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# The Evolution of 'Design Build Fly' Led Teaching in Aerospace Engineering

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**ABSTRACT:** This paper describes the evolution of a 'Design - Build-Fly' (DBF) approach to the delivery and assessment of a Stage Three Aircraft Design module. It focuses on the primary learning outcomes around the design and manufacturing functions associated with the development of a remotely controlled aircraft. The work covers a six year period from 2011 to present mapping the transformation of the module from report based assessment to a more hands on approach resulting in a fully functioning remotely controlled aircraft. Results show that both the staff and student experience improved across key performance metrics including student feedback, learning and competency development. Challenges still remain in methods of placing students within teams and maintaining technical rigour in reporting as students develop vocational skills and more reflective writing styles.

**KEYWORDS:** Aircraft Design Education

## 1. Introduction

Projects in Higher Education involving practical, hands on activities are an effective means of diversifying assessment into more practical elements of student learning. They provide motivation and promote transferable skills which are attractive to potential employers [1]. Improved motivation can help to stimulate interest through the opportunities that students have to make choices for themselves. Relevant project work also provides the practical reinforcement of taught materials that Brown et. al. [2] advocate for the improvement of learning and by effectively linking feedback to learning outcomes, lecturing staff can also enhance learning in line with the work of Gibbs [3]. Gibbs and Habeshaw [3] have stated that assessment can be used effectively to direct student learning by informing and orienting them as to what the important elements of the module are, making the provision of more timely feedback an important element of this approach. Although 'hands on' or practical experience in the student's academic field, promotes the more vocational aspects of their discipline, Brown and Atkins [4] highlight that research and project supervision is probably the most complex and subtle form of teaching in which we engage. In an engineering context, this comes about as promoting team working as well as time and resource management skills are added to the academic challenge of a project. Experience does not always lead to knowledge acquisition and theories of experimental learning have focused on the importance of reflection in the learning process. The most well-known model is based on Kolb's learning cycle [5] which suggests that in order to learn effectively from experience, there must be a movement through reflection on experience. Gibbs and Habeshaw [3] emphasise this point stating that learning opportunities will be wasted if

students simply 'go through the motions' and do not reflect upon their experiences.

In practical terms, the Aircraft Design 3 module that had been used for a number of years up to 2009 in the School of Mechanical and Aerospace Engineering at Queens, had been showing signs that the method of delivery was not aligned with the academic reasoning presented above. Students working in groups, were tasked with developing a full scale aircraft system concept such as an Airbus A320 or Lockheed C130 transport equivalent. Individual team members worked in disciplinary areas such as aerodynamics, structures, manufacturing, procurement etc. Formative feedback was presented to students based on group meetings and presentations as well as a mid-module peer assessment exercise. Summative assessment was based on a final report and a second peer assessed element at the end of the module. Although students covered the conceive and design elements of the CDIO (Conceive, Design, Implement, Operate) principles which had been previously adopted by the School, the implementation and operation elements were not addressed nor could they be when using a full scale aircraft as the focus of the project. These missing CDIO elements also lead to gaps in learning outcomes and competency development aspects when considering the UK Spec. requirements (see Tables 1 & 2). These summarise expectations in terms of the Royal Aeronautical Society (RAES) for accreditation purposes. Students themselves had also expressed dissatisfaction with the module citing poor group dynamics, workload concerns, and time constraints as their main areas of concern.

This paper covers the process of continuous improvement covering the evolution of Aircraft Design 3 to a '*Design – Build – Fly*' format. Initial organisational changes were based on the above shortcomings as well as the need for alignment with RAES accreditation criteria. Additional year on year changes made between 2010 and 2016, were implemented based on student feedback and staff observations which were considered annually as part of the module review process within the School of Mechanical and Aerospace Engineering. The introduction of additional learning outcomes meant that assessment was also re-structured to take account of new and existing learning outcomes.

## **2. Method**

Quality control measures within the School meant that module feedback was recorded at the end of each semester and used as the basis for making improvements for the next academic year. Individual module feedback was supplemented with comments received as part of the Student Staff Consultative Committee (SSCC) when they arose. The Module review process within the School was used to assess educational needs based on a balanced review of all data arising from the module. Having identified weaknesses in delivery, the module description and handbook was formally changed year on year by the module coordinator and was presented to each year group at the start of the spring semester.

**Table 1: Design Based Learning Outcomes From UK-Spec**

|     |  |
|-----|--|
| D1  | Investigate and define a problem and identify constraints including environmental and sustainability limitations, health and safety and risk assessment issues |
| D1m | Wide knowledge and comprehensive understanding of design processes and methodologies and the ability to apply and adapt them in unfamiliar situations.         |
| D2  | Understand customer and user needs and the importance of considerations such as aesthetics   |
| D3  | Identify and manage cost drivers   |
| D4  | Use creativity to establish innovative solutions   |
| D4m | Ability to generate an innovative design for products, systems, components or processes to fulfil new needs.   |
| D5  | Ensure fitness for purpose for all aspects of the problem including production, operation, maintenance and disposal  |
| D6  | Manage the design process and evaluate outcomes  |

**Table 2: Competence & Commitment Standards for Chartered Engineers**

| Code | Competence & Commitment Standards for Chartered Engineers   |
|------|---|
| A    | Use a Combination of general and specialist engineering knowledge and understanding to optimise the application of existing and emerging technology |
| B    | Apply appropriate theoretical and practical methods to the solution of engineering problems   |
| C    | Provide technical and commercial leadership   |
| D    | Demonstrate effective interpersonal skills  |
| E    | Demonstrate a personal commitment to professional standards, recognising obligations to society, the profession and the environment                 |

The following paragraphs detail the main year on year changes which were made on the basis of the module review process. Figure 1 maps aircraft development in the period 2010 to 2016.

**2010:** The students were tasked with modifying an ‘off the shelf’ kit design to carry payload (water). Although this involved the use of an existing model plane, the task of modifying it to carry additional weight meant that students had to review the performance envelope of the aircraft to adjust the size of all control surfaces and modify the structure to accommodate and carry the extra weight. Although students were able to achieve the required objective through a flight demonstration, a number of aircraft were lost due to poor piloting skills. The new format proved popular with students and module feedback scores improved by 37%.

**2011:** The class was presented with the specification for the American Institute of Aeronautics and Astronautics (AIAA) Design Build Fly Competition. This required the development of a remotely controlled aircraft for the purpose of carrying golf balls. Students built the aircraft from scratch in a newly assigned design lab. A certified pilot was used for the flight test which enabled students to reflect and improve on their design for their final flight. Levels of student engagement and module scores remained high. Students were assessed as

follows: 40% Report, 40% Aircraft Performance (Payload Carried, Pilot Rating), 10% Presentations, 10% Teamwork (Including Peer Assessment).

**2012:** The AIAA specification was used again. Build quality improved as laser cutting services were used to manufacture parts. Students were able to assemble aircraft with more accuracy in shorter times. Again, flight tests were followed by a final assessed flight conducted by a qualified pilot. The involvement of a local model flying club meant that we had access to an improved flying site and levels of safety were also improved.

**2013:** The British Model Flying Association (BMFA) Electric lift Challenge specification was used with a view to entering the main competition after the academic module had been completed. Aircraft were tasked with carrying a payload of water and Queens entered the formal event which took place in June of that year. Further improvements were evident in build quality and aircraft performance. Queens won the overall prize competing against other UK Universities.

**2014:** the British Model Flying Association (BMFA) 'Payload Challenge – Quantity' specification was used again but in this case aircraft were tasked with carrying a payload of tennis balls. At this stage the School had invested in a prototyping lab and students had improved access to CNC laser and hot wire cutters as well as a 3D printer. An internal requirement based on the use of pusher only configurations was imposed to avoid re-use of previous aircraft designs arising from this module. Queens University were placed 7th in the BMFA Electric Lift competition.

**2015:** The British Model Flying Association (BMFA) 'Payload Challenge – Quantity' was used. The payload was once again, tennis balls. Innovation was added to the assessment criteria to encourage diversity in aircraft configurations. Students were assessed as follows: 40% Report, 40% Aircraft Performance (Payload Carried, Pilot Rating, Innovation), 10% Presentations, 10% Teamwork (Including Peer Assessment). One team developed an innovative, lifting body design but overall quality and performance levels were down when compared to previous years. Students were again given the opportunity to compete at the BMFA event but were not available over the dates of the event so Queens was not represented in 2015. This reflected an overall view of this particular cohort that levels of interest and therefore engagement were low for this group.

**2016:** The British Model Flying Association (BMFA) 'Payload Challenge – Quantity' was used. Five viable aircraft were produced which aligned with the Staff observation that levels of student engagement were better than 2015. As a result, build quality and aircraft performance improved relative to 2015. Efforts to motivate students by setting assessment against an upper expected performance level of 200 balls proved unpopular. This was reduced when the winning score at our internal flight test was 62 balls. This unsettled students which was reflected in lower module scores, however these were still higher

than pre-2010 levels. Students from Queens again performed well at the BMFA event where they were placed third having carried 186 balls in the time allowed.



**Figure 1:** Sample Aircraft From Aircraft Design 3 Module 2010 – 2016.

### 3. Results

In order to cover the main assessed elements (see section 2) the module format now includes bi-weekly team meetings and presentations including formative feedback from staff, as well as manufacturing and test phases leading to a final, fully assessed fly off where teams compete and aircraft performance makes up a significant proportion of the final mark. The main outcomes resulting from a move to a DBF based approach can be expressed in terms of quality, feedback, learning and competency development.

**3.1 Quality** of finished aircraft increased steadily between 2010 and 2016 when access to CNC equipment meant that students were less reliant on construction skills which are not core to the module learning outcomes. The inclusion of performance based assessment also motivated students to build better products. The quality of written reports improved as the inclusion of implementation and operational experience meant that students were better equipped to reflect and conclude on their design decisions.

**3.2 Module Feedback Scores** increased from an average of 3.3 prior to 2010 to an average of 4.1 between 2010 and 2016. Scores have varied between 3.9 and 4.5 during this period reflecting natural variances in cohort experiences and staffing changes.

**3.3 Learning Outcomes** for Aircraft Design 3 are now aligned with UK Spec for accreditation purposes (See Table 1). Outcomes D4, D4m, D5 and D6 are now fully accommodated in the new module format with innovation included as an assessed element and flight tests enabling better informed reflective elements in reporting based on actual aircraft performance.

**3.4 Competency** codes A, B, C and D (see table 2) are now fulfilled through the completion of Aircraft Design 3. Although professional standards in

teamwork and individual behaviour are expected from students, it is acknowledged that Competence code E requires further work in developing better awareness of societal obligations and the environmental impact of design decisions.

#### **4. Discussion**

Section 1 of this paper detailed the reasoning behind the changes made to Aircraft Design 3 in the period between 2010 and 2016. Educational theory as well as the observations of staff through the quality control measures that were in place within the School, were able to build a good case for re-configuring the module to deliver a better learning experience which was more in line with accreditation requirements. As a result, the module has seen improvements across the quality of student outputs, module feedback scores, learning outcomes and student competency development. Peer assessment has helped to reinforce staff views on relative working contributions within groups. School investment in equipment including a laser cutter, CNC foam cutter and 3D printer has improved build quality as students learned to design structures in a kit format relying less on ad hoc build methods. This had the added advantage of improved build times allowing the completion of flight tests earlier in the module. In addition to these benefits there are a number of issues which still require attention. The majority of student groups tend to move straight from conceptual design to manufacture without any significant detailed design phase. Aspects such as joint design, electronic configuration and payload management typically only receive attention when the aircraft is under construction. In good reports, the articulation of student designs has improved significantly through the broader application and use of computerised techniques (CAD, FEA, CFD etc.) and their subsequent validation through physical tests. Some groups have failed to exploit these tools fully when articulating design decisions. Further staff guidance is therefore required across these elements. The net result is still an upward trajectory in terms of aircraft performance and the student learning experience.

#### **5. Conclusions**

1. Staff & student experience improved across the key performance metrics of quality, feedback and learning.
2. Peer assessment outcomes reflect / reinforce staff observations in relation to student contributions within teams.
3. Upgrade of support structures in online ordering systems and computer aided manufacture have allowed students to focus on main technical elements leading to improvements in learning.
4. Challenges remain in team selection & make up and the exploitation of simulation platforms for detailed design
5. To maintain our process of continuous improvement, further year on year changes will be made based on student feedback. Evolution never stops!

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