Project Based Learning activities as a means of adapting conventional curricula to the demands of the 21st century aeronautical engineer

The design and building of the EYEFLY 1

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Abstract— **In this paper we report the process of designing and building the EYEFLY 1, a real UAS platform which has just performed its maiden flight. For the development of this aircraft, 30 groups of students from successive years at the Escuela Universitaria de Ingeniería Técnica Aeronáutica (EUITA) of the Universidad Politécnica de Madrid (UPM) carried out their compulsory End of Degree Project as a coordinated Project Based learning activity. Our conclusions clearly indicate that Project Based Learning activities can provide a valid complement to more conventional, theoretically-based, teaching methods. The combination of both approaches will allow us to maintain traditional but well-tested methods for providing our students with a sound knowledge of fundamental engineering disciplines and, at the same time, to introduce our students to exciting and relevant engineering situations and sceneries where social and business skills, such as communication skills, team-working or decision-taking, can be put into practice.**

Keywords-component project based learning, CDIO, end of degree project.

I. INTRODUCTION (HEADING 1)

The principle which would eventually lead to the new paradigm in engineering education crystallized in a series of documents published in America in the years around the turn of the century. In 1966 the Boeing Company published the list of desired attributes of an engineer (Boeing 1996). The new accreditation standards (ABET EC 2000) reflected the ideas over engineering education which had been put forward in the previous decades. In 2001 MIT launched the CDIO Syllabus [1].

Paralleling this process, in Europe, a complete re-structuring of the higher education system was taking place. The starting point was the declaration of the ministers of higher education of European countries commemorating the anniversary of the oldest university in the world: Bolognia.

Both processes present such a wide and fertile variety of education theories and methodological tools that resuming them in a simple sentence would undoubtedly be a futile intent. However it will be generally accepted that the distinct feature they both share is the adoption of a Learner's Centred Approach to teaching.

It is against this methodological background that the conception and development of the Project Based Learning PBL) activity which we present in this paper has taken place.

For over 75 years the formation of aeronautical engineers in Spain was exclusively the responsibility of two schools: the Escuela Técnica Superior de Ingenieros Aeronáuticos and the Escuela Universitaria de Ingeniería Técnica Aeronáutica (EUITA). The former offered a five- year degree program whilst the latter offered a 3 year-degree program. As a consequence of the so called Bolognia Process , a political decision was taken that all graduate degrees in Spain must be 4-year-programs. Thus, both Schools merged to create the Escuela de Ingeniería Aeronáutica y del Espacio (EIAE), which is already offering the new four –year-bachelor degree in aerospace engineering.

Simultaneously to the design process of the new curriculum, a group of professors from the EUIT Aeronáutica had undertaken the development of an engineering project: the design and building of Unmanned Aerial System (UAS). They soon realized that this engineering project could be approached as a Project Based Learning activity to be developed by the students as apart of their compulsory Final Project.

By taking this initiative we expected to acquire enough knowledge and expertise to decide whether a multidisciplinary-teamwork PBL activity could be introduced as part of a conventional lecture/laboratory based curriculum. If this was the case, we also intended to know whether the adoption of this Project Based Learning approach would be useful to actuate on those learning areas which would have to be enhanced in the new curriculum, namely personal and professional skills, team work, communications and those activities enabling the integration of conceptual knowledge and technical skills to the designing and building of engineering products.

Thus the objective of the PBL activity described in this paper was twofold: designing and building a real and industry competing UAS and testing the adoption of a PBL as an influential part of our new curriculum without changing it to a pure PBL

II. THEORETICAL FRAMEWORK

Project Based Learning is considered as one of the best examples of the socio-constructivism. As opposed to skinner's behaviourism, constructivism, and more particularly socio-constructivism, understands learning as a process where the construction of knowledge derives from building on previous knowledge and interacting with the environment, that is, what we understand is a function of the content, the context, the activity of the learner and of the learners' own goals [2].

However there is not a single specific theory from which it can be said that PBL is directly derived, rather, there are various constructivist schools of thought [3] whose ideas have foster PBL, both as a teaching and learning method and as a curriculum development.

Further more, new insights on PBL history [4] seem to conclude that the link between PBL and any particular theoretical corpus has only very recently been established and that the source originating PBL as a teaching and learning approach was rather a number of pure pragmatic experiences, using the trial and error method to develop it. This might well be the case for a very adequate use of the saying "there's nothing so practical as a good theory and there's nothing so theoretically interesting as good practice" (Gaffney & Anderson in [2]).

The lack of a universally accepted opinion on its origins and the variety of features which have been considered as typical of PBL had made it difficult to reach a common and comprehensive definition of this concept. Probably one of the simpler and most significant definitions is the one provided by J.W Thomas when he says that PBL is a model that organizes learning around projects.

The model some Scandinavian engineering universities and schools have adopted is precisely the organization of the whole curriculum around projects. This is consistent with some definitions of PBL which use the term only for those situations where projects are central to curriculum [5].

As we have previously indicated we had neither the capacity nor the intention of reorganizing a curriculum which had just been developed on the basis of a well established and long tested previous model. Our aim was not to make the PBL activity proposed a central part of the curriculum, but nor did we plan it to serve as a pure complementary practice, which was the role of the existing Final Project .We would like it to be influential enough as to develop some students' skills and aptitudes which were not completely emphasized in the curriculum.

To resume, if our research had to be listed under one of the four different forms that, according to John W Thomas [3], research on PBL takes, this would be the first one, that is the one whose purpose is to make judgments about the effectiveness of PBL; although we do not consider its effectiveness in a broader sense but only with respect to the goals we have exposed above.

III. METHODOLOGY

We consider that the principles of the CDIO didactic approach are a good materialization of the new paradigm in engineering education. Conceive, design, implement and operate are the stages of a product development and engineering studies should also be planned adopting that point of actuation. Thus the project – on the small scale- has swept through all the different stages of an aerospace project.

A. Definition of requirements

The aim of the project was to design an UAV for civil aerial observation. Once its mission had been defined, a wide research analysis of similar airplanes was carried out since, in the initial stage of the project, it is quite common to look at similar airplanes for estimating some important data of our design. Next, the preliminary sizing was undertaken, taking as a basis weight and wing loading estimations, the latter parameter being essential because it will allow us to study one of the most important elements of the plane: the wing.

The objective of the first working team was to establish an initial airplane layout, taking into account that many modifications will be required as the development of the project progressed.

Previous to the preliminary sizing, another group of students devoted themselves to study similar airplanes. In this way we were able to compare common features shared by different aircraft and to estimate, at this first stage, some numerical values which were needed for the pre-design stage.

B. Analysis of Similar airplanes (State of the art)

By means of carrying out a comparison with similar planes, on a first approach, parameters were estimated: maximum takeoff weight, payload, range, altitude, and cruising speed.

- Maximum weight at take-off: 30 kg.
- Payload: consisting of a video camera (or webcam), batteries and an air-to-ground radio transmitter.
- Range: an estimated value of 425 to 450 km with maximum payload and a 10% fuel reserve.
- Altitude: approximately 800 m.
- Cruising speed: around 30 to 34 m/s

C. Preliminary sizing

In the pre-design stage we specified two main parameters: weight estimation and wing loading estimation.

1) Weight estimation

We concluded that the preliminary values for weights would be:

- Maximum take-off weight: 30 kg.
- Empty weight: 13 kg.
- Fuel weight: 8 kg.
- Maximum payload: 8 kg.

These values are selected taking into account the endurance and range requirements, and the payload required for civil aerial observations (digital infrared camera, etc.)

2) Wing Area Estimation

Before calculating the wing area, and, therefore, being able to establish our prototype's wingspan, we needed to calculate the wing loading. This value was conditioned to the corresponding phase of flight we are going through; as a consequence, we had to determine the wing loading for each of the possible situations. Wing loading depends on the following conditions: stall speed, take-off run length, landing distance, cruising speed, climbing speed, time of climb to a specific altitude, maneuvers.

D. Initial Layout

Once all the preliminary sizing data had been determined, the following stage of the project was deciding the aircraft's layout.

- Making a decision on the type of fuselage to be used was one of the first objectives of this stage. The main requirements that the fuselage structure should meet were the following:
- An aerodynamic design.
- Light weight (an essential element for our design).
- Not difficult to manufacture and assemble.
- Easy to maintained.
- Maximum cargo capacity (open plan structure).

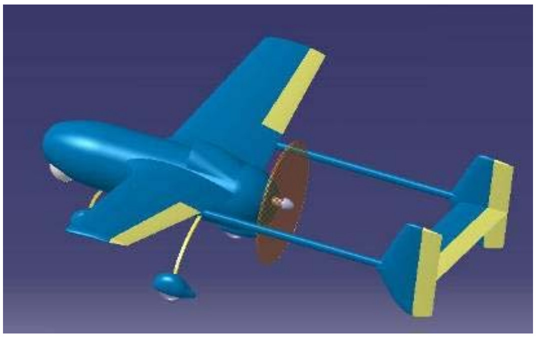

Figure 1. Shows the draft of the initial plan view and the profile of the initial configuration of our design

E. Aerodynamic Analysis

The following stage in the project, after determining the preliminary configuration, was calculating all aerodynamic features and the aircraft's performance so that they could later be checked and recalculated. To complete all these steps, a sound analysis of the most important elements of the aircraft had to be done, from the geometric and the aerodynamic points of view.

F. Analysis of the aircraft's flight dynamics

We approached the analysis of the aircraft's performance from three different points of view:

- First, a study of the performance by means of calculating the different power values, that is to say the power required for flying and the power developed by the power plant.
- Next, we calculated the basic performance characteristics from three different approaches:
- Maximum and minimum speeds of flight, as well as rate of climb (maximum and optimum).
- Theoretical and practical ceiling as well as calculation of the time of climb
- Flight envelope calculation.
- Flight range and endurance.
- Finally, we undertook the analysis of special performance, establishing take-off and landing run distances as well as maneuvers.

Previous to all this, was determining the power available which was defined as the product of the propeller efficiency by the power developed by the engine. Therefore we needed to know the propulsive efficiency, for the different flight conditions, by defining the characteristic parameters of our propeller.

- Selecting the type of propeller or the family of propellers.
- Matching the propeller to maximum efficiency condition.

Once the required power and the power available had been defined, we could embark on the analysis of the basic performance.

After the study of the performance, we proceeded to check dynamic and static stability, together with the aircraft control characteristics.

G. Analysis of the aircraft's structure

Once the study of the airplane from the aerodynamic point of view was completed, we had to carry out a basic structural study.

Before doing so, we needed to determine the maneuvering diagrams.

H. Wing tunnel tests and drag checking

Before constructing the final prototype and as an essential part of the whole project, we carried out a series of test at our workshop. We concentrated on testing aerodynamic forces using our wind tunnel. We also checked the most critical structural elements by means of static load tests.

I. Building the prototype

After we had concluded the stage corresponding to the preliminary essential calculations we moved forward to the detailed design and manufacturing stages. A global design was developed and we had to define materials, joining elements and fasteners. The assembly of the prototype and the actuations to get it ready for flight was the last stages of the project.

To sum up this part we would like to point out that we had not set out to establish a new mark nor conquer a pre-established level. We considered that the challenge of placing the responsibility for the whole project in the hands of the students would be valuable in its own right, because it would imply nothing less than their being responsible for all the stages mentioned.

Nine years have gone by since the starting point and we are now in a position to state that it has been a truly rewarding experience and that we can now see the flight of the UAV on the horizon. The following are just a few figures of what this effort has required:

- More than 15000 hours/man.
- 46 students (their enthusiasm and dedication).
- About 20000 €.
- Great amounts of patience.

IV. CONCLUSIONS

Our main conclusions are related to the research questions we started from:

1 . *Is it possible to produce in an academic setting a real UAS technically comparable to any other produced by conventional aircraft manufacturers?*

The answer to this first question is evident: the Eyefly 1 (Fig 1) has already made its maiden flight.

Figure 2. Maiden flight of the Eyefly 1

2 . *Could this task, taken as a multidisciplinary- teamwork PBL activity be introduced as part of a conventional lecture/laboratory based curriculum?*

The fact that the aircraft has been designed and built in the academic setting and as part of the curriculum clearly allows us to give an affirmative answer to this question, too.

Once again we must repeat that we did not set off to build a new curriculum round project based learning activities. Our aim was to design an activity which could balance the possible weaker points of a well tested high performance curriculum. Our project did not intend to be the central activity of the curriculum. However we have found that the project has influenced the methods and learning techniques of some specific subjects, providing a real reference for some rather theoretical points.

The beneficial effects are very evident, such that a new project has already started: a VTOL aircraft is being designed. This time we will try to introduce the development of some of the initial stages at some point around the middle of the curriculum, so that students at the end of the second year can participate. In this way we would try to follow the suggestions of the CDIO Initiative which recommends "…a curriculum that includes two or more design-build experiences, including one at a basic level and one at an advanced level" (CDIO Standards 2004).

3 . *We also wanted to know whether this kind of PBL activity would be useful to enhance personal and professional skills such as team work, communications and those activities enabling the integration of conceptual knowledge and technical skills to the designing and building of engineering products.*

With respect to this question our position was not completely neutral. All the studies on the effectiveness of PBL from Barrows to the present moment (Kolmos 2004) indicate that the skills referred to are precisely the ones more positively developed by an PBL activity.

Although no quantitative assessment has been carried out yet, we are certain that in our case the capacity to communicate with others, working in teams and integrating conceptual knowledge into real products have largely and positively increase by the students involved in the design and building of the EYEFLY 1.

As opposed to this, some of the greatest difficulties which both students and teachers have had to face have been in the area of team coordination, ability for building and assembling, lack of solid financial support and the constant doubt of reaching success.

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