

FLYABLE – DESIGN OF FUSELAGE FOR TWO SEATER AIRCRAFT TO BE FLOWN BY A DISABLED PILOT: LEARNING OUTCOMES FROM DIFFERENT APPROACHES TO LECTURES

Katherine FROST, Sara LINDA, Ahmed KOVACEVIC and Sham RANE
City University London

ABSTRACT

EGPR (European Global Product Realisation) is an undergraduate project, which involves collaboration between 5 European universities and an industrial partner. The aim of the course is to develop students' engineering design skills and to build confidence in being part of a team in different locations.

Usually, engineering students are placed in international teams, which use videoconferencing tools to hold regular meetings and online storage facilities to share documents. Videoconferencing tools are also used to enable all students to attend lectures given by staff from the participating universities. At the end of each design phase reviews are held where each team presents and produces a report showing their main findings or deliverables. The design process and deliverables from the EGPR project held from February to June 2013 are explained in this report.

Lectures delivered by staff through two EGPR projects have been evaluated. The first project involved only engineering students and lectures were task-based according to the design stage that the students were at. The second project involved both engineering and product design students, and the lecture content was initially more focused on developing team-building skills. It was decided to investigate how this difference in lecture content affected student satisfaction and their learning outcomes, as students who participated in both projects noticed a great difference between the two.

A questionnaire was distributed among students who had taken either or both of the EGPR projects mentioned. Information gathered included an overall rating of the lectures; a choice of preferred lectures; and reasons for the certain lectures being preferred.

The results of the questionnaire showed that overall satisfaction was much higher for the first project, as the lectures helped guide the students through the design process step-by-step. The lectures of the second project were found to be enjoyable and interesting to students, but they struggled to apply the material to their own situation.

Keywords: Engineering design process, international team, task-based, team-based, lecture content

1 INTRODUCTION

EGPR is a group project module taken by students in participating European universities that offers the opportunity to develop engineering problem solving skills and provides the experience of working in an international team in conjunction with an industrial partner. Students take part in a preliminary conceptual design project from October to January which helps prepare them for the more difficult realisable design project, which runs from February to June.

From February to June 2013, engineering students from universities in Bristol, Budapest, Ljubljana, London and Zagreb completed a project with the aim to design and build a prototype fuselage for disabled pilots. The design project was named 'Flyable'.

To solve the design problem, 5 teams were formed, all consisting of members from each participating university. Through 5 project phases the teams followed the engineering design process by attending lectures, holding meetings and developing their knowledge and understanding of the brief until a detailed design had been produced and approved.

All participating staff and students attended a residential week-long final workshop in the UK, where the students manufactured a full-sized prototype airplane and wheelchair. In testing, a person using the

wheelchair could enter, demonstrate use of, and leave the airplane unaided; showing the potential and suitability of the design for further development. This report gives a detailed description of the progression of the Flyable project.

From October 2013 to January 2014 a new group of students joined the EGPR course and undertook the task to design and build a more effective aeroplane tray table. Two of the students had previously taken the Flyable project. A more detailed description of this project is available [1].

The teaching approach for each project varied into two distinct styles: the Flyable project was very much task-based, and the tray table project was team building based. The lecture titles for each project are presented in this paper and the objective is to determine how the lectures affected student satisfaction and their learning outcomes.

2 PROJECT DESCRIPTION

The industrial partner for the 2013 main project was Condor Projects Ltd., a specialist contractor to the civil engineering industry. Condor Projects Ltd. defined the design problem as the owner of the company, Martyn Wiseman, had a keen interest in aircraft. A friend of his, who he had once enjoyed flying with, unfortunately had a severe stroke and was left unable to talk or walk. Mr. Wiseman took his friend flying as a passenger in his light aircraft and found that once in the air his friend was able to operate the plane just as he had before his stroke.

Mr. Wiseman began researching planes with hand controls and disabled access and found that there was no complete solution in the existing market: planes could be modified to suit the user's needs but these modifications were often cumbersome, expensive and required input from another person. Mr. Wiseman contacted the engineering departments of several UK universities and eventually came into contact with City University, and it was suggested that the prototype be developed within the EGPR course. The official project task was 'design and optimisation of the fuselage for an airplane to be flown by disabled people', which was later extended to include design of the whole airplane.

In February 2013 students taking part in the EGPR course were introduced to Condor Projects and the coaches and members from the other universities. Members were informed of which team they had been placed in so that a good mix of subject areas, and therefore skills, was established. The general timeline and plan of the project was described, so that at least one cycle of an engineering design process could be completed by the end date.

3 PROJECT TIMELINE AND DELIVERABLES

The total time (disregarding assessment periods) spent on this project by students was 14.5 weeks. The engineering design process was followed in five stages, namely research; concept development; preliminary design; detailed design; and manufacturing. At the end of each design phase each team produced a report and gave a 15 minute presentation to the company, university staff and their peers. The main tasks and deliverables from each stage are summarised in this section.

3.1 Research

Each team conducted general and overall research, but with an emphasis on the area or task given in Table 1. The research phase lasted for 4 weeks in total.

Table 1. Review of team's tasks during phase 1

Team	Research area or task	Main findings
Team 1	Existing aircraft and modification methods, licensing regulations.	Several modifications available for hand controls, access always requires auxiliary mechanism. Limits to be adhered to for airworthiness.
Team 2	Define requirements.	Weighted objectives list made, contact established with supporting charities and organisations.
Team 3	Aircraft structure, components and cockpit layout.	Knowledge of typical layout, arrangement of masses, and issues important to a buyer.
Team 4	Company and market, user and usage, normatives.	UK market size of about 20 planes, potentially more with injured service people returning from conflicts. Industry standards for several countries. Problems encountered by people in wheelchairs.
Team 5	Functions of each component,	List of pros and cons of different aircraft configurations

	design problems of each.	(tractor vs pusher, high wing vs low wing etc.)
--	--------------------------	---

3.2 Conceptual Design

The Conceptual design phase lasted for 2.5 weeks. Following feedback from coaches and Condor Projects, each team had to come up with at least three complete solutions to the design problem, each with descriptions of the process of usage, potential advantages and disadvantages, and a functional model. The details were provided in a report and presentation from each team.

Over 20 different aircraft configurations were suggested, with some examples shown in Figure 1.

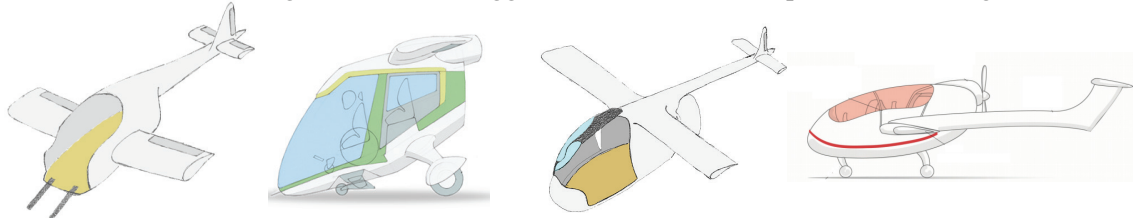


Figure 1. Examples of aircraft configurations produced by teams

3.3 Preliminary/Embodiment Design

An aircraft configuration which was recommended by students had twin booms, a puller configuration, and access for the pilot via a ramp at the rear which, when closed, was also part of the fuselage. This design is shown in Figure 2.

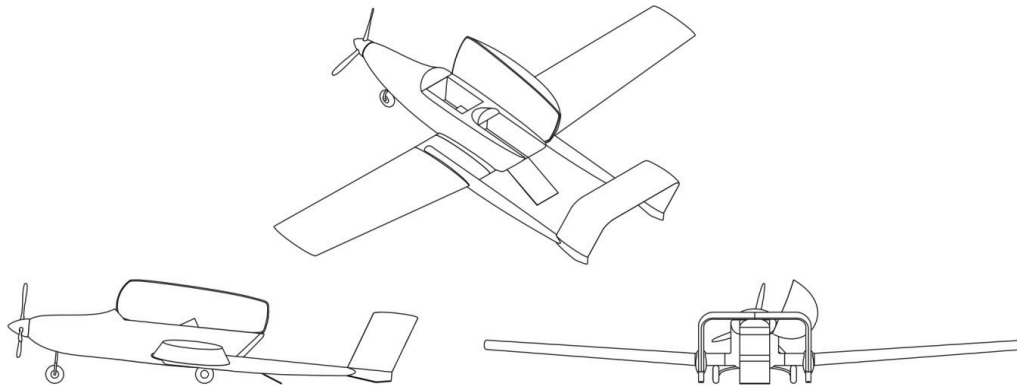


Figure 2. The configuration which was chosen as the basic overall design for all teams to work on

This design was proposed based on the use of the decision matrix and technical-economy diagram and was accepted as the design for all teams to work on by the supervisors of teams and the company.

The embodiment design phase lasted a further 2.5 weeks. Each team was assigned a specific area of the aircraft to concentrate on for embodiment design.

- Team 1: Control system design and interior design;
- Team 2: Engine mounting, fuel tank, landing gear;
- Team 3: Wheelchair;
- Team 4: Ramp/door and overhead canopy; and
- Team 5: Frame design.

As could be expected, many tasks crossed over between the teams and so required regular correspondence. For example, team 4 needed to inform team 5 of any changes made to the ramp so that the frame design could be changed accordingly, and vice versa. To help to organise cross-team communication, a new team was formed from selected members of the existing five teams and was called the cross-team board (CTB).

At the end of this phase each team submitted several proposals for designs of specific components for their respective tasks. Although the decision on the aircraft configuration had been made and teams had completed the preliminary embodied design so that the project could be moved into the detailed design phase, some large changes were about to happen in the detailed design phase.

3.4 Detailed Design

The detailed design phase lasted for 4 weeks. Feedback provided to the teams gave guidance on which of their conceptual ideas had potential for development and which were not suitable. Using this feedback, the teams used decision making methods to determine which of their sub-assemblies should be chosen for detailed design, with the chosen outcome maximising both technical and economical requirements. After deciding on concepts of sub-assemblies, teams proceeded with detailed design of these components and were required to provide all necessary documents for manufacturing, including 3D models, CAD drawings, and a Bill of Materials (BOM).

A large amount of the time during this phase was spent by each team making small changes to their designs to ensure that they fitted in with the other sub-assemblies. The CTB was responsible for assembling all these components and sub-assemblies provided, which were in hundreds. The CTB took into account mass distribution, airworthiness, stability and other aspects of the design. It occurred that in order to make the aircraft statically stable and manoeuvrable in flight, some drastic changes had to be made, namely it was necessary to replace the twin boom to a single boom as shown in Figure 3.

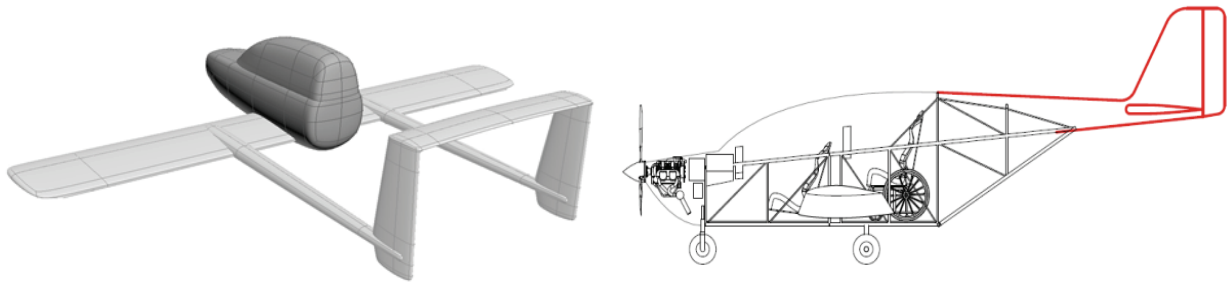


Figure 3. The design expected at the start of phase 4 (left) and the actual design at the end of phase 4 (right) [2]



Figure 4. The final 3D design of the aircraft design to be flown by disabled people

As this major change happened at such a late stage it could have proved difficult to complete all tasks on time, but it actually provided an opportunity for teams to improve certain aspects of their design that had been restricted beforehand. For example, the ramp had previously been limited in length, meaning that the wheelchair had to climb a slope of 30° . The change of design allowed the ramp to have an incline of 14° , which could be climbed by the electric wheelchair designed for this purpose. At the end of this phase, teams presented and documented the final sub-assemblies, and the CTB presented the final design of the aircraft, shown in figure 4.

3.5 Manufacturing

The manufacturing phase lasted for 1.5 weeks. Before the students' arrival in London for the final workshop, employees of Condor Projects Ltd had begun the sourcing of materials and manufacture of the prototype. Upon their arrival students were given full access to professional workshop facilities including water jet cutters and welders.

By the end of the phase, and the project, students had produced a steel frame, half of the model's skin, a ramp, a firewall, and a working electric wheelchair. Images of the prototype are shown in Figure 5.



Figure 5. Photographs of the prototype model at the final workshop

On the day of the final workshop the prototype was presented to university academics and industry professionals who were generally impressed by the depth of knowledge developed by students and the amount that had been achieved in the allocated time.

4 TEACHING MATCHED TO TASKS

Throughout the Flyable project, lectures were tailored to suit the tasks that the students were undergoing. For example, the course began with a lecture on the engineering design process so that all students were familiar with the style and order in which coaches and the company wanted work delivered. The number of lectures given each week decreased over the course of the project as students undertook more detailed and specific work, until there were no lectures given during the manufacturing phase. The summary of lectures given to students is shown in Table 2.

Table 2. For the Flyable project the lectures were tailored to help students with their current or a future design phase

Design phase	Lectures given
Research	'Project presentation and deliverables'; 'Static stability of small aircraft'; 'Creativity in design'; 'Control systems of small aircraft'; 'Design process: functional decomposition, concept generation and evaluation'; 'Ergonomics and human factors: interaction between user and device'
Preliminary design	'An engineer's guide to intellectual property law'; 'Use of the DesignVUE tool'; 'Structural design of an aircraft fuselage'; 'Economy and costs in design'; 'Detailed designing'
Concept development	'Materials and technology for small aircraft'
Detailed design	'Manufacturing methods'

5 COMPARISON WITH OTHER TEACHING STYLE

From October 2013 to January 2014 a new group of EGPR students began the course, with two members being allowed to carry on from the previous group for a second year (the authors of this paper). A conceptual design project was completed with the aim being for teams of engineering and product design students to design and build a more effective aeroplane tray table. The partaking universities were the University of Malta, the University of Strathclyde and City University London. The setup of EGPR projects is always the same, with each of the universities giving lectures on issues relevant to the students. The lecture content used in this project, however, differed from the previous one, as the methodology of design process was not the main focus. Instead, introductory lectures focused on creating awareness of the differences between and difficulties faced by team members in different locations. A strong emphasis was placed on promoting strong team cohesion and easing the collaborative process.

A summary of the lectures delivered over the project is given in Table 3.

Table 3. Lectures given were aimed at helping distance teams collaborate

Design phase	Lectures given
Weeks 1-4	'Introduction: assessment and relevant literature'; 'Project briefing and culture'; 'Teams'; 'Distributed project management'.
Weeks 5-8	'Global working', 'Causal maps'; 'EGPR: European Global Product Realisation'; 'Selecting concepts'; 'Detailed drawings and rough models'.
Weeks 9-12	'Critical design information'.

7 FEEDBACK AND LEARNING OUTCOMES

An anonymous-response questionnaire was distributed among students who had taken part in either or both of the mentioned EGPR projects. The questionnaire asked students which project they had participated in, and how they found the lectures on the scale between extremely useful (response =5) or not helpful at all (response =1). Students were then asked to name their preferred lectures from the lists provided in Table 2 and Table 3; and then to give reasons why it was their preferred lecture. It should be noted that the vast majority of responses were probably from engineering students, who, due to familiarity with the questionnaire author and distributor, may account for a higher proportion of responses than product design students.

For students who responded that they had taken the Flyable project the average response to overall lecture rating was 4.5. The most commonly selected preferred lectures and some of the quotes given for reasons why are listed:

- ‘Project presentation and deliverables’ – “The problem was made very clear. Knowing what was expected of us early on helped me plan in my head how I could tackle the design problem and made me think and link ahead rather than work on one thing at a time”.
- ‘Creativity in design’ – “It gave a clear understanding on processes and tools needed to be employed to complete the project”.
- ‘Detailed designing’ – “Advice on how to approach detailed design as a large team was helpful”

For students who responded that they had taken the aeroplane tray table project the average response to overall lecture rating was 2.5. Attention at this point should be drawn again to the increased probability of the response being from an engineering student, who was unfamiliar with the lecture content compared to a product design student.

The most commonly selected preferred lectures and some of the reasons why are listed:

- ‘Global working’ – “This lecture gave interesting examples of global design in action and I gained a new insight on how multinational companies operate.”
- ‘Cultural differences’ – “This was a really interesting lecture in terms of learning about other cultures but I didn’t really see how it applied to my project. The people in my team were just like the people I usually spend time with so I didn’t need to be sensitive to their culture”.
- ‘Causal maps’ – “Seeing a new way of doing a familiar task was useful. Seeing the similarities between causal mapping and the techniques I am used to made me think that the design processes aren’t too different and we managed to mix of our skills because of this”.

8 CONCLUSION

The responses from the questionnaire showed satisfaction with the quality and timing of lectures, especially for the Flyable project. Students felt the Flyable lectures were tailored to their needs and addressed issues that they were facing. For the tray table project, students found the lectures interesting but did not have the opportunity to practice the team building-skills that they had learned of as their new team members were relatively ‘normal’ to them and required no special considerations for cultural differences.

From further response inspection, it can be interpreted that team performance did not suffer due to the distance between members or cultural differences. There were some team problems encountered during the tray table project as not all students were familiar with using the same design techniques, and arguments over which design tools to use occurred. However, in some cases students relished the opportunity of learning a new technique and this was facilitated by the lectures given.

Overall, the findings point towards task-based lectures improving student understanding and ease of progression. However, these projects were both based within Europe and therefore all students shared a common culture – if the project was worldwide and involved students from alternative cultures then it is highly likely that the team-building education would have proven extremely useful and applicable.

REFERENCES

- [1] Linda S., Frost K., Advani R., Gwashavanhu E., Samatar M., Rane S., Read M., Sharif M., and Shafiq S. When global design meets European Global Product Realisation – design techniques and challenges.
- [2] Modify. *Modify: Modifying flight*. Available: <http://www.modify.co.uk/> [Accessed on 2014, 27 February].