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## **Blended Teaching and Learning and Implementation of Online Laboratories in STEM Education Using a Virtual Learning Environment**

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### **Abstract**

*This keynote paper is about ePedagogical Challenges / Difficult Tasks for STEM Study Programs Leading to International Accreditation in 21th Century: Implementation of E-learning, Blended Learning, Virtual Learning Environments (for example Moodle), Virtual and Remote Laboratories, OER (Open Educational Resources) and MOOC (Massive Open Online Courses).*

**Keywords:** Blended teaching and learning model for STEM, ePedagogy, Virtual Learning Environment, Virtual and Remote Laboratories, Open Educational Resources, Massive Open Online Courses.

### **1 Introduction**

This review paper presents the current e-pedagogical methods to develop a Project Design for STEM (Science, Technology, Engineering and Mathematics) Education Study Programs including online laboratories.

### **2 Preparing STEM Teachers to use blended learning environments**

Luând în considerație experiența celor patru universități și competența Facultății de Științe ale Educației din Iași, recomandăm ca pregătirea profesorilor pentru blended and online teaching să conțină 12 capitole/module pe care le detaliem în articol. These modules can be completed sequentially in the order below, however they can also be viewed as stand-alone resources.

#### **2.1 Online Teaching Skills**

This module/chapter enables instructors to determine their readiness to teach online. Through self-evaluation and reflection, teachers can develop an action plan to improve their practice and become an effective online teacher. They will also discover the pedagogical, technical and administrative skills required for successful online teaching and learning.

Agenda (Topics and Subtopics): Teaching online vs. teaching face-to-face (similarities and differences); Online teaching skills (Pedagogical; Technical; Administrative); Self-assessment activity

Learning Outcomes. By the end of this module, participants should be able to: Compare skills required for online versus face-to-face teaching success; Identify the necessary skills for successful online teaching; Assess personal readiness to teach online.

## 2.2 Instructional Design Models and Theories of Learning

This chapter/module introduces the advantages benefits and impact of instructional design methodology used during course development. Learning theories (from behaviourism, cognitivism, constructivism and connectivism) will be 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 assessment tasks; Design activities that will make desired results happen / learning events).

Key characteristics of these learning theories, models and processes for course design are presented, to ensure that instructor apply an appropriate framework to his/her teaching approach.

Learning Outcomes. By the end of this module, participants should be able to: Identify key characteristics of selected, commonly used instructional design models; Identify three main learning theories (behaviorism, cognitivism, constructivism), and their relationships to instructional design models; Recommended steps for module/course design using instructional design and learning theory.

## 2.3 Online Course Development

This chapter/module emphasizes the importance of planning stages in the development of online courses when using a project and team-based approach. In this module participants will discover the roles and responsibilities of team members and potential institutional resources in the online course development process, as these differ from face-to-face, individual teaching approaches. In this section, students will develop the main elements of a lesson plan (storyboard) for one module (week, unit) of a future online course.

The goal of this chapter/module is for participants to identify the project-based process of instructional design as well as institutional resources and team roles related to the development of online courses. The team-based approach (used in the development of blended and online courses) together with the need for the course to be developed ahead of time (as opposed to just-in-time teaching) is quite different from the individual-based approach to teaching that is common in face-to-face teaching. If participants are delivering a full program in blended and online teaching and learning, it is recommended that they to include this module after Instructional Design Models and Theories of Learning.

Topics: 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)

Learning Outcomes. By the end of this module, participants 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 module (week, unit) of their future online course.

At the same time, within this module the characteristics and the didactic principles for generating the contents delivered online can be discussed, as follows:

Characteristics of virtual instructional content [36]:

1. Granularity and sequentiality of the knowledge conveyed. The didactic knowledge, as the main reference to be accessed, is structured so that there is certain independence of the entities that compose it, but also to ensure certain solidarity of the whole.

2. Modularity, respectively the property of ensuring a global articulation of the content elements and a circumstantial reconfiguration. Each cognitive element is linked or "seeks" another element that leads to enrichment on the whole. Something can be linked to something else, the combinatorics being endless.

3. Flexible dimensioning of the contents, according to the "extent" of the educated, in accordance with multiple individualities and particularities. Individualization involves a multi-storey configuration of the contents so that each subject will find in the offer made available convenient elements, that will interest them and that they can understand.

4. Ensuring a particular performance and rhythms of access and comprehension. No one is obliged to go to the whole cognitive complex and understand everything. Each can progress at its own specific pace.

5. The entrance to the field of knowledge can be done through several places, none imposing itself as privileged. What is important can be learned without knowing all the elements of the ensemble. "Fractal" learning has finally found a concrete form of manifestation. Access to knowledge remains open, with no single "royal gate" entering the edifice of knowledge.

6. The self-structuring character of the content, in the sense that it is self-managing and self-edifying, through the methodological elements that accompany the actual knowledge path. Throughout, the learner finds methodological indices of understanding, additional markers of significance and broadening of the edifice of knowledge. You are given not only knowledge, but also ways of interpreting them, paths to new meanings, alternatives of search and understanding.

At the same time, the structuring of such content must respect the following didactic principles [37]: 1. Relevance (Refers to the adequacy / suitability of the issues raised in support in relation to the needs, objectives and goals of the user - the student, the teacher, etc.). 2. Transparency / accessibility (Refers to those characteristics of the medium that, from a cognitive point of view, contribute to facilitating access and use. 3. Validity (Refers to the internal consistency of the content / materials, to the way the content and method are supports each other - which facilitates the teaching-learning process 4. Attractiveness (This principle summarizes all those characteristics of the curricular support that appeal to the student and, as a result, contributes to reinforcing the motivation for learning it. 5. Flexibility (Se refers to the individual modalities – both cognitive and affective – of approaching the teaching-learning process, to those characteristics of the curricular support that are sensitive to the individual specificity of the user, including the differences between the different groups) 6. The open / generative character (It refers to the characteristic of the curricular support to facilitate cognitive development and transfer of what has been learned in other contexts and in more general tasks). 7. Participation (It refers to the ability of the curricular support to offer the student and the teacher the possibility to make choices and to share the responsibility in the teaching-learning process). 8. Socialization (It refers to the "added value", namely: the exercise of collaborative skills, the search / valorization of otherness, the formation of an intercultural awareness).

#### **2.4 Learning Outcomes as Master Plan for Design**

This module introduces the role of learning outcomes in online, face-to-face and blended course design. During this module blended teachers will use Bloom's Taxonomy of Educational Objectives to develop clear learning outcomes for an online or blended course or module. They will also evaluate students learning outcomes to make sure they are specific, measurable, attainable, relevant and timed appropriately for the length of your course or module.

Topics. Recommendations for Outcomes Based Education:

Why Learning Outcomes: What are Learning Outcomes; What is the Purpose of Learning Outcomes;

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 Outcome statements may be broken down into 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: Specific skills/value/knowledge;

Measurable and/or demonstrable; Attainable by students at current level; Relevant for students, course, program, degree; Timed appropriately for module or course length

Evaluating Achievement of Learning Outcomes: Assessment Strategies

Learning Outcomes. By the end of this module, participants should be able to: Explain the role of learning outcomes in (online, face-to-face, and blended) course design; Apply Bloom's Taxonomy of Educational Objectives to write clear, succinct learning outcomes

## **2.5 Benefits and Challenges of Online Education**

This module addresses the benefits and challenges of online teaching and learning for both instructors and students. They will review the skills required for successful teaching and learning in online environments, as well as discover strategies to overcome challenges and techniques to assist students. This module is designed to help instructors feel prepared to teach online.

Topics: Skills for Successful Online Learning; Online Learning Quiz for Students; Instructor Assistance with Skills; Online Teaching Skills.

Learning Outcomes. By the end of this module, participants should be able to: Describe the potential benefits and challenges of online teaching and learning for both student and instructor; Outline strategies to address challenges related to online teaching and learning; Develop strategies to assist students in online environments; Self-evaluate readiness for teaching online.

## **2.6 Assessment in Online Environments**

This module introduces strategies for planning assessments, grading student work and providing effective feedback in online learning environments. You will discover how to select formative and summative assessment tools and activities, as well as how to develop grading rubrics and generate effective feedback in relation to student learning outcomes. Appropriate use of self and peer assessments will also be covered.

Topics: Place and Purpose of Assessment: Assessment in Constructive Alignment; Formative and Summative Assessment; Assessment Tools and Activities; Effective Feedback through Grading Rubrics: Characteristics of Effective Feedback; Grading Rubrics.

Learning Outcomes. By the end of this module, participants should be able to: Explain the purpose of assessment from the perspective of constructive alignment; Distinguish between formative and summative assessment; Identify characteristics of effective feedback; Select a grading rubric for an online assessment; Determine when self and peer assessments might be effective and viable options.

## **2.7 Communication Strategies in Online Environments**

This module introduces teachers to tools and strategies that can help them communicate effectively with students in the online environment. They will review how you can 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 discussions. In this module, teachers will design a communicative learning activity to increase interactivity in the online environment.

Agenda. Topics and Subtopics: 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.

Learning Outcomes. By the end of this module, participants should be able to: Distinguish between the various types of communication available in online contexts; Outline the importance of clarity in written expression; Design a communicative learning activity that will increase the level of interactivity in the online environment.

## **2.8 Synchronous and Asynchronous Tools**

### **8 Synchronous and Asynchronous Tools**

This module introduces appropriate synchronous and asynchronous technological tools for online learning activities and communication. In this module, teachers will be expected to apply one synchronous and one asynchronous tool in the design of an online or blended course or module. Educational technologies such as discussion boards, web-conferencing, blogs, wikis and social media will also be evaluated.

Agenda. Topics and Subtopics: Defining Educational Technology Tools: What is Educational Technology; Synchronous vs. Asynchronous Technologies (Purpose of each type and when to use); Selecting Educational Technologies: SECTIONS Model for Selecting Technology (Students; Ease of use; Costs; Teaching functions; Interaction; Organisational issues; Networking; Security and privacy).

Learning Outcomes. By the end of this module, participants should be able to: Evaluate a variety of educational technologies on the basis of hands-on experience, including experience with LCMS (Learning and Content Management Systems), email, discussion boards, blogs, ePortfolio, wikis, social media, text chat, and web-conferencing; Apply one synchronous and one asynchronous tool in the design of a course or module; Explain choice of educational technology based on considerations of purpose of activity, learning outcomes, and learner characteristics in selection process.

## **2.9 Online Learning Communities**

This module introduces strategies for building a sense of community among online learners and activities based in social learning theory to ensure successful educational experiences. In this module, you will compare methods for developing online social presence and identify strategies and activities for developing and maintaining supportive online communities.

Agenda. Topics and Subtopics: Defining Online Learning Communities: Function; Identity; Participation; Interaction

Online Learning Communities and Online Classes/Collaboration: Using Ice-breakers/ Intros in Online Spaces; Learner/Peer Feedback; Group Assignments; Strategies to Develop Successful Online Learning Communities: Modeling; Articulation; Coaching; Exploration; Reflection; Scaffolding.

Coaching is a form of development in which a person called a coach supports a learner or client in achieving a specific personal or professional goal by providing training and guidance.

Instructional scaffolding provides sufficient support to promote learning when concepts and skills are being first introduced to students.

Learning Outcomes. By the end of this module, participants should be able to: Develop strategies for building social presence in online courses; Compare different methods of creating community online; Identify how to use educational technology and design learning activities that help to develop online learning communities.

### **2.10 Interaction, Engagement and Motivation**

This module introduces strategies for improving student interaction, engagement, and motivation in online and blended learning environments. According to Keller's ARCS Model, there are four major conditions for motivation: Attention, Relevance, Confidence, and Satisfaction. In this module, you will analyze the conditions for learner motivation, and develop strategies for improving student interaction, engagement, and motivation in a course or module that you would like to design or redesign for online or blended delivery.

Topics: Interaction and Engagement: Equivalency Theorem; Modes of Interaction [Student-student interaction (live); Student-student interaction (online); Student-content interaction; Student-teacher interaction]; Motivation for Learning: Why Should We Motivate; Primary Motivational States; Keller's ARCS Model; Learning Outcomes. By the end of this module, participants should be able to: Describe several strategies for improving interaction and engagement in a course; Analyze the four major conditions for motivation according to Keller's ARCS Model; Develop strategies for improving motivation for learning.

### **2.11 Gamification in Education**

This module introduces the concept of gamification, which involves using the same kinds of thinking and processes that drive games, but in a non-gaming context. Motivation in gaming is intrinsic and comes from the joy and sense of accomplishing something that requires skills, effort, and correct decisions. In this module, you will learn how gaming principles can be applied to online and blended courses to keep students engaged and appropriately challenged.

Gamification means: The use of game thinking and game mechanics to engage users and solve problems.

Topics: What is Gamification: Game Time; What Happens When We Play a Game; Making Predictions; Gaming Principles in Learning.

Learning Outcomes. By the end of this module, participants should be able to: Explain what "gamification" means; Describe several gaming principles used in education.

## **3 Online laboratories in engineering education**

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. Online laboratories [37]-[64] are fundamental to the experiments performed by students during the individual study (see an example in Figure 4.). Thus, remote students can acquire introductory experiences and become familiar with real life phenomena. These on-line experiments can be conceived in various fields of engineering study. 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.

### **3.1 Remote Labs used in Engineering Education Programmes**

ABET (Accreditation Board for Engineering and Technology) includes in their program outcomes the expectation that students will have "the ability to design and conduct experiments" and "the ability to use the techniques, skills, and modern engineering tools". EUR-ACE (European Accredited Engineer) program criteria expect students to have: "Ability to select and use

appropriate equipment, tools, and methods”, as well as, “An understanding of applicable techniques and methods, and of their limitations.”

Many STEM programs now incorporate remote (and/or virtual) labs into their instruction: to save money; to extend scarce resources, or to share equipment with another institution; for pedagogical reasons. Depending on how the labs are deployed, those benefits are likely to include: increased student access to equipment (time-on-task per student); greater flexibility in lab scheduling; a wider range of possible assignments or activities, and; enhanced opportunities for collaboration among students. If labs are accessed online, students can (potentially) be engaged in learning at any time and from anywhere they have Internet access, as opposed to hands-on activities that rely on the times that campus buildings are open and staff members are available. Increased access opens the door to activities that may take longer than a typical class meeting time or multi-part assignments that require students to use equipment for several short periods over the span of a week or more, both of which pose logistical barriers in a hands-on environment. Finally, there may be enhanced opportunities for student collaboration when labs are accessed online, by removing the same time same place constraints posed by traditional work groups. For tomorrow’s engineer, working on a team whose members are scattered around the country (or around the globe) may be the norm and giving students practice with skills useful in this work environment (communication and teamwork, for example) can give them a head-start.

### **3.2 Experiment Course Delivery**

1. The Experiment course, based on pedagogical considerations, began with an introductory lecture on “X” to familiarize students with the topic and its applications in various domains.

2. The students then reviewed the theory section and took an online self-evaluation to assess their knowledge level before performing the experiment.

3. Next, Students will be introduced to the simulation and animation, followed by a question and answer session. This reinforced and improved understanding of concepts introduced in the theory session.

4. Students then perform the experiment using the Remote Panel, and subsequently are able to visualize and analyze their results. This process offered the added benefit of helping students to understand the debugging process in real time.

5. Students then will give individualized assignments to deepen and extend their cognitive grasp of the concepts in each application along with assessments to evaluate their overall understanding of the subject knowledge.

To effectively utilize the RT Lab, each student who starts the experiment should follow the steps below:

- a. Become familiar with the aim, objective and theory behind the experiment.
  - b. Understand thoroughly the procedure, prerequisites, hardware details and each step involved in conducting the experiment, along with the procedural details of how to effectively use the Remote Panel.
  - c. Undertake self-evaluation to assess knowledge and understanding of theoretical concepts.
  - d. View the animation to gain a procedural understanding of the experiment.
  - e. Perform a simulation of the experiment to deepen understanding of the theory and its application.
  - f. Perform the experiment in a real-world setting using the Remote Panel to achieve hands-on experience.
  - g. Undertake assignments in various contexts to realize implications and broad applicability of the theory.
  - h. Study the suggested references for additional information.
- Components of Remote Laboratory

The existing remote-laboratory solutions are heterogeneous. A set of typical components of a remote laboratory are identified, some of these components can be duplicated:

- 1) The experiment itself.
- 2) Instrumentation devices and equipment allowing the control of the experiment as well as acquiring results from the experimentation; this equipment could be based on standard equipment or custom-made interfaces.
- 3) A laboratory server that will assure the control and monitoring of the experiment, through the control of the instrumentation devices and equipment.
- 4) A server that will assure the link between remote users and the laboratory server, normally through the Internet; the solution for this server varies from dedicated applications and very “naïf” web servers (normally presenting a simple description of the experiment and containing additional learning materials) to a complex LMS handling the users and time allocation for the use of the experiments (booking system). This component could be decomposed into a set of web servers (or layers) with specific functions, namely, performing the presentation of related materials (experiment information, theoretical background, etc.), user authentication, experiment booking, management of the learning path, etc. The referred functionalities can be accessed through a web portal, acting as the front page for experiments established by an institution or by an inter institution consortium, providing access to a pool of remote experiments.
- 5) A webcam server that can be used by remote user to get a visual and audio feedback of the experiment status; this functionality could also be included in the previously referred web server, but it is common to rely on a dedicated hardware–software platform to accomplish this goal.
- 6) Collaborative tools allowing audio, video, and chat communications between users.
- 7) Client workstations assuring remote users to be connected to the experiment and associated resources; it is important to stress that some remote laboratories rely on a simple web browser, while others will need to have specific plug-ins or download client programs in order to get proper access to the experiment (in case using LabView-based server platforms).

#### **4 Science, Technology, Engineering and Mathematics (STEM) Education in Europe**

Studies on Education Policies and Practices in Europe funded by the European Commission have shown that in European education systems in Europe: STEM studies have a low attractiveness and the labor market in the STEM-related sectors is not satisfied. The Scientix Moodle program [34] was designed as a platform for peer learning for an exchange of best practices between STEM teachers throughout the European Union. The latest 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 [35]

#### **5 Conclusions**

It is obvious that learning in the knowledge society involves an effort to renew teaching practices by integrating the innovations brought by the new information and communication technologies, this effort assuming courage, creativity and collaborative activism from several actors, both “traditional” (teacher, didactician, school manager, etc.), as well as “modern” (computer scientist, system engineer, web-designer, etc.). The present and future challenges will be brought not only by the dynamics inherent in the contents of knowledge, but also by the ways of making them available that cannot be neglected. On the contrary, they can print another value to the learning

contents, which will be put in a new light precisely by the new frames of knowledge transmission. Therefore, teacher training should be oriented not only to learning content in the future, but also to new technologies with a view to integrating them for use in the learning process. Teachers need to develop new skills, not only to select and manage pre-existing pedagogical objects, but also to construct, in whole or in part, important parts of them, to intelligently combine or re-assign content modules, to reconfigure curricular assemblies, appropriate in one situation or another, to encourage the students to come with their share of contribution. A good teacher will have not so much competence over the content, but for the presentation of that content through the use of technical supports that maximize and motivate the learning process.

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