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Project Based Learning Methodologies Applied to Large Groups of Students: Airplane Design in a Concurrent Engineering Context

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Abstract: This article presents a college course experience taught in the final academic year of the Aerospace Engineering program at the University of Seville, in which students design an airplane taking the specification submitted by the instructor, following the Project Based Learnig (PBL) methodology. Students are organized into groups forming "companies" that have to defend their proposed design with the "client". The article presents the usual steps of the PBL methodology showing the feasibility of applying this methodology to large workgroups.

The complete design of an aircraft is the result of a compromise between knowledge, experience and teamwork in a collaborative environment. The students need to understand that each of the different areas are necessary pieces of the larger puzzle of aircraft design, and they need to find the key that solves this puzzle. The main objective of this course it to provide instructions to complete that puzzle by introducing concurrent engineering and PBL methodologies.

Keywords: project-based-learning; large groups; concurrent engineering; aerospace.

1. INTRODUCTION

The complete design of an airplane marks the end of the education of many aeronautical engineers. Students, during their educational journey, acquire a series of training tools that they will use once the move up to their better life: working in the industry. The problem is that these tools are just pieces of a quite complex puzzle, that in the context of airplane design, range from aerodynamics, structural design, propulsion, performance, systems engineering, stability and control, and modeling and design, that although are not the only aspects that contribute to the aircraft design, they are the most important.

The following sections describe the teaching experience of Aircraft Design which uses the project based learning (PBL) methodology. This methodology provides solution to one of the main teaching-learning needs that appear in the European Space of High Learning Education concerned with the need of creating education environments with capabilities of providing the future engineers with the necessary competences (Feisel 2005).

Throughout the duration of their academic training, students rarely receive the instructions of how these pieces of the puzzle are put together in order to understand the context that they will enter once they move to the industry. The main objective of the course presented in this article, Cálculo de Aviones, is to provide students with the instructions that will allow them to understand the aircraft design process. For simplicity of reading, from now own the course will be refereed in the text by Aircraft Design.

The following sections describe the teaching experience of Aircraft Design which uses the project based learning (PBL) methodology. This methodology was first introduced in the Aerospace Program in the 2006-2007 academic year, and the results here presented cover the experience until the last year of implementation in the 2013-2014 academic year. It's important to note that the experience here described focuses on the results of the five-year extinct aeronautical engineer degree, and also important to note that this same methodology has been implemented in the four-year degree program currently implemented in the Spanish University system due to the Bologna process (Musselini, 2004). The following sections will describe the experience, placing first the course within the context of the Aeronautical Engineering curricula at University of Seville (US), explaining the objectives of the course, the methodology employed, and finally, presenting the results of applying the PBL methodology, with special attention to how it is applied to large group of students.

2. AIRCRAFT DESIGN

2.1 Aerospace Engineering Degree

To understand the context in which the PBL experience presented in this article is framed, it is interesting to present the Aeronautical Engineering Curricula at the Escuela Técnica Superior de Ingeniería (ETSI) of the US, which comprises two cycles without intermediate qualification, and is structured in courses spread over five courses, with a total of 390 credits (1 credit being equivalent to 10 hours of

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course). In order to obtain their degree, students need also to conduct a Final Project. The first cycle of Aeronautical Engineering consists of disciplines structured in two academic years of 152.5 course credits, where 97.5 credits correspond to core subjects, 39 credits to mandatory subjects and 16 free election credits.

The second cycle of Aeronautical Engineering is structured in three academic years of 237.5 course credits, where 112.5 credits correspond to core subjects, 43.5 credits to mandatory subjects, 52.5 credits of optional subjects, 23 credits of free election subjects, and 6 credits to Final Project.

Aircraft Design is one of the core subjects of the Aeronautical Engineering degree at the ETSI. The number of credits of this course is 4.5 and is taught during the second semester of the 5th year. This subject is the responsibility of the Aerospace Engineering Department. The subject has a workload within the curriculum of Aeronautical Engineering, 42 teaching hours and about 68 hours of student work. The course content is similar to that taught at the equivalent subjects in many other universities in Spain, but with a very different teaching focus by using the project based learning philosophy being used in the best universities around the globe.

The teaching project presented here is highly influenced by educational programs based on PBL, in which the students are oriented to conduct independent learning and cooperation among themselves. This teaching philosophy for Aircraft Design is being used at numerous leading aerospace university programs in countries as UK, USA, Germany, Holland, and Italy, to name a few. It should be noted that the experience presented here has been designed by the authors as to meet the qualification requirements of the Aeronautical degree at the ETSI in Seville, taking into account the limitations of credits given, so although the methodology exhibits many similarities with the methods used in other universities, it has been adapted so that both faculty and the students are able to meet the needs of the subject.

Given the complexity associated with the design of a system like an airplane, it is necessary that students acquire a series of aeronautical technical skills such as propulsion, aerodynamics, structures, flight mechanics, stability and control, and finally, the capability of organization and management of large scale projects. It is also important to emphasize that students must also possess basic mathematical skills as calculus, algebra, geometry, and Computer Aided Design (CAD), so the location of this course in the second quarter of the last year is ideal to ensure that students are able to study a large number of subjects with cross competences. The following sections will describe the PBL teaching experience on the Aircraft Design course.

2.2 Aerospace Engineering Degree

The design of an aircraft is the result of a compromise between knowledge, experience and teamwork of students who are organized in different design groups that have to undertake the task of designing an airplane. These design groups are made up of very diverse areas of specialization, particularly in the ETSI of the US, focus on only six areas of expertise: aerodynamics, structures, performance, propulsion, stability, and finally, design and systems. It is natural to understand that each of the different areas of design are equally important when designing an airplane, but this is not unimportant, since students often are not aware of this obvious, and they think that their area of responsibility is more important than the other areas, which could cause to the wrong design methodology as seen in the famous idealization of the CW Miller "Dream airplanes" (Sohler 1948) Figure 1, which describes what could happen if each of the areas involved in the design of an airplane was considered the most important when undertaking the design of an airplane.

Figure 1. Dream Airplanes. C.W. Miller.

Working in a concurrent engineering environment teaches the students to work in a coordinated and cohesive environment, allowing them to integrate the different areas in a more efficient manner. This will be possible if they understand that they are necessary pieces of a larger puzzle, and that they need to find the key that solves this puzzle.

This task falls to the instructor by applying the PBL methodology so that students can convey the degree of interconnection between each of the areas, and thus create a cohesive concurrent engineering environment. To achieve these objectives the teacher uses theory sessions and tutorial sessions (which will be explained in more detail below) to transmit to the whole group the degree of interaction between the six working areas, always emphasizing that each group is responsible for maintaining communication lines between