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Article *in* International Journal of Engineering Education · January 2015

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García-Peñalvo, F. J., & Colomo-Palacios, R. (2015). Innovative teaching methods in Engineering. *International Journal of Engineering Education (IJEE), 31*(3), 689-693.

Innovative teaching methods in Engineering

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Engineering and innovation are inseparable concepts [1]. This symbiotic relationship is shown in engineers' workplaces, in engineering research and development processes but also is present in engineers' education methods.

Innovating in the teaching methods in the Engineering scope is a mandatory activity due to different reasons.

First, innovation skills should be present in all the higher education teachers, but especially in ones devoted to Engineering.

Second, structures, practices and methodologies of the current educational systems are not suitable enough to support the learning needs of the Knowledge Society. During the latter half of the past century, international thinking about education began to shift to a new paradigm. This shift was driven by an awareness of massive and on-going social, economic and technological changes, and the exponentially increasing amount of human knowledge being generated as a result. International thinking began to examine questions about the role and purposes of education in a world with an unprecedented degree of complexity, fluidity and uncertainty [2]. Alongside above-mentioned changes, many serious challenges characterise current society. Some authors describe these as wicked problems, because they are highly complex, uncertain, and value-laden [3], spanning multiple domains: social, economic, political, environmental, legal and moral. Thus, it is broadly argued that students (and faculty also) need support to actively develop the capabilities they need to productively engage in this wicked problem solving from an Engineering perspective.

Third, future engineers are called to be high-qualified professionals that should lead and head companies in their careers. These professionals are expected to develop creative ideas and innovations in order to achieve competitive

advantages and new business opportunities [4]. In fact, an IBM poll of around 1,500 CEOs identified creativity as the key leadership competency [5].

And fourth, innovation is directly linked with the capability to solve problems. To resolve the complex situations future engineers must face, they will have to be continuously learning from formal, non-formal and, especially, informal sources [6-8].

Innovation is essentially the creation and implementation of new processes, products, services and methods of delivery, which result in significant improvements in the efficiency, effectiveness or quality of outcomes [9]. Thus, three are the most important elements regarding innovation:

1. It means the creation of something new.
2. It is a process.
3. It should provide some kind of quantitative or qualitative improvement in the outcomes.

If we focus on the educational innovation, we may define it, based on the ideas expressed in [10, 11], as the process to change teaching or learning activities that produce improvements in the learning outcomes. However, in order to consider this process as educational innovation, it should respond to some needs: 1) it should be effective and efficient; 2) it should be sustainable over time; and 3) it should produce transferable outcomes beyond the particular context in which it arose.

Teaching engineering methods are always open for evolution in order to include the huge possibilities that technological advances arise. Remote and virtual laboratories, robotic applications, 3D virtual worlds, augmented reality developments, complex data visualizations and mobile applications are just some examples of emerging technological supports for teaching methods based on problem-based learning, cases-based learning, online learning…All these approaches are related to a more active student-centred education in engineering subjects.

On the other hand, other trending topic that is interesting to be discussed is open education issue in engineering education, especially with regard to the MOOC (Massive Open Online Course) phenomenon. The main question is how to achieve the personalized interaction that Engineering processes require with the massive audience of MOOC approaches.

Therefore, it is important to analyse the real impact of these innovative teaching approaches in engineering education just in order to be ready to spread and share this successful case studies and lessons learned from previous experiences. Specifically, this special issue covers some of the above-mentioned topics in the twenty selected papers from the eighty-seven received contributions. We have grouped the main themes of the papers in the following ones.

Mobile devices have a great penetration in education in general [12, 13] and in Engineering field specifically [14]. Three papers of this special issue address this topic from different perspectives. First, González-Rogado et al. paper “Mobile Technology in the Teaching Lab” applies mobile technology in the teaching lab with the threefold purpose of creating a safer environment for students, enhancing their culture of safety, and training professionals sensitized on safety, which eventually will allow them to make responsible decisions in their professional practice. Merayo et al. explain how to use the smartphones as learning platform to deliver learning packages throughout a multiplatform software application, called AIM-Mobile. Tuan Le et al., in their contribution entitled “A Framework for Using Mobile Based Virtual Reality and Augmented Reality for Experiential Construction Safety Education”, use the mobile devices with safety purposes too. They propose the combination of virtual reality and augmented reality to promote safe and healthy working environment in the construction area.

Tuan Le’s paper might be classified into other of the considered topics of interest of this special issue, the advanced Human-Computer Interaction paradigms [15], which have an extended usage in the educational innovation methods in Engineering. Four papers fall into this topic. In the paper “Learning Systems through Haptic Simulators – A Domain Expertise Approach” Esteban et al. proposes the modelling of an e-learning system for surgical procedures using haptic virtual reality simulators that helps in the teaching and learning of surgical procedures. Fonseca et al. in their paper entitled “Are Engineering Students Prepared for Academic Use of Augmented Technologies?” present a mixed-method study that combines quantitative and qualitative techniques to evaluate the technological profile and the motivation and satisfaction of Multimedia Engineering degree students using augmented visualization methods. This study will show us that the students are motivated and have access to these technologies with the capacity to be used in the classroom, but the process is hindered mainly by the lack of standard systems that allow the visualization and conversion of complex 3D models. The paper “User-centered Development of Generative Educational Systems for Computer Engineering: The *Evaluators* Case Study", by Rodríguez-Cerezo et al., is devoted to describe *Evaluators*, an educational system oriented to the generation of different kinds of interactive simulations for introductory Compiler Construction courses in Computer Science and Computer Engineering degrees. Other interesting topic, very related to HCI issues, is the introduction of adaptive capabilities in the educational software or in the learning process [16, 17], a characteristic that has been explored several times regarding the programming skills [18] and in the assessment stage [19-20]. Precisely, Molins-Ruano et al. paper “An Adaptive Model for Computer-Assisted Assessment in Programming Skills” combines these two elements in order to propose a methodology aimed to improve the quality of the assessment process for subjects related to basic programming.

Gamification [21,22] and game-based learning [23] are other interesting topics with a growing presence in the innovative educational movement in Engineering specially oriented to achieve more engagement and motivation among the students [24]. Two papers about these themes are selected in this special issue. The first one, by Lasse Hakulinen, is entitled “Using Alternate Reality Games to Teach Computer Science Concepts – Case: Stop Toilworn Diamond”, is devoted to introduce an alternate reality game called Stop Toilworn Diamond in order to study the potential of using this kind of games in computer science education. The second one is entitled “Mecagenius®, an Innovative Learning Game for Mechanical Engineering”, by Galaup et al., and describes Mecagenius®, a learning game to teach mechanical engineering at an engineering faculty.

Other topic of interest is the usage of robots in the classroom as a didactical and innovative method [25]. The paper of Blanco et al. “Improving Robotics Teaching in the Computer Engineering Degree through the Action-Research Approach” may be classified under this descriptor and it describes an experience using Action-Research as the method to study the educational reality of robotics teaching in the Computer Engineering Degree, to improve its comprehension and to achieve its transformation in line with the European Higher Education Area (EHEA).

Perhaps the largest group of papers, with eight contributions in this collection, is regarding the development of transversal skills [26], competence assessment [27, 28], multicultural issues [29, 30] and informal learning activities [31, 32] in Engineering. De la Torre et al. in their paper “STELLA 3D: Introducing Art and Creativity in Engineering Graphics Education” defend that improvement of spatial skill is a basic competence to develop together with other general ones such as the decision making, teamwork, creativity and so on and they propose achieving this improvement throughout a workshop activity about creative three-dimensional modelling (Stella 3D). Martín-Gutiérrez et al. also consider the spatial skills as one of the most important for the professional development of an engineer. Their paper “Improving the Teaching-Learning Process of Graphic Engineering Students Through Strengthening of their Spatial Skills” presents the training activities based on virtual reality, augmented reality and PDF3D they have used for, and they make a comparison with the intention of finding which of them yields the best results as a training tool and improves the academic outcomes of the students in the subject of Engineering Graphics. In the paper “Monitoring Indicators for CTMTC: Comprehensive Training Model of the Teamwork Competence in Engineering Domain” Fidalgo-Blanco et al. apply a white-box testing method for the assessment of the learning of the teamwork competence. However these kinds of methods are effective, but not productive, thus they proposed improvements regarding the efficiency of these. López et al. in their paper entitled “Acquisition of Transferable Skills Associated with Software Maintenance and Development Using Tools for Versioning and Task Management” describe the usage of control version tools promoting and assessing the acquisition of certain generic skills related to the software

engineering topics. Balderas et al. paper “A Domain Specific Language for Online Learning Competence Assessments” introduces the Simple Assessment-Specific Query Language (SASQL) in order to help a course coordinator to extract different objective indicators to assess competencies defined in the syllabus using simple queries. Čok et al. investigate in their paper “Multicultural Issues of Product Development Education in Virtual Teams” multicultural background of virtual team members from two different aspects: how it influences the team’s creativity and how various cultural backgrounds of creative team members could lead into different perceptions of particular design features. Informal learning recognition is the base for the papers of Casañ et al. and Conde et al.

The linked open data is an approach for interlinking data that allows digital resources to be shared, reused, and accessed [33-35]. Using linked open data, repository owners can publish structured data and establish categorized links between their repositories and from other sources. In the paper entitled “Interlinking Educational Data: an Experiment with Engineering-related Resources in GLOBE”, Rajabi et al. present a report primarily focused on evaluating the interlinking of engineering-related resources of a significant educational repository (GLOBE) to one of the most important datasets (DBpedia) on the Linked Open Data (LOD) cloud. After considering various interlinking approaches for link discovery, the paper focuses on the use of one of the interlinking tools (LIMES) and outlines the number of resources linked to the DBpedia dataset.

The final covered topic in this special issue is devoted to the MOOC phenomenon. MOOC are controversial, some love them and think this kind of massive and open education will revolutionize and transform the education reality, but others question the validity and quality of the MOOC model [36]. This special issue is not devoted to discuss about the present and future of MOOC, but it is true that MOOC are highly accepted by engineering students and by Engineering practitioners. In regard to this, Morales Chan et al. paper “MOOC Using Cloud-based Tools: a Study of Motivation and Learning Strategies in Latin America” describes the motivational and cognitive learning strategies used by students of the large-scale MOOC titled “Cloud-based Tools for Learning,” which consists of using free Web 2.0 tools for learning.

Finally, guest editors would like to thank Professor Ahmad Ibrahim, Editor in chief of International Journal of Engineering Education, for the opportunity to edit this special issue. In addition we are grateful to the pool of reviewers who generously devoted time to provide feedback to the authors.

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