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Project Based Learning experiences in the space engineering education at Technical University of Madrid

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Abstract

This work describes the innovation activities performed in the field of space education since the academic year 2009/10 at the Technical University of Madrid (UPM), in collaboration with the Spanish User Support and Operations Center (E-USOC), the center assigned by the European Space Agency (ESA) in Spain to support the operations of scientific experiments on board the International Space Station. These activities have been integrated within the last year of the UPM Aerospace Engineering degree.

A laboratory has been created, where students have to validate and integrate the subsystems of a microsatellite using demonstrator satellites. In parallel, the students participate in a Project Based Learning (PBL) training process in which they work in groups to develop the conceptual design of a space mission. One student in each group takes the role of project manager, another one is responsible for the mission design and the rest are each responsible for the design of one of the satellite subsystems. A ground station has also been set up with the help of students developing their final thesis, which will allow future students to perform training sessions and learn how to communicate with satellites, how to receive telemetry and how to process the data.

Several surveys have been conducted along two academic years to evaluate the impact of these techniques in engineering learning. The surveys evaluate the acquisition of specific and generic competences, as well as the students' degree of satisfaction with respect to the use of these learning methodologies.

The results of the surveys and the perception of the lecturers show that PBL encourages students' motivation and improves their results. They not only acquire better technical training, but also improve their transversal skills. It is also pointed out that this methodology requires more dedication from lecturers than traditional methods.

Keywords: Active learning; Project Based Learning; Team work; Satellite design

Abbreviations: *AFSK, Audio Frequency Shift Keying; APSK, Amplitude Phase Shift Keying; BPSK, Binary Phase Shift Keying; CDIO, Conceive-Design-Implement-Operate; CG, Control Group; E-USOC, Spanish User Support and Operations Center; ECTS, European Credit Transfer and Accumulation System; EHEA, European Higher Education Area; ESA, European Space Agency; ESA CDF, ESA Concurrent Design Facility; ESW, Experimental Software; GENSO, Global Educational Network for Satellite Operations; GFSK, Gaussian Frequency Shift Keying; ISS, International Space Station; MCS, Mission Control System; Morse CW, Morse Code, Morse Continuous Wave; MWIRD, Medium Wave Infrared Detector; NIT, Near Infrared Technologies; NOAA, National Oceanic and Atmospheric Administration; PBL, Project Based Learning; PCM, Phase Changing Material; STK, Satellite Tool Kit; UPM, Universidad Politécnica de Madrid (Technical University of Madrid); VEII, Space Vehicles II*

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1. Introduction

In recent years, a transformation in teaching and learning methods in European universities has taken place, aiming at increasing active learning (Johnson et al., 1998; Prince, 2004). The transformation has been mainly driven by the creation of the new European Higher Education Area (EHEA) (Ministers of Education of the European Union, 1999). The model proposed by EHEA involves the transition from an education system based on teaching to a system based on learning, making the student the center of the educational process.

The application of these new models particularly benefits engineering education, because training in engineering has an essential practice component. In particular, subjects in the second cycle of the degree, which have a very technological and systematic nature, are more suited to implement active learning methods such as Project Based Learning (PBL) (Kjersdam and Enemark, 1994; Luxhol and Hansen, 1996; Krajcik et al., 1999; Thomas, 2000; Frank et al., 2003; Mills and Treagust, 2003; Dym et al., 2005). PBL enhances not only the students' acquisition of competences specific of each subject, but also the development of generic competences as communication, team work, leadership, etc., that are increasingly valued in the professional field.

This work describes the educational innovation activities performed in space engineering education since the academic year 2009/10 at the UPM, aligned with the model proposed by EHEA. These activities have been performed in collaboration with the Spanish User Support and Operations Center (E-USOC, www.eusoc.upm.es), a center in the UPM delegated by the European Space Agency (ESA) to operate scientific experiments on board the International Space Station (ISS); it supports fluid science experiments performed within the European Columbus Laboratory and experiments in the Microgravity Science Glovebox in the U.S. Destiny module of the ISS.

These innovation activities have been integrated along the last semester of the Aerospace Engineering degree at the Higher Technical School of Aerospace Engineering of UPM. Students in this semester have not been exposed to Project Based Learning previously, and after completing their five-year degree they usually transition directly into industry.

The main activities implemented are: (a) "Use of demonstrator satellites for teaching" and (b) "Conceptual design of a satellite mission", which have been both integrated in the "Space Vehicles II" (VEII) course; (c) "Development of a satellite tracking ground station", (d) "Development of a laboratory satellite", and (e) "QB50 project", which have been integrated as Final Thesis.

The "Conceptual design of a satellite system" was introduced in VEII in the academic year 2009/10. In order to improve its outcomes, in the following three years it was reshaped taking into account the lecturers and students feedback. The "Use of demonstrator satellites for teaching" was introduced in the academic year 2010/11, and was also modified in the next academic year. In the years 2012/13 and 2013/14, the VEII course structure was frozen and several surveys were conducted. The main objective of these surveys was to evaluate the impact of the PBL methodology in the students' engineering skills, in their acquisition of generic competences, and to determine the students' degree of satisfaction. The principal results are summarized in this paper.

The work is organized as follows: Section 2 describes the main learning activities performed. A description of the application of PBL methodology is contained in Section 3, and its main results are presented and discussed in Section 4. Sections 5 and 6 summarize the instructors' perception and the overall conclusions, respectively.

2. Activities description

The main goal of the activities carried out has been giving the students a training as complete as possible, covering both the engineering learning and the acquisition of generic skills and maturity. Moreover, all the activities were aimed at bringing the students closer to the current technologies and to the way of working in the aerospace industry.

The design of the activities was done not knowing the CDIO initiative, led by a team at the Massachusetts Institute of Technology (MIT) (Crawley, 2002; Crawley et al., 2011) and implemented by over 20 Universities worldwide (Smith et al., 2011). Even though the CDIO syllabus was not known to the authors, the underlying design principle of the activities implemented is fully in line with this international effort. The CDIO design principle is basically that "the graduating engineers should be able to Co nceive-Design-Implement-Operate complex value-added engineering systems in a modern team-based environment" (Crawley et al., 2007). And in order to do it effectively in an enterprise, societal and environmental context, they should also possess qualities such as teamwork, leadership, and communication.

In this context, the activities at UPM were designed to give the students the opportunity to cover the complete space vehicle life cycle. As the duration of the VEII course was not enough (6 h of formal class per week, for 10 weeks), it was decided to introduce the design, integration and verification phases in the VEII course, and leave the implementation and operations phases for the Final Thesis.

The learning objectives of VEII are:

- To comprehend the relations between the space vehicle subsystems.
- To comprehend the implications of different requirements.
- To be able to design a space vehicle (mission and subsystems) given the mission statement. Identifying different design possibilities, being creative, managing imprecise and scarce data.