discussion; Debates and role play; Lecturing or instructor-directed activities; *Socratic* questioning.

4. The ***Learning Outcomes as Master Plan for Design*** chapter introduces: the role of learning outcomes in online, face-to-face and blended course design. Here blended teachers will use *Bloom*'s Taxonomy of Educational Objectives to develop clear learning outcomes for an online or blended course or chapter. They will also evaluate students learning outcomes to make sure they are specific, measurable, attainable, and relevant and timed appropriately for the length of a given course or chapter. Topics include: *Introduction to Course Design Cycle*: Constructive Alignment (Learners construct meaning from what they do to learn. The teacher makes a deliberate alignment between the planned learning activities and the learning outcomes.). *Writing Learning Outcomes*: Learning Outcomes have three main components: an action word that identifies the performance to be demonstrated; a learning statement that specifies what learning will be demonstrated in the performance; a broad statement of the criterion or standard for acceptable performance.

Bloom's Taxonomy of Educational Objectives (guide to choosing action words): Affective, Cognitive, and Psychomotor domains; Action Words for Learning Domains; Evaluating Learning Outcomes: **SMART** outcomes: **S**pecific skills/value/knowledge; **M**easurable and/or demonstrable; **A**ttainable by students at current level; **R**elevant for students, course, program, degree; **T**imed appropriately for chapter or course length.

Evaluating Achievement of Learning Outcomes: Assessment Strategies.

5. ***Communication Strategies in Online Environments*** chapter introduces teachers to tools and strategies that can help them communicate effectively with students in an online environment. They will review how to apply the Community of Inquiry model to increase cognitive, social and teaching presence, as well as tips and techniques for planning and moderating effective online discussion. Teachers are expected to design a communicative learning activity to increase interactivity in the online environment. Topics and Subtopics are: Online Courses as "Communities of Inquiry": What is Community of Inquiry; Cognitive, Social & Teaching Presence; Types of Asynchronous Communication: Meaningful Online Discussion; Discussion Board/Forum Facilitation; Types of Synchronous Communication: When to Use Synchronous Communication; Preparing for a Synchronous Session.

6. An important chapter introduces ***Synchronous and Asynchronous Technological Tools*** for online learning activities and communication. Teachers are expected to apply one synchronous and one asynchronous tool in the design of an online or blended course or chapter. Educational technologies such as discussion boards, web-conferencing, blogs, wikis and social media are also evaluated.

By the end of this chapter, participants should be able to: Evaluate a variety of educational technologies on the basis of hands-on experience, including experience

with LCMS (Learning Content Management Systems), email, discussion boards, blogs, e-Portfolio, wikis, social media, text chat, and web-conferencing.
7. The chapter ***Online Learning Communities*** introduces strategies for building a sense of community among online learners and activities based in social learning theory to ensure successful educational experiences. This chapter helps the trainee to compare methods for developing online social presence and identify strategies and activities for developing and maintaining supportive online communities.
Topics and Subtopics are: Defining Online Learning Communities: Function; Identity; Participation; Interaction; Online Learning Communities and Online Classes/Collaboration: Online Spaces; Learner/Peer Feedback; Group Assignments; Strategies to Develop Successful Online Learning Communities: Modelling; Articulation; Coaching; Exploration; Reflection; Scaffolding.

8. Virtual and remote laboratories in engineering education

ABET (The Accreditation Board for Engineering and Technology) stipulates that Engineers who have completed a study program should have the "ability to design and conduct experiments" and the “ability to use the techniques, skills, and modern engineering tools necessary for engineering practice." (Adãscãliţei et al., 2019). The Criterion of the EUR-ACE (European Accredited Engineer) program calls for future engineering students to obtain the completion of their studies: "Ability to select and use appropriate equipment, tools and methods" and "An understanding of the applicable techniques and methods and also which are the limits of these processes."
Many Engineering programs currently include remote (and / or virtual) laboratories: to save money; to expand the use of limited resources or share equipment with another educational institution; or for pedagogical reasons. Depending on how laboratory experimental work takes place, these benefits may include: increasing student access to equipment (workload and student time); greater flexibility in programming laboratory work; a wider range of possible activities; increased collaboration opportunities among students.
Essential experimental skills of engineer students can be developed with remote labs and simulations. Developing critical thinking while students work with virtual resources is very important and students need to understand what kind of results they collect and analyse for each experiment. It is important for the student to be able not only to perform the experiment correctly but also to interpret the results correctly. Remote students can acquire introductory experiences and become familiar with real life phenomena. Software simulations that use the web are called "Virtual Labs" and use only the software. "Remote labs" consist of real hardware and allow people to use real-world hardware equipment through software.

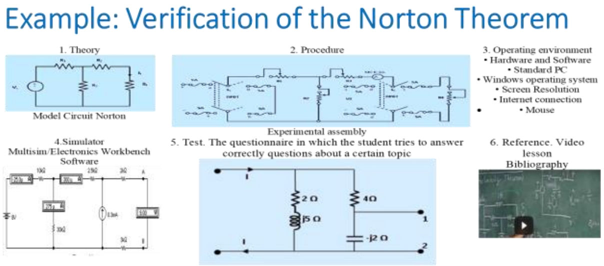

Fig. 3. Didactic scenario of a virtual or remote experiment.

An online laboratory can be divided into three types of laboratories: 1. Remote laboratory; 2. Virtual lab; 3. Hybrid Laboratory (an online lab that combines real-world hardware experiments with software simulations). An online lab may contain one or more experiments in various fields of science and engineering.

An experiment can be ranked according to the interactivity between the experiment and the experimenter as follows: 1) Observation Experiment for which the parameters of the experiment under observation and the experimental environment are fixed (unmodified); 2) Fixed Experiment environment is fixed, but experiment parameters can be remotely changed, and one or more remote measurement tools may be controlled; 3) Adaptive Experiment for which the parameters, as well as the experiment environment, can be remotely changed. For example, a circuit configuration can be changed.

9. Pedagogic scenario of a virtual or remote experiment

Pedagogic scenario of a virtual or remote experiment has the following stages [Fig. 3.]:

1. The student has to read an introductory teaching material that presents the subject, purpose, objective, and theory behind the experiment and to understand the applications of the phenomenon in different technological fields.

2 The student then takes an online test to assess their level of knowledge and understanding of the stages of the experiment (procedure, prerequisites, hardware and software details for each stage of the experiment, procedural details on how to use the remote-control panel effectively).

3. The student follows, with the help of simulations and video sequences, the illustration of the theoretical concepts in order to deepen and better understand the taught concepts.

4. The student answers a questionnaire with questions, for which they can receive additional information.

5. Using the remote-control panel, the student will perform the experiment, viewing and analysing the experimental results. In this way, students understand and learn the procedures for correcting unwanted developments in the experiment.

6. To deepen the cognitive understanding, each student receives additional tasks and is evaluated after the execution of each operation to understand the experimental phenomenon.

10. Activities and achievements that complement the use of learning technologies in steam education

1. BTL courses at the Departments of Teacher Education at UAIC and TUIaşi on moodle.ee.tuiasi.ro and elearning.utm.md/moodle/ platforms;
2. Active participation of TUIaşi in the project "Acquiring competences in the field of interactive teaching and learning techniques and ICT", i.e. the DIDATEC project (coordinated by the Technical University of Cluj-Napoca). An online course was developed located on the moodle.ee.tuiasi.ro platform, which teacher students at TUIaşi can use;
3 Participation in the CRUNT Program "Création d'un Réseau d'Universités Numériques Thématiques en sciences appliquées et sciences économiques en Moldavie" (Creation of a thematic digital network of universities in applied sciences and economics in the Republic of Moldova). An online course on the network platform in the Technical University of Moldova, Chişinau, has been developed. The papers published in collaboration with universities from the Republic of Moldova can be viewed and downloaded from the National Bibliometric Instrument, the country’s biggest open access electronic library: https://ibn.idsi.md/ro/author_articles/47281.
4. Participation of TUIaşi professors as members of the Scientific Committee, reviewers and authors, in national and international conferences dedicated to Learning Technology in Education, such as: International Conference on Virtual Learning (ICVL); National Conference on Virtual Education (CNIV); International Scientific Conference on e-Learning and Software for Education (eLSE); etc.
In 2009, the CNIV and ICVL Conferences were hosted by the Faculty of Electrical Engineering, "Gh. Asachi", Technical University, with support from the Branch of the General Association of Engineers in Romania (AGIR), Iaşi branch.
5. Collaboration with Menoufia University, Faculty of Engineering, Egypt. (Zein El-Din et. al., 2018; Adãscãliţei, et. al., 2019; Zein El-Din et al., 2019; Adãscãliţei, et al., 2020; Adăscăliței et al., 2021) in the BTL field, also using virtual laboratory experiments and simulations.
6. Collaboration with other Romanian Universities and Universities in the Republic of Moldova.

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