Bridging the Gap – An Active / Interactive Approach to Introductory Aerospace Education

BRIDGING THE GAP- AN ACTIVE/INTERACTIVE APPROACH TO INTRODUCTORY AEROSPACE DESIGN EDUCATION

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Abstract: The transition from secondary level classroom-based education to the university experience can prove to be a challenging experience. Many initiatives have highlighted the benefits of engaging students in active learning, and over a number of years, Queen’s University Belfast has worked towards embedding this principle into the teaching of Aerospace Design through the CDIO initiative. An introductory module, Introduction to Aerospace Engineering, has been specifically developed to bridge this gap between traditional school-based learning and the independent thought and critical analysis required in the university environment. The module is focused on providing students with a platform to develop a deeper understanding of the theoretical principles of traditional engineering subjects in a hands-on exploratory Aerospace environment. This is aimed at enhancing engagement and enthusiasm of the students for the subject, while simultaneously providing context for some of the more abstract theoretical principles. This paper highlights the ethos behind the structuring of the module, and explores how the active/interactive approach to Aerospace design can enhance the learning experience for the students through the creation of a stimulating environment for engineering discovery.

Keywords; Aerospace, Design, Education, Problem Based Learning, CDIO

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1. INTRODUCTION

The concepts of active and interactive learning embedded within engineering education have increased in popularity in recent years due to their potential to enhance the effectiveness of the engineering lecture [1]. The active learning process is generally regarded as an engagement of students in meaningful activities designed to reinforce and enhance the learning experience, complimented by periods of reflective practice. Interactive learning brings this one step further, initiating a 'partnership in learning' between the learner and both their peers and the academic staff. The ideals of active/interactive learning have been generally accepted as a positive step in engineering education, leading to significant improvements in learner motivation, understanding of principles and application of theories to the development of engineering solutions. It enables an easy accommodation of a range of learning styles as it encourages students to become responsible for their own learning. To this end, the educational process becomes largely student-centred, with academic staff becoming facilitators in the learning process.

However, time constraints and ever-evolving demands for the skills required by graduate engineers can present challenges in embedding some of the more practical elements of engineering into the syllabus. A careful balance of traditional lecture-based material, to ensure the required depth of knowledge in fundamental disciplines, complimented with sufficient opportunity to demonstrate this knowledge through laboratory and workshop based exercises is often required in order to ensure that students are both technically and practically competent on graduation. While this does not prove difficult for discipline-specific learning, this does lead to challenges in providing environments where students can obtain experience of interdisciplinary design, particularly in the earlier years of the degree courses when students have limited appreciation for the technical competencies contributing to the design process. Opportunities to engage in meaningful design exercises are essential for engineering undergraduates to improve motivation and highlight the practical relevance of the subjects that are being studied within their degree programmes [1,2,3]. Practical design education also provides a valuable platform to foster creativity and improve student confidence in their engineering ability. To this end, the international CDIO (Conceive, Design, Implement, Operate) initiative presents a philosophy for reforms to engineering education in which technical fundamentals are aligned with practical learning activities [2]. Modern pedagogical approaches and teaching methods are adopted within flexible learning environments to enhance the overall student learning experience. It is based in the idea that reflecting on theory through practice will help to embed principles much more effectively than through the delivery of theory alone, leading ultimately to a deeper working knowledge of the engineering fundamentals required for future professional careers.

In particular to Aerospace Engineering, the modern Aerospace industry is evolving at a rapid rate, and it is an increasingly important requirement for graduate engineers to have a deep appreciation of the interdisciplinary nature of the design processes. It can also be argued that engineering is, in a professional capacity, a practical activity, and therefore practical training in the application of engineering theory and methods should be embedded at every level [4]. To achieve this in a structured manner, the transition from secondary to tertiary level education requires careful planning, as many students are unfamiliar with learning which requires this level of interdisciplinary appreciation. Care needs to be taken in ensuring that the student can clearly identify connections between interdisciplinary learning experiences and their own expectations of the degree course (often built from their previous educational experiences), and it should be remembered that many of these expectations are connected to the students' appreciation of the relevance of the subjects they are studying. To ease this transition, a new module 'Introduction to Aerospace Engineering' was incorporated in the BEng/MEng Aerospace Engineering degree programme in Queen's University Belfast to compliment both the learning requirements of a first year Aerospace Engineering student, the CDIO philosophy and the required learning outcomes of UK-SPEC.

UK-SPEC defines five main categories of specific learning outcomes required for accredited engineering education within the UK [5]. These are defined as:

(i) Underpinning science and mathematics, and associated engineering disciplines
(ii) Engineering Analysis
(iii) Design
(iv) Economic, social, and environmental context
(v) Engineering practice

These SLO's are designed to ensure that engineering graduates are fully equipped for integration into their future professional careers. As a significant portion of introductory engineering education is traditionally focussed on addressing the needs of (i) and partially (ii), a lack of opportunities for addressing (iii) to (v) can exist within Level 1 education (part due to the lack of in-depth technical knowledge of the students at this stage in their education). The design of the introductory course specifically addresses this concern through provision of a number of carefully structured projects introducing theory at appropriate points from the supporting core technical disciplines, providing a platform for students to gain familiarity with the principles of design, engineering practice and professional conduct, whilst practicing the fundamental science and analysis presented in the discipline specific courses. The module has been developed as 72 hours of contact time over two semesters, and is taught by two academic staff members with varying interests in both teaching and research in order to ensure that the Level 1 students receive a rounded and balanced introduction to engineering design at an early stage.

2. METHODOLOGY

The rationale behind the course design was to develop a framework to showcase the interdisciplinary nature of the design process, and to provide a platform for linking the core disciplines introduced in Level 1 of the BEng/MEng Aerospace Engineering degree programmes. Through a series of structured activities, students are encouraged to engage with engineering practice in a hands-on environment, and develop an appreciation for the design process. This is aimed at ensuring that an attachment of principle to practice in a working engineering environment is developed at an early stage in their education, and to assist in the development of a broad multidisciplinary scientific and engineering background – promoting creativity, innovation and questioning capabilities.

A large percentage of students entering into the Aerospace Engineering programme at QUB have limited previous experience of aviation, and while they have excellent records of academic achievement, they often have abstract expectations of the technical content of the course. Additionally, students will often have mixed A-Level (or equivalent) subject combinations in their background (all students have A-Level Mathematics or equivalent), so the course is structured to assume a minimal level of prior knowledge, concentrating on learning gained through the technical disciplines in the syllabus. Ultimately the purpose is to expose student engineers to processes and procedures which are associated with engineering design practice. The course is built around a single premise – ***to enthuse and motivate Level 1 students about Aerospace Engineering in an aviation-themed practical environment.***

The educational model has been structured to provide an integrated educational environment with mutually supporting disciplines, explored through a number of aviation-themed projects. Students learn experientially to develop deeper understanding of fundamentals of the core technical activities (for instance, Flight Mechanics, Engineering Design, Dynamics and Mathematics), while simultaneously developing their skills in Design Principles, Professional Conduct, Time Management, Engineering Practice, Communication and Team Work (Figure 1). The current Level 1 Aerospace Engineering course is common to both BEng and MEng cohorts, so there is a requirement to ensure that the course is able to cater to a wide range of abilities, while providing opportunities for more capable students to further challenge themselves. This is accomplished through open-ended questioning and 'discovery' based challenges, enabling students to explore concepts to a level of depth which is appropriate to their understanding.

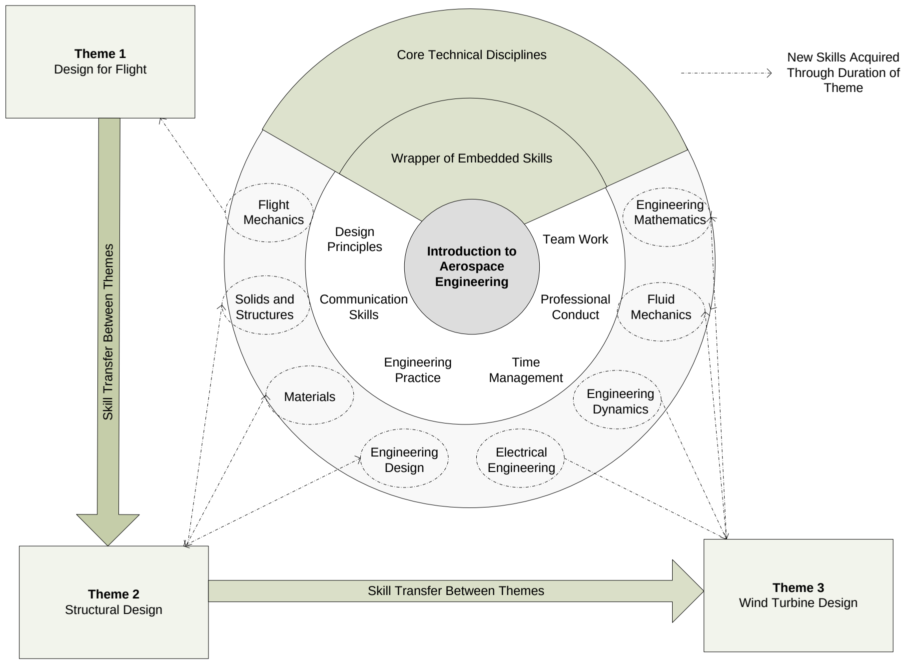

Figure 1: Introduction to Aerospace Engineering Course Structuring

As the main aim of the programme is to provide hands-on experience of the tasks and responsibilities of an engineer, and reinforce the disciplinary knowledge required to execute those tasks, a number of 'real life' exemplars were developed. This was achieved by blending complimentary groups of the technical disciplines from the Level 1 syllabus together to develop learning activities which would reinforce the learning outcomes. Through evaluation of the pathway structure, these were grouped into mutually supporting activities under 'themes' – 'The Flight Experience', 'Structural Design' and 'Wind Turbine Design' (Figure 1). Each theme is supported through embedded professional skills, engineering practice and design activities, and builds upon the previous theme so that by completion of the module students are fully integrating theory from all eight core disciplines together into final engineering solutions (Figure 2). The development of these themes can be considered to be a five step process:

Step 1 Identify the Drivers Students will have prior expectations of a course which have driven the initial subject selection. A series of focus groups with current and past students enabled exploration of the expectations of Aerospace Engineering from a student perspective, and as could be expected, a keen interest in aviation and flying was central. In order to transfer that expectation into a motivator, this was used to develop the first key theme (Flight).

Step 2 Review the Technical Competencies A review of the current technical competencies within 1st year was necessary to have an understanding of when key theories are introduced. This was used to provide a basis for the discipline groupings, and determined the timing of the laboratories during the 24 week period. A review of practices (both lecture and laboratory-based) was required to ensure that any activities developed provided complimentary learning activities without significant levels of overlap.

Step 3 Development of Themes Once the viable groupings had been identified, these were further developed into 'themes', ensuring relevancy again both to student expectations and overall subject specific learning objectives. The themes were structured to ensure that students are provided with sufficient hands-on opportunity for learning about interdisciplinary design practices (with a sufficient level of theory in the disciplinary classes to support this), and that the themes 'build' from one another to encourage a process of cyclical learning [6] (Figure 2).
Step 4 Review of Aims and Objectives As the purpose of the course is to enhance, rather than overlap, with the core disciplines, a review of the learning outcomes of each of the themes was required. This again ensured that the course would enhance the understanding of key technical principles without introducing significant levels of overlap (and the potential for demotivation).
Step 5 Evaluation The new structure was fully evaluated against a series of intended learning outcomes defined through UK-SPEC and the CDIO framework, to ensure that the educational outcomes of the course fit with those intended for an accredited engineering degree programme.

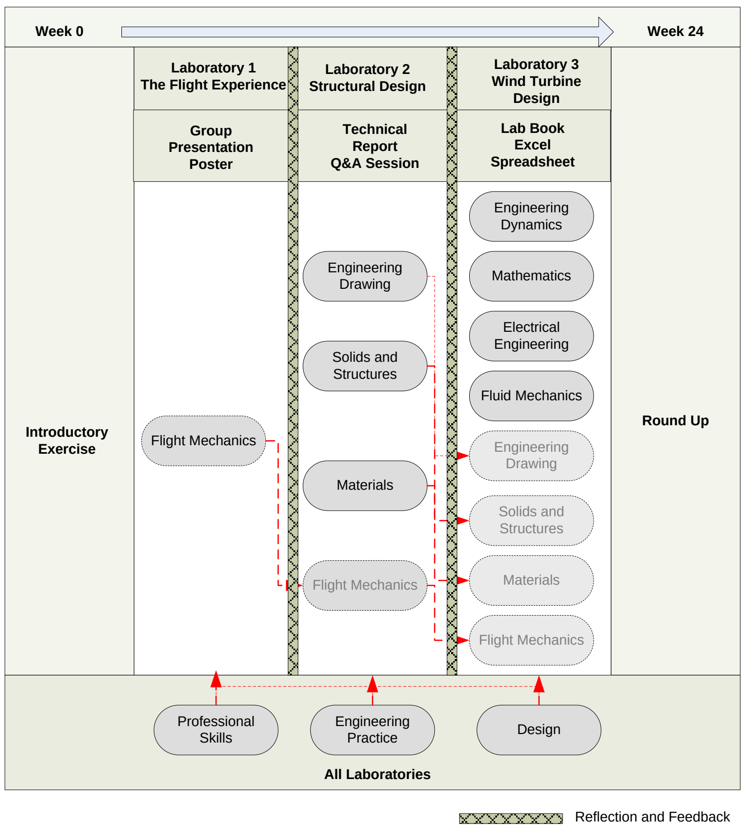

Figure 2: Course structuring for thematic progression

Once the overall structure of the module was determined, the learning outcomes were mapped to assessment methods to ensure a balance of assessment practices across the course. Assessment reflects that the problems do not necessarily have a single 'correct' answer, and is therefore based on performance - willingness to participate, how appropriate information is distilled from technical disciplines and applied to the design problem, and how critical analysis of the proposed solution is undertaken. This represents a major deviation from many of the Level 1 modules, and again is unfamiliar for many Level 1 students. A week of reflection was built-in after the completion of each laboratory and associated assessment, where students are provided with feedback on their performance in the previous laboratory, and encouraged to reflect on their performance, more importantly, the areas in which they can improve in their design practices, complimented with peer review exercises.

3. COURSE EVALUATION

The Introduction to Aerospace Engineering course at QUB has been set up to reflect the principles of the CDIO imitative, and to promote integrated curriculum learning set in a practical environment. The students are encouraged through the exercises to work in groups to solve tangible real world examples, encouraging students to take a greater level of responsibility for their own learning. In doing this, a number of observations have been made about both the course structure and the student participation in the module:

Course Structure: Introductory Exercise

The course is initiated through an introductory glider exercise in Week 0. It was identified as important to 'gain the students attention' as quickly as possible, and this was achieved through a design-build-fly exercise centred on a glider design. This was aimed at increasing student confidence in group work and to introduce some basic terminology associated with aerospace design. While there is no theory to reinforce, the exercise ensures that students are enthused about their choice to study aerospace early on, and introduces them to the team-working.

Course Structure: Thematic Areas

The selection of the project themes and ensuring a gradual 'building' of material through the module is critical. The students not only gain a deeper appreciation of the technical competencies by not being over-whelmed early in the process, but also are introduced to the truly flexible nature of engineering skills they are developing and its applicability to a wide-range of areas (some of which are outside of the initial narrow view of many student engineers). The initial laboratory examines the consequences of poor design on flight operations using the School flight simulator, simultaneously introducing students to flight controls and aircraft design, while demonstrating the practical consequences of a poorly conceived design process. Student engineers often do not fully appreciate the iterative nature of design, and a fully looped design-build-test-analyse-redesign-rebuild-retest-reanalyse proved to be an extremely successful concept for the structural design laboratory (and in all instances, the students significantly improved their designs on the second of these tests through careful analysis and redesign of their structures). This reinforces the idea of there being no single correct answer in an engineering design environment, and that design is a process of trade-offs. The final project in the design of a wind turbine was selected to introduce some of the less traditional areas in which the skills of an Aerospace Engineer can be employed, embedding concepts of sustainability and social awareness into their learning outcomes, while still providing an environment in which the students could learn about the interdependence of all of the technical disciplines in the Level 1 syllabus.

Course Structure: Reflection and Feedback

To embed an appreciation for the design process, all students were encouraged to reflect on their performance in the laboratories. Similar to the technical content, this was built up in stages to give the students an appreciation of the nature of reflection and feedback. In the first laboratory, due to the unfamiliarity of the students with these types of exercises, this was facilitated by the academic staff members through questioning of what the students had learnt, asking them to identify areas of new learning, how learning from technical disciplines mapped to what they understood about the design process. In the second laboratory, this was extended to students being questioned by classmates about their designs and experienced. For the final exercise, the students were asked to reflect on their own performance, and how they could improve both their technical and interpersonal performance in future projects that they will encounter throughout their pathway. This reflective practice was complimented with feedback from the staff (both during the laboratories to provide guidance, and also during the question/answer sessions). This not only encouraged the students to reflect on their practice, but for them also to start to offer advice and guidance to their peers, based on their own experience.

Course Structure: Professional Skill Development

Complimentary development of professional skills of groupwork (exercises are undertaken in teams, and teams rotating for each exercise), reporting, communication, time management and engineering responsibility are embedded into all of the exercises undertaken during the course to reinforce the professional nature of engineering.

Observations on Students: Inability to function in groups

One of the major challenges which needs to be overcome is the lack of prior experience in group work the majority of students have. While many of the students are highly capable and can work to a high level autonomously, they struggle with some of the more socially-oriented skills required for professional working environments – in particular time management, conflict resolution, communication skills and the ability to equally distribute workload between group members. This was resolved in the 1st exercise by concentrating on the development of these core professional skills integrated with one supporting technical discipline. In most instances, the students demonstrated a greater awareness of how to allocate work between members and communicate more effectively by the 2nd project, and the greater sense of community in the teams alleviated most of the time-management and conflict resolution issues.

Observations on Students: Unfamiliarity with the process of design prior to tertiary level

Based in many of the preconceptions from secondary level education, students are often focused on the concept of the 'right answer', and many struggle with the idea that there are multiple correct pathways to choose in a design environment. They are unfamiliar with taking initiative, and more at ease with following instructions to develop 'the solution'. Planning actions within design is also not well-formulated, and often the students are not capable of anticipating problems with design or embedding concepts of risk (for instance, assuming that all team members will be available for each week of the project). This was again addressed in the 2nd exercise by introducing an iteration into the design process to demonstrate that planning can reduce the number of problems, and that 'emergent' behaviour within the design process is something that they should be aware of (not everything will always go as planned, and that risk analysis is important).

Observations on Students: Uncomfortable with interdisciplinary analysis

In general, there was a limited view of how to apply knowledge from a number of disciplines to a single engineering design problem. This was again dealt with by a ramping of the number of disciplines required to fully appreciate an engineering problem from project to project to prevent students from becoming overwhelmed with the quantity of information they were required to process and to guide them through a gradual process of both technical and professional skill development.

Observations on Students: Absenteeism and motivation

Absenteeism and lack of motivation is endemic in Level 1 engineering classes, and can in part be attributed to a complete lack of motivation on the part of the student (something that was widely reported in the focus groups undertaken). However, over the last academic year with the implementation of the new course structure, absenteeism has been reduced to almost zero, with virtually 100% attendance at each class over both semesters. Students have reported enjoying the class, and linked this to their attendance.

Observations on Students: Instructor integration with class

Through working in a student-centered learning environment, the two lecturers attached to the class became more aware of many of the learning barriers and issues of individual students, much more so than in a normal lecture/laboratory based environment. In many instances, issues with individual students were picked up much more quickly than otherwise would have been, and a level of engagement with the students was achieved much more quickly than in the traditional learning settings. This is tightly linked with the need for the supporting academic staff to fully embrace this change of educational environment, which is again significantly different from that traditionally encountered in Higher Education.

4. CONCLUSIONS

The Introduction to Aerospace Engineering class at Queen's University Belfast has provided a valuable opportunity for students to gain experience of the engineering design process while simultaneously developing an appreciation for some of the challenges which face the professional engineer in their working environment. The model which has been developed for facilitated integrated design education progressively introduces students to the ideals of interdisciplinary design in a setting which encourages professional skill development, and fits with the ideals for learning outcomes and programme structuring set out in UK-SPEC and CDIO.

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