Abstract

A greater number of Engineering graduates is fundamental for the economic growth in developing countries, but also in those countries, E-Learning may be the only viable means of scaling the number of engineering students and reaching all the desired audiences.

There are many E-learning based courses in Higher Education, but in the Engineering domain they are usually focused on post-graduate degrees. On those courses, the practical works can be done using simulation tools and models, while in undergraduate degrees, for pedagogical reasons the practical works should be done with real equipment.

Remote Laboratories are the solution to the problem of giving E-Learning students access to practical experiments and equipment, without physically distributing all the required equipment by all the participating students. But, in order to develop effective courses, the diverse theories related to learning, cognition, teaching and instructional design need to be analysed considering that they will be applied to Engineering courses, that will work online (in E-Learning) and using Remote Labs.

The e-Lives Project is an Erasmus+ project, coordinated by the University of Limoges that aims to identify the best practices in e-Engineering, the development of reliable remote laboratory solutions, the development of practical open staff training, the assessment of the pedagogical innovation solutions used, and the promotion of the concept of e-Engineering within the South and Eastern Mediterranean countries.

In the development of this project, and considering the previous experience of the project partners in the EOLES project, a program in Electronics and Optics e-Learning for Embedded Systems, an “e-Learning 2.0” English-taught 3rd year Bachelor degree course, several pedagogical approaches and theories were considered.

They range from different Learning Theories, Instructional Design theories, Learning Taxonomies, Problem and Project based Learning, and they all can be applied to E-Learning Engineering Degrees, with some adaptations, and always considering the desired outcomes. This paper will review the different pedagogical methods that should be applied in the development of e-Engineering courses, according to the analyses done by the e-LIVES partners.

Keywords: E-Learning, e-Engineering, Distance Education, Remote Labs.

1 INTRODUCTION

1.1 Engineering Education Issues

In the development of South and Eastern Mediterranean countries, the Engineering sector in general, and in concrete, a strong focus on Engineering Education can have a critical role. But, traditional education assumes that teacher and students are together in the same place, at the same time. They must be “synchronized” geographically and chronologically, in a physical place (the school).

For this to happen, first the school needs to exist and possess all the required laboratories (usually expensive and big in Engineering degrees). Then the students must physically go to the school, a task that is complicated in countries with population distributed over a wide territory. They must be in school at the same time as the teachers, and that may be complicated for working students, who already possess some engineering knowledge, or for students who work on other areas, but wish to pursue an engineering career. Those students have usually the motivation needed to succeed and their will to study is the proof of an entrepreneurial spirit.
The availability of time is complicated because the main issue with the time “we have available” is not only, that it is getting smaller, but that it is getting more unpredictable. We may still have “free time”, but we have less and less control, over when and how long we will “be free”. Our “free time” is becoming more and more “fragmented”.

1.2 Distance Education & Engineering

Distance education is a natural answer to the issues described on the previous section, but the application of distance education and e-learning technologies to engineering courses has been limited to blended learning, or to the use of e-learning platforms as information repositories. Among the few exceptions, the EOLES [1] online degree deserves a special focus, as the first fully online undergraduate engineering degree.

For graduate degrees, where it is assumed that the students already are familiar with the fundamental technologies, much work can be done using simulation and/or theoretical analysis. On an undergraduate degree, there is the need to place the students in contact with the instruments and technologies of their engineering domain, in order to provide them with a solid understanding of the tools, methodologies and theories that will support their future work.

The EOLES undergraduate degree has been a success [2], because it has resulted from a synergy between sound pedagogical methods and correct application of online technologies, such as Moodle, Video-Classes, and Remote Labs [3]. The EOLES project has ended in 2016, but the EOLES course is active and with a good health.

As a successor of the EOLES project, the e-Lives project [4] aims to profit from all the resulting knowledge, widening the area of intervention, in a geographical way, in the role of the partners, and in the type of the partners.

While the EOLES project had as a target the countries of Argelia, Morocco and Tunisia, the e-Lives project includes also Jordan. In the previous project, the support backbone of all the course was supported by the University of Limoges, while one of the work-packages of the new project is the creation by each of the target partners, of their support infrastructure for the support of online engineering degrees. Also included in the project consortium are a commercial producer of Remote Lab Solutions (Labsland), providing the required market knowledge, and the IAOE (International Association of Online Engineering) in a very special role.

This supposes also the adoption (or the adaptation) of sound pedagogical methodologies that will work in synergy with all the technological infrastructure. This paper will discuss the various learning theories and how they can influence or guide the implementation of online engineering degrees.

2 PEDAGOGICAL THEORIES AND INSTRUCTIONAL DESIGN

In (online) education one needs to understand the diverse learning theories, and to support the design of an online course, it is useful to consider a learning taxonomy, and/or an instructional design methodology [5].

The field of pedagogy, for an engineer or someone from the hard sciences is very strange in a first approach, because in the so called “hard sciences”, theories are true or false. As an example of a false theory, we can cite the example of the “flat earth”. On “soft sciences”, one can have different theories that are not analyzed on a true/false basis, unless they are completely absurd, but can have various degrees of complexity, applicability and validity for explaining the same event. So, when deciding on a theory, one needs to consider also the surrounding constraints to apply the most adequate theory.

The basis behind the behavioral theory is that knowledge is not observable, so it cannot be measured. But behavior can be observed, so one equates behavior with knowledge. The theories behind the application of behaviorism to educations are exposed on [6] and were one of the pillars of the first computer based teaching systems, the PLATO system [7].

The behaviorist philosophy of education, called Direct Instruction may be a valid model for some courses or subjects, when applied in the right way, using Direct Instruction, Expository Teaching or Teaching as Assisted Performance [8]. Sometimes the Direct Instruction model is mistaken with a Lecture based approach to education, with the student in a passive role. But, as can be seen from the
“behavioral” label, a passive student, having no “behavior” is incompatible with the Direct Instruction model. Also the instruction methodologies should always take into account what is being taught [9].

According to Magliaro [8] the Direct Instruction model is adapted to e-Learning because it is based on:

- Breaking down the curriculum (and the materials) in the correct sequence of small items.
- Supporting new knowledge on the learner’s previous knowledge.
- Stating clear objectives related to learner outcomes or performance.
- On each item provide practice and feedback after each practice.
- Give independence to the learners using additional practice opportunities.

A further elaboration of this model can be found on the works of Gagné [10] where each lesson is divided in three phases: Introduction, Main Presentation and Practice. The Introduction phase besides presenting the objective, serves to gain the attention of the learner. The Main Presentation should provoke in the learner the recall of the prerequisites, present the materials and provide the learner guidance. The Practice phase where the learner applies the knowledge, is useful not only for the assessment, but for the feedback to the learner and for a better knowledge assimilation and retention.

This model was further developed by Smith and Ragan [11] where the model was expanded and completed with four phases: Introduction, Body Conclusion and Assessment, and where on each phase it is specified what the learner does and what the teacher (or the instructional material) should do.

These models have been updated with more iterative approaches like those cited in Brown and Green [12]. These approaches are basically variations of an iterative process compose of three phases: Analyze the situation, implement the Instructional Design and Evaluate the results. One of those, the ADDIE model is one of the most popular [13] and more used. It consists of five phases: Analyze, Design, Develop, Implement and Evaluate.

A more complete approach to Instructional Design can be found on Dick and Carey [14], where a Systematic Iterative approach is described with the following interconnected phases:

- Identify Instructional Goal(s)
- Conduct Instructional Analysis
- Analyze Learners and Contexts
- Write Performance Objectives
- Revise Instruction
- Develop Assessment Instruments
- Develop Instructional Strategy
- Develop and Select Instructional Materials
- Design and Conduct Formative Evaluation of Instruction
- Design and Conduct Summative Evaluation

These phases are integrated in a continuous improvement and revision cycle with Plan, Develop, Implement and Evaluate steps.

This approach takes into consideration recent learning models like the constructivist and the connectionist models [15]. The constructivist approach can be summarized by a focus on the construction of knowledge by the learner, instead of focusing on general learning principles.

This presumes that the learner takes a “more active” role than in previous models, where the learner could be considered a “passive listener”. Against this perspective, the critics point that “listening” is not a passive activity, but a listener is active decoding the words, the tone of voice of the speaker and relating the speech to their own experience.

The constructivist theory can be subdivided into three different perspectives about the construction of knowledge:

- Exogenous – The learner builds a model of the external world, and if the model reflects what happens in the known world, then it is considered as accurate.
• Endogenous – Knowledge derives from earlier structures, by an abstraction mechanism.
• Dialectical – Knowledge derives from interactions with the external world.

These perspectives are complementary and can be applied for different purposes. The exogenous perspective assumes that the learner reconstructs the structure of the world, using schemata and memory networks. This has a strong influence on modern information processing theories. The endogenous perspective has the advantage of being predictable, as it is independent of the (unpredictable) order of the interactions with real world. What matters is the coordination between the cognitive actions. The dialectical perspective is a synthesis of the other two, focusing on the interactions with the real world, and the social environment of the learner. This has been the focus of theories about the social environment [16] that are also applied to other domains [17].

While the social constructivist approach, being a middle point between the other two, has more applications, the exogenous view is interesting when studying the perspective of a learner relative to a knowledge domain and the endogenous view is useful to study the progression of a learner.

The trouble with learning theories, is that they provide a high level orientation of the learning process, but the implementation of the low level details is left to the implementer. As a consequence there are various books that aim to provide the implementer with practical advice in the design of online courses, but have different degree of applicability and practicality. Every theory needs to be validated by experience, like the experience EOLES teachers have [18].

A very interesting model for Instructional Design is the 4C/ID model [19] further refined into a Ten Steps approach [20]. The 4C/ID model consists of four related blueprint components:

- Learning Tasks
- Supportive Information
- Procedural Information
- Part Task Practice

The Learning Tasks are based in real-life problems aiming to develop not only knowledge, but also skills and attitudes, and are arranged in increasing degrees of complexity and learner autonomy.

Supportive Information is the information needed for learning and performing the learning task. This information is valid for a type of task and can be considered as the “important” or “hard to find information”, and also the relation with what the learners already know.

Procedural information is the information required for the routine aspects of performing a task and should be made available only when needed. The “How-to guides” are an example of this type of information.

A Part Task Practice is a set of practices designed to provide experience with a type of task to the learner and a high level of automaticity, when the cognitive obstacles have been surpassed.

This model as it focuses on complex learning avoids compartmentalization and fragmentation, with the right amount of variability in the learning tasks. Another characteristic of this model is the relation with the Cognitive Load Theory [21], that considers human cognition [22] should always be considered in Instructional Design.

The Ten Steps model has also a strong compatibility with the Pebble-in-the-Pond Instructional Design methodology proposed by Merrill [23]. This methodology has the characteristic of being content centered, instead of being centered in the educational outcomes. So, the Ten Steps are usually presented in an order influenced by the Pebble-in-the-Pond methodology.

1 Design Learning Tasks
2 Design Performance Assessments
3 Sequence Learning Tasks
4 Design Supportive Information
5 Analyze Cognitive Strategies
6 Analyze Mental Models
7 Design Procedural Information
It is important to note that this model is also complementary to the ADDIE iterative model, that can be used to support the Instructional Design phases not specified in the Ten Steps, but always in the perspective of Instructional Design applied to Higher Education [24].

3 RESULTS AND CONCLUSIONS

As was seen the use of modern technology in the teaching of engineering courses is compatible with a large number of learning theories, and modern technology can provide a framework to support different teaching styles and methodologies, always considering the students and the curriculum.

These considerations have resulted in the current structure of the EOLES course, where the modules are structured in sequences of individual learning tasks. All the experience in the EOLES Project [18] has been useful in order to validate the theoretical analysis and all the results are incorporated in the “e-Engineering Good Practice Guide” produced by the e-Lives project and available at https://e-lives.eu/.

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REFERENCES


