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Blended teaching and learning approach applied to electrical and computer engineering education

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Abstract. The article presents a review of the current e-pedagogical methods to develop Electrical and Computer Engineering Education (ECEE) Study Programs using Blended an Learning (BTL). Engineering crucial experimental competences can be developed with the help of remote labs (RLs) and simulations. These online experiments can be found in different engineering fields. Instructional Design (ID) Model is based on the ADDIE model that includes Analysis, Design, Development, Implementation, and Evaluation phases. Virtual Learning Environments (VLE) or LCMS (Learning Content Management Systems) are used to refer the on-line interactions for a variety of kinds that take place between students and teachers. Moodle (Modular Object-Oriented Dynamic Learning Environment) is known as a Course Management System (CMS). The review article provides resources to help teacher educators, administrators and policymakers better apply ICTs to EE programmes. The resources were developed by Faculties of Electrical Engineering Technical University "Gh. Asachi" Iași, Romania , and Technical University of Moldova, Chișinău, with extensive experience in the integration of ICTs into engineering teacher preparation programmes.

Keywords: Blended Learning and Teaching (BTL) model for engineering education (EE); Virtual and Remote Laboratories; Virtual Learning Environment; ePedagogy; Electrical and Computer Engineering Program.

1. Accreditation of EE in Europe

Using BTL classes and Virtual labs (VLs) and Remote labs (RLs) for international EE is one of the main objectives of this review paper. Accreditation System for EE in EU: SEFI (European Society for Engineering Education) fully supports the development of the EUR-ACE (European Aredited Engineer) System being based on cooperation and mutual recognition between existing National accreditation bodies, and being based on LO (Learning Outcomes) for its implementation. The EUR-ACE System has acquired global visibility through contacts with the Washington Accord, the Sydney Accord, and the whole International Engineering Alliance (IEA). SEFI wishes to ensure its strong support and involvement regarding European Network for Accreditation of Engineering Education activities in EU (European Union). EUR-ACE is a system for accreditation of EE programs, first defined in 2006. EUR-ACE has been developed with the support of a sequence of EC-DG EAC (Directorate-General for Education, Youth, Sport and Culture, of the EU projects. The learning objectives defined in the EUR-ACE Framework Standards, are fully compatible with the European Qualification Frameworks, apply to first and second level degrees, and can be used also by institutions in countries that have not yet established a National Engineering Accreditation Agency. ***Criteria to be satisfied by ECEE programmes to be accredited include the following***: The BTL environment is appropriate to the programme objectives and structure, preparedness of the students at intake, and the stated outcomes as evidenced by: a progressive learning experience, development of independent learning, effective programme co-ordination, and monitoring student progress; Students have access to sufficient literature and computer resources to support their learning. ***EE*** is the activity of teaching knowledge and principles to the professional practice of engineering. ***SEFI and IGIP (Intl.Soc. for EE) Curriculum Engineering Education Model***: **A** steady workload is better than 'binge learning' 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. The teaching in undergraduate courses in the Science, Technology, Engineering and Mathematics (STEM) and ECE disciplines has increasingly started adopting the more learner-centred teaching, such as Problem-Based Learning (PBL). This shift is fuelled by the need for future engineers to demonstrate the use of higher order thinking, problem solving, and more interpersonal aspects of a career, such as communication, social, and team-work skills (National Academy of Engineers). It is important for EE to re-examine the use of typical lecture-based teaching methodology and consider incorporating learner-centred teaching. PBL has the potential to help students to cope with the demands of complexities of the field and problems they will face in their future careers. **PBL** develops the following skills of Students: Teamwork; Project management and leadership; Oral and written communication; Emotional intelligence; Tolerance for uncertainty; Critical thinking and analysis; Application of content knowledge; Research; Decision making; Problem solving across disciplines.

2. Blended teaching and learning

Pennsylvania State University developed core competences/skills for online teaching success, and divided them under skills related to pedagogy, technology and course administration; this division is generally accepted at North America's and European universities. Teaching in an online environment can be considerably different in nature than teaching face-to-face. The competencies listed in this document are intended to provide faculty and administrators with a better understanding of the instructional requirements of online teaching. ***Competencies and Skills for BTL are: Pedagogical, Technical, and Administrative***.

Technical Competencies: Successfully log into the Learning Management System (LMS) and access courses; Navigate course page without problems; Setup and manage the grade book including releasing grades to students and exporting final grades to be submitted to the grades system; Successfully use the LMS (email, discussion boards and chat; Setup teams/groups; Manage files and folders); Manage the course roster to add teaching assistants and colleagues to the course; Setup and fully utilize assignment drop-boxes for student submissions, including uploading and downloading content; Use of software to record lectures.

Administrative Competences: Log in to the course regularly (often daily) in order to respond to students; Communicate to students, in advance, when assignments and exams will be graded and returned; Familiarity with policies regarding the Freedom of Information and the Protection of Privacy Act (FIPPA) regulations; Mediate course-related student conflicts as they arise; Revise course content and instructions based on student feedback as appropriate; Identify the appropriate procedures and resources for getting assistance and support when encountering a technical problem; Communicate expectations of student classroom behaviour (netiquette guidelines). *Rules of Netiquette* are: Remember the Human; Adhere to the same standards of behavior online that you follow in real life; Know where you are in cyberspace; Respect other people's time and bandwidth; Make yourself look good online; Share expert knowledge; Help keep flame wars under control; Respect other people's privacy; Don't abuse your power; Be forgiving of other people's mistakes.

Pedagogical Competences: Know how to direct the BTL process in an online environment and provide appropriate educational experience for diverse learners; Respond to student inquires in a timely manner; Provide prompt, clear, detailed feedback on assignments and exams; Communicate with students about course progress and changes regularly; Create a learning environment that is safe, respectful, and inviting; Monitor and manage student progress; Communicate course goals and outcomes; Play an active role in online discussion when appropriate and provide a good model of expected behaviour for all course communication; Demonstrate sensitivity to disabilities and diversities, including aspects of cultural, cognitive, emotional and physical differences. **BTL skills are**: interaction; course management; course organization; use of technology; content knowledge; teamwork.

Pedagogical Skills: Facilitation, Online presence & responsiveness, Promoting collaboration, Monitoring student progress & providing frequent feedback. Teaching online focuses one's efforts on facilitating, guiding, and directing learning, as well as assessing progress towards the course goals. The key to success in an online course rests not with the content that is being presented, but in learning activities that are built in" and "in order to have a high degree of interactivity, instructors need to give up a degree of control and allow learners to take the lead in learning activities. The main focus should be on learners' needs (what will they be able to do, know after they finish the course? which activities will help them achieve this?) instead of solely on course content. Because what is communicated online is often written and, in some ways, permanent, higher standards are necessary and an instructor's writing serves as a model. Being able to communicate in a clear and concise manner will make the learning experience more positive for all involved. The asynchronous communication may feel impersonal and instructors need to make an extra effort to humanize the online environment. Tone of communication should always be positive and *'Netiquette' rules* should be presented to students. Instructor needs to create an inviting atmosphere that promotes the development of a sense of community. The collaboration promotes deep learning and collaborative activities can help to reduce the feeling of isolation and loneliness that learners may experience in the online course. Instructors need to provide regular feedback and to be specific about areas of strengths and those that need improvement. They should also encourage learners to reflect on their own learning process throughout the course because these reflections aid deep learning.

Technical Skills: mastering LMS / LCMS, and/or VRL; Web navigation; File management; Grade management; Other software (to record lectures, for example). Instructors need to invest time in learning different technologies. They should be comfortable with the LMS they use, as well as with all other technologies which are part of their course. The choice of technology should depend on teaching needs. Technology used in the online course should be simple to operate, user friendly and functional. Instructors and the ID team should ensure the online course is easy to navigate.

Administrative Skills: Log-in regularly; Establishing expectations and guidelines; Policies and procedures; Where to find help. For both instructors and students it is important to check a course often. This gives instructors an opportunity to clarify possible misunderstandings, answer students' questions and model what students should do in order to be successful in the course. It is very important to present clear guidelines, expectations, and the course structure. Instructors should tell students when they can expect their responses and feedback, and how often they will respond to email messages, questions, etc. This shows respect for students' work, encourages progress, and reaffirms students' beliefs in their ability to succeed in the course. It is important for instructors to become familiar with privacy regulations and ways in which instructors need to protect student privacy. Talk about resources at your institution and where instructors can go for assistance if in doubt. To ensure student success, instructors need to be aware of Equity policies, Accessibility regulations, and Student Support Services. Talk about resources at your institution and where instructors and students can go for assistance.It is important to identify help contacts before the course begins and share the relevant contact information with the students. Course design team or administrative unit should be able to direct you to resources when a technical issue arises. Teachers should spend some time explaining which departments can help both instructor and students: computing services, BTL unit, library, support services for students, etc. and you should also provide contact information of the most important departments.

3. Virtual and remote laboratories in EE

Essential experimental skills of engineer students can be developed with RLs and simulations [1]-[5]. Developing critical thinking while students work with virtual resources is very important and students need to understand what kind of results they collect and analyze 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 [6]. Online laboratories [7, 8] are fundamental to the experiments performed by students during the individual study. Thus, remote students can acquire introductory experiences and become familiar with real life phenomena. On-line experiments can be conceived in various fields of engineering study. Software simulations that use the web are called VLs and use only the software. RLs consist of real hardware and allow people to use real-world hardware equipment through software. Because lab experiments and tools are becoming more and more sophisticated and expensive to acquire and keep functioning by universities, RLs are becoming increasingly used. RLs are a practical alternative solution for students through which students can conduct online experiments regardless of time and space. Compared to traditional laboratory practice experiments, RLs offer students a flexible learning mode that does not depend on time and place, access to a large number of experiments distributed over an extended geographic area and a reduction in operating costs. RLs, as collaborative educational strategies, are becoming more widespread, offering great opportunities for students to interact while studying they are selling a common goal.

An **online lab** is an environment that allows a person to perform experiments and/or simulations using the Internet. Online laboratories contain software-based simulations or experiments that use real hardware. An online laboratory can be divided into three types of laboratories: 1. Remote laboratory (RL); 2. VL; 3. Hybrid Laboratory (an online lab that combines real-world hardware experiments with software simulations) and may contain one or more experiments in various fields of science and engineering.

An **experiment** is defined as the smallest unit of an online lab and allows for virtual or real-world experiments to observe the behaviour and outputs of a technological system under study. An experiment can be ranked according to the interactivity between the experiment and the experimentator 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.

Remote and virtual laboratories (VRL) are: *1. Simulations* are imitations of operating systems through time, via computers [9, 10]. Simulations Labs represent a process on the basis of a model that is cheaper, faster, less risky and more affordable than the real process. Simulation Laboratories are primarily used for: a. Pre-lab experience to give students some idea of what they will encounter in an actual experiment; b. Substitute for physical lab exercises; c. Substitution, when the system studied is dangerous, expensive or large, and not practical for a typical educational laboratory. Simulation-based labs on the Internet which use software can be classified into two groups: a. Processing on each client: simulators of real-lab tools/experiments can be run on students' computers; b. Processing on a server: the simulator is run on a server and is accessed by students remotely through the web. The interface is a www browser. *2. JAVA-applets.* Classical simulations contain certain elements of laboratory experiments and are available on the Web (online) or are available as JAVA-Applets (or accessible with plug-ins) (Cyber Labs). *3. VR* is: a) a Science laboratory which simulates a virtual technology system on the computer screen; b) an online laboratory which provides software simulations or applications and exploits the potential offered by modern media technology key features: technical interaction, and direct and plausible manipulation of objects and parameters. *4. Virtual Reality Labs (VRLs)* are computer-based and highly interactive. The user becomes a participant in a "virtually real" world, in a three-dimensional artificial optical environment. These workshops have a complex interface that includes real-time three-dimensional simulations and uses different sensory channels. *5. RLs Controlled by Distance* (otherwise known as online labs or workbenches) include real experiments conducted from a distance with the use of telecommunications (accept commands via the Internet [11]), while the user uses this technology from another location [12]. Most of the VL software consists of computing applications running on the local user's computer, for speed and security reasons [13]. The control of real hardware and the realization of real measurements is possible for RLs.

RLs used in EE Programmes. ABET (Engineering and Technology Accreditation Board) includes in the results of a study program that Engineers will have the "ability to design and conduct experiments" and "ability to use engineering, engineering and engineering tools." 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 for either: saving money; 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 between students. If laboratories are accessed online, students can (potentially) be involved in learning an experiment anytime and anywhere they have access to the Internet, unlike practical activities based on when campus buildings are open and staff members are available. Finally, VRLs may be increased student collaboration opportunities when laboratories are accessed online, while eliminating the same constraints on the location of traditional working groups. For a tomorrow's engineer, working in a team whose members are scattered around the country (or around the globe) can be a habitual thing and provides students with practical skills to get useful skills in this working environment (communication and teamwork, e.g).

Virtual and Remote Laboratories Architecture. Collaborative Accessibility or Virtual Lab Platform (VLP) to Support Distributed VLs [14] has a multi-tier architecture, based on Moodle LCMS, which supports technological variations, and also allows for collaborative development, publishing in various online and prints formats, security, audit, and access controls. The system provides the standard functions of a LCMS in ways that can accommodate effective development and use of VLs and RLs. VLP may reside in the cloud, while remote equipment will be located at various geographically distributed labs behind institute firewalls. It maintains the technology-independent data of multi-institutional labs along with the metadata of parts of labs that are dependent on proprietary software technology or remote equipment in the cloud. Simulations that require proprietary software and remote equipment are maintained at local institutional servers. Labs from different institutes may add existing simulations or RLs to the system using customizable templates and protocols for RLs. VLP also requires secure user access to remote equipment, thus ensuring the safety of expensive equipment. Lab owners may reuse components such as simulations, animations, videos, and assessments from other labs to create new components. The instructor can create groups, add students, assign learning modules, give assignments, monitor student usage and evaluate student performance. VLP offers rich content management and collaborative authoring environment, with versioning of all changes along with automatic logging of data and related data analytics. Configurable templates offer a similar look and feel regardless of the source’s technological constraints while allowing further customization by the developing institute. In addition, the system supports a simultaneous deployment of multilingual labs and uses a modular format for text storage that lowers the cost of translation. VLP supports content versioning and allows collaborative lab developers to revise, create and manage versions, while also allowing restoration to previous versions. The templates separate the content, the visuals, and the structure, allowing the final output to be defined based on the device type or publishing to media types such as web applications or print materials. VLP provides a flexible work structure for users: developers, educators and students. No matter how the laboratories are engineered, VLP offers pedagogical facilities to developers of laboratory work and provides structure for the learning environment. The learning environment is made up of screens and / or tables associated with various aspects of pedagogy, such as **conceptual background and theory,**

procedures, video demonstrations, animations, exact mathematical simulations, and online access to remote equipment, as well as assessment tools learning. In this way, students can achieve the conceptual, procedural, and experimental abilities. Finally, Students are able to conclude on findings and reports as a result of their laboratory experiments. Lab developers may tailor both the order and the presentation style to suit various teaching styles as well as diverse student needs. ID Model of the VLP is based on the ADDIE model: **Analysis -** Identification of learning objectives, goals, audience, delivery options, and timeline of project; **Design** of the learning platform, experiment planning, contents to publish, media selection, arrangement of various formats of the contents and prototyping by means of Instructional Objectives; **Development -** lab developers designed the experiments and performed continuous testing, validation, and debugging for the labs; **Implementation -** Ensuring the proper placement of contents, tools, and media as well as the procedure for training educators and students; **Evaluation -** A ***formative evaluation*** was conducted for each individual stage of the process, and the resulting feedback information was immediately integrated into process revisions for that stage; The ***summative evaluation*** was performed by collecting feedback from users and incorporating their suggestions. The IEEE Draft Standard for Networked Smart Learning Objects for Online Laboratories [20], [21] defines methods for storing, retrieving, and accessing online laboratories as smart and interactive learning objects.

Examples of Online Labs

A. STEM Education in Europe. Studies on Education Policies and Practices in Europe funded by the EU have shown that in European education systems in Europe: STEM studies have a low attractiveness and the labour market in the STEM-related sectors is not satisfied. The Scientix Moodle program [15] was designed as a platform for peer learning for an exchange of best practices between STEM teachers throughout the EU. The courses on the Moodle platform have been developed by teachers from different countries who shared their experiences of using different tools and teachers in classrooms. Courses are self-paced and can be accessed by anyone at any time, and users do not need to create a Moodle account to study. Created by European Schoolnet, the Future Classroom Lab (FCL) has six learning areas; visitors can explore key elements in delivering 21st century learning: student and teacher skills and roles, learning styles, learning environment design, current and emerging technology in education, the socio-economic requirements and expectations affecting education [16]

B. Labs Virtual India: Learn, Simulate, Practice, Self Evaluate. The VLs [17] - [21] are a project initiated by the Ministry of Human Resources Development, the Government of India, under the coordination of the National Mission for Information and Communication Technology Education. **Objectives**: Providing remote access to laboratories in different disciplines of science and engineering; Encourage students to experiment by stimulating their curiosity and helping them learn basic and advanced concepts through remote experiments; Provide a complete LMS around virtual labVLs where students can benefit from the various learning tools, including additional web resources, video lectures, animated demonstrations and self-evaluation; Distribute costly equipment and resources that are otherwise available to a limited number of users due to time and geographical distance constraints. **Characteristics**: 1)VLs provide students with the result of an experiment by: Modelling the physical phenomenon with a set of equations and performing simulations to obtain the result of a particular experiment and providing an approximate version of the "real experiment"; Provide measured data for VL experiments corresponding to data previously obtained by measurements on a real system; Performing a real-time experiment in a RL and providing students with the help of the computer interface the control of the RL experiment; 2) VLs can be more effective and more realistic if they offer students more communication channels, such as audio and video streaming as they accompany an experienced phenomenon, and the operation of real equipment. In this laboratory, students will get to explore and learn various concepts regarding analogue electrical signals, networks and measurement of various electrical components. The experiments are developed on open source web based platforms, so that the student doesn't need to download or install any third party application. In each experiment, the student first get to learn the theories well and then perform the experiment to enhance their knowledge.

4. Conclusions

The article provides resources to help engineering teacher educators, administrators and policymakers better apply ICTs to engineering education programmes. The resources were developed under suppervision of the University Departments for Teachers Education with extensive experience in the integration of ICTs into engineering teacher preparation programmes.

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