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A Student's Perspective on the Progression of a Problem-Based Learning Module for Final Year Aerospace Students

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ABSTRACT

This paper describes the development and continuous improvement of Flight Handling Qualities (FHQ) from a student's perspective. FHQ is a Problem-Based-Learning (PBL) core module for 4th year Aerospace Engineering Master of Engineering (MEng) undergraduates at the University of Liverpool (UoL). The module is now in its fourth year of operation and has continually evolved to its present form with the aid of feedback from the participating students and others experienced with PBL activities. The authors of this paper have all graduated from the UoL MEng Aerospace Engineering programme and have completed the FHQ module through each of the three previous years of the course's evolution. Consequently, the authors can offer a unique first-hand perspective of their experiences and the progression and development of the CDIO module. In addition, one of the authors now acts as an FHQ group mentor and can offer an interesting insight into the module's current form. The aim of the module is to equip students with the skills and knowledge required to tackle aircraft handling qualities (HQs) and related 'whole aircraft' problems. The students are presented with the theory of handling qualities engineering in a series of interactive lectures and work in teams of 4 or 5 to undertake a number of team-building exercises throughout the first semester. The teams are presented with the idea that the aircraft, with its handling qualities deficiencies, is the focus for knowledge acquisition and skills development. Each team is given the task of assessing and quantifying the HQs of a particular aircraft in a particular role, and then developing fixes to any handling deficiencies identified. Significant changes in the evolution of the module include; an increase in the duration of the module and the introduction of group mentors who provide additional support and guidance to the students. The contents of the paper will consist of a detailed description of the module and intends to give a unique student perspective on the experiences gained and continuous improvement of an established CDIO module.

INTRODUCTION

Flight Handling Qualities (FHQ) is a final year module for all students on the University of Liverpool's Master of Engineering (MEng) course in Aerospace Engineering. The aim of the module is to engage students in 'whole aircraft' problems – bringing together all of the previous learning that the students have undertaken during their undergraduate education. The module brings together aspects of aerodynamics, structures, power systems and avionic systems. Additionally, students have to consider factors such as flight safety, economics and project viability. Students must work to tight deadlines, while facing the pressures of demanding targets and satisfying pilots' demands.

Students work with the University's flight simulation facilities (Heliflight, refs 1 & 2), and are initially required to investigate the handling qualities of their designated aircraft.

Handling qualities were defined by George Cooper and Robert Harper in 1969 as "*Those qualities or characteristics of an aircraft that govern the ease and precision with which a pilot is able to perform the tasks required in support of an aircraft role*" (ref 3). Since then, handling qualities have grown into a discipline in their own right, with the development of testing methodologies, analytical response criteria and design standards, with the aim of ensuring that neither operational performance nor safety are compromised by handling qualities deficiencies.

Handling qualities engineers must work with designers, operators and pilots to reach consensus on the priorities and compromises in the aircraft design process. Serious problems are often discovered during the flight test phase of development due to a lack of concurrency, together with insufficient modelling and simulation during the early design phases.

Handling qualities can be assessed in one of two ways. Firstly, an aircraft's response to open loop tests can be assessed. The desired response is typically specified in a design standard (e.g. refs 4 & 5), and comparison with these shows the areas that are deficient in handling qualities. The second method of assessment is closed loop testing, performed by asking a pilot to fly a designated manoeuvre against a set of performance requirements. The pilot then rates the aircraft's handling qualities according to the Cooper-Harper Handling Qualities Rating Scale (ref 3).

Students are required to *conceive* strategies for addressing the deficiencies in their aircraft, *design* the resulting aircraft modification to ensure handling qualities deficiencies are addressed and that the modification is viable, *implement* the modification in the Flightlab modelling environment, and finally, *operate* the modified aircraft on the University's flight simulator, with the aid of a test pilot, to verify that the modification has been successful in resolving the aircraft's handling qualities deficiencies.

This paper presents a student's perspective on the FHQ module, looking at the activities that the student's undertake while working on the module, and how these activities help students to build their knowledge of the subject area, together with many other skills and abilities that are useful to them in their future careers. It also discusses some of the resources provided to assist with student learning, such as the team mentor and the use of a personal learning journal. Conclusions are then discussed.

THE UNIVERSITY OF LIVERPOOL'S FLIGHT SIMULATION FACILITIES

The software at the heart of the flight simulation environment is FLIGHTLAB, which provides a modular approach to the development of flight dynamics models. The user is able to build up a simulation model from a library of pre-defined components, such as rotor systems and wings. FLIGHTLAB provides a set of Graphical User Interfaces (GUIs) to enable the user to generate and analyse models.

There are several applications for the development and modification of models. One allows the user to specify the aircraft's components, together with the location of each component. Another provides the user with the ability to develop control systems.

It is normally desired to assess the aircraft's handling qualities without a pilot in the control loop. This is done using a further application, and enables the testing of many aircraft performance requirements.

However, for the complete picture of an aircraft's handling qualities, a pilot must fly the model in real time. This is performed on the University's HELIFLIGHT simulator.

HELIFLIGHT is a PC-based reconfigurable flight simulator consisting of five main components:

- The FLIGHTLAB modelling software with a real time interface
- 6 degree-of-freedom motion platform
- 4 axis dynamic control loading
- 3 channel collimated visual display for forward view, together with 2 flat panel chin windows, providing a wide field of view
- Re-configurable, computer-generated instrument panel and Head Up Displays

The control pod is shown in Figures 1 and 2.

Figure 1: The HELIFLIGHT control pod

Figure 2: Pilot's eye view from inside the control pod

THE FLIGHT HANDLING QUALITIES MODULE

The Flight Handling Qualities module was first run in academic year 2002-2003. The students taking the module are split up into teams and each of the groups is assigned an aircraft to work with. Aircraft used in this module include the Wright brothers' 1903 Flyer, the Grob Tutor training aircraft, the Bell XV-15 tilt rotor, the MBB Bo105 and the Sikorsky UH-60 Blackhawk helicopters.

The teams are then given a mission, against which the aircraft is assessed to identify any deficiencies. These missions include Search and Rescue for the XV-15; Combat Training for the Grob Tutor and Anti-Submarine Warfare (ASW) for the Bo105. The task that each team is given is to design and implement modifications to their aircraft (which could be either structural, power plant or avionic) to confer Level 1 handling qualities for the designated mission profile. Handling qualities of an aircraft are considered to fall into one of four levels. Level 1 indicates handling qualities that do not require improvement, while Level 2 indicates that, although minor, the deficiencies present must be improved. Level 3 means that there are significant deficiencies that must be improved, and Level 4 typically indicates that it is impossible to complete the given mission safely.

Part of the requirement for the modifications is that they should be both technically feasible and economically viable, thus incorporating an important element of real world decision making into the work involved.

To help the teams with their task, a series of lectures are given on the theoretical basis of aircraft handling qualities. Topics covered included fundamental aircraft dynamics; response types; handling qualities criteria and their rationale and methods for improving handling qualities. In addition, two workshops on the use of the simulation software are provided, the first for model analysis methods, and the second for aircraft modification methods. The purpose of these 'formal' learning sessions is to prepare the students for the problem-based core of the module.

Each team is assigned a 'mentor', whose role is to facilitate learning. While the mentor's role is primarily one of assisting with technical issues, such as the use of the FLIGHTLAB software, they can also encourage other aspects of students' learning.

The students additionally take part in a number of 'team building' activities, including the building of a tower from newspaper, and the analysis of a report on handling qualities ratings data interpretation (ref 6).

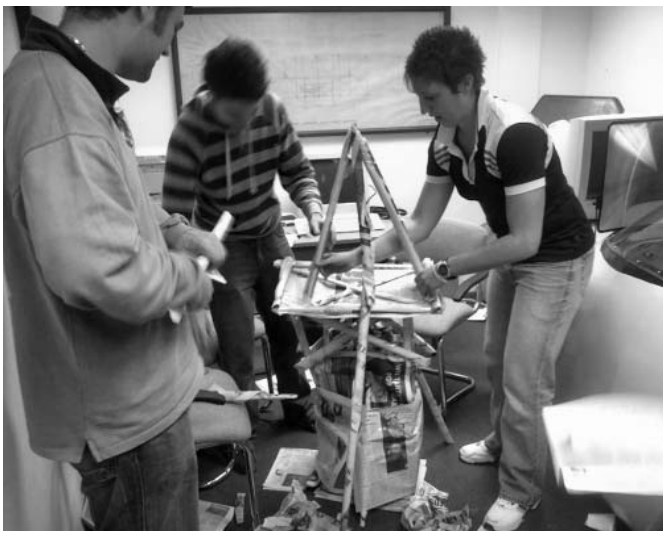

Figure 3: Team building exercise, tower construction

Each team is required to assess the handling qualities of its baseline aircraft using both offline testing and piloted simulation. This provides a picture of the deficiencies that the aircraft suffers from. The teams must then develop improvements to their aircraft, which are assessed through a further round of both offline testing and piloted simulation.

The module is assessed in three parts. The first of these is a full report on the analysis and improvement work, counting for 50% of the overall module worth. The second part of the assessment is a team presentation on the work completed. The presentation is given to an audience that consists not only of the academic staff involved with the module, but also another FHQ team and practicing engineers from industry. The presentation counts for 20% of the total module mark.

The final part of the assessment is the Personal Learning Journal, which each student was required to keep throughout the duration of the module. The learning journal serves several purposes. Firstly, the journal acts as a reflection tool, encouraging students to think about their learning. The journal also acts as a record of the student's learning and contribution over the course of the module. The learning journal is assessed on a fortnightly basis, with the overall mark for it making up the remaining 30% of the total FHQ score.

The FHQ module has been described in greater detail by Padfield (ref 7).

THE USE OF THE PERSONAL LEARNING JOURNAL

The Personal Learning Journal (PLJ) makes up an important part of the FHQ module. Not only is it worth 30% of the marks for the course but it is intended to act as a diary, reference manual and also helps to increase the students awareness of the skills that they are developing.

The PLJ covers four key areas, knowledge and understanding, intellectual abilities, practical skills and generable transferable skills.

The knowledge and understanding section allows the students to make a note of more specific technical content which can then be used at a later date as a reference tool. In the early stages of the course there is a steep learning curve and, given the PBL nature of the module, the onus is on the students to note down some of the technical content and work to a point where they understand it.

The intellectual abilities section can cover many areas, one of which may be the thought process involved in creating a vision for the project based on the start point and the target end point. The FHQ module requires that the students have to consider a wide range of potential courses of action to take and select the most appropriate based on a number of factors (time, technical feasibility, cost etc.) The development of ideas which lead to the formulation of a project strategy is ideally suited to the intellectual abilities section.

Practical skills may relate to the software used, for example FLIGHTLAB, which has many features that the students must learn to utilise, the Linux based operating system which the vast majority of students are unfamiliar with, and many other skills which fall into both the practical and transferable categories.

The general transferable skills developed during the course of the module are numerous and include planning, teamwork, leadership, time management, communication.

Writing the PLJ itself is a useful and rewarding experience as most students will have never documented course information in such a way before. The PLJ stands up to scrutiny during the module and can also be used for reference purposes many years after it has initially been written.

THE MENTOR'S ROLE IN FACILITATING STUDENT LEARNING

The team mentors are all familiar with the aircraft with which their group are working. They are also familiar with the deficiencies that the aircraft possesses in fulfilling the new role which has been prescribed. Their knowledge of the simulation environment is available to the students so that they can work towards improving the aircraft's handling qualities.

The role of team mentor is to act as an advisor who is available to guide the students when they have difficulties with a task. The students are encouraged to set up regular meetings with their mentor in order to prevent any stalling within the FHQ module. During meetings the mentor is available to help to answer any questions the students may have. The role of the mentor, however, is not to answer questions directly but rather to guide the students into answering the questions they have for themselves. The mentor encourages the students into finding solutions to address the problems of the aircraft through the knowledge gained from other modules and also through background reading.

As the mentor is familiar with many aspects of the FLIGHTLAB software and the simulation environment, the mentor is also available to run the simulation when modifications have been made to the students' aircraft model. The mentor will keep the students informed about all the processes that are required when using the FLIGHTLAB software so that they may learn how the software operates. The mentor is also available to answer any technical questions stemming from using FLIGHTLAB to make the modifications to the aircraft.

THE FLIGHT HANDLING QUALITIES LEARNING PROCESS

The first few weeks of the Flight Handling Qualities module are primarily taken up with technical learning. This consists of lectures on handling qualities theory (although these continue throughout the module), together with the first workshop on the use of the FLIGHTLAB software. These activities provide students with the core knowledge needed for the rest of the module. Also, the team building activities take place during this period, which serve to improve communication skills, including interpersonal communication and report writing skills. These activities also help with encouraging team working abilities.

Following the first workshop, analysis work can begin on the aircraft. This period provides a real opportunity for learning, and enhancing skills already present. Firstly, practical skills involved with the use of the simulation software can be improved. Although the FLIGHTLAB workshop provides the foundations for this, actually using the software to assess specific handling qualities parameters greatly increases the rate at which the use of the software becomes familiar. The second, but no less important aspect of learning is in the understanding of the handling qualities theory that is presented during the lectures, and how it impacts on the assessment of the aircraft's handling qualities. A key outcome here is the intellectual ability of being able to analyse a result (for instance a performance characteristic of an aircraft), and rationalise why that characteristic occurs. This skill is critically important when it is time to fix the aircraft, as if it is not known why a handling qualities deficiency occurs, it is very difficult to design a modification that will improve the aircraft.

Another opportunity for learning comes with the piloted simulation trials. Prior to these, it is necessary for each group to design the trial schedule, in order to cover as much as possible of the new mission requirement of the aircraft. The mission is broken down into small segments – mission task elements – that can be tested individually on the simulator. Preparation for the trial involves the production of a briefing document for the test pilot, which must describe the aircraft that is to be tested, together with the testing methodology. Also, a briefing document for the simulator operator (usually the team mentor) must be prepared, covering the information required here, such as starting positions and speeds etc. Finally, each team must think about the timing of the activities they wish to complete during the trial, so that they can make the best possible use of the limited time available with the pilot. Together, these activities require team members to communicate their ideas and plans in writing, and to organise the trial so that time is not wasted.

On the day of the trial, the team must conduct a briefing with the pilot, in order to ensure that the pilot fully understands what will be required during the trial itself. While the pilot is flying the mission task elements, it is necessary to communicate with the pilot constantly, firstly in order to get him to comment on the handling qualities of the aircraft, but also to discuss with him the reasons why he says particular things about the aircraft. Following the completion of the trial, a debriefing session takes place, in which the opportunity arises for further discussion of the handling qualities, and clarification of issues. In addition to the obvious experience of practicing communication skills, the trial provides the opportunity to gain real experience of working with a test pilot, including the briefing process and the communication procedures during the trial itself. Also, the trial enables students to gain from the pilot's experience of testing, by picking up tips from him on the running of a trial.

During a trial, a large amount of test data (control movements, aircraft movements etc.) will be generated, and it is necessary to analyse this following the completion of the trial. This is to ensure that the pilot is correct in his assessments of the aircraft, as well as to produce plots which illustrate for others the aircraft's performance during the trial. This analysis work is typically performed using MATLAB, and so skills in the use of this software tool must be improved.

The process of designing modifications for improving the handling qualities of the aircraft requires many skills. First and foremost amongst these, of course, is the key knowledge gained through the formal lectures and personal reading on the technical subjects required to design successful modifications to an aircraft, such as control system design. While it would not be possible to successfully modify the aircraft without this knowledge, many other skills are also required. The ability to work well within a team is key here, as the time available for designing and implementing modifications is usually quite limited. In order for the team to work effectively, it must be well lead, and must be highly organised. Also, it is important that the resulting modifications work within the constraints placed on the design, such as that it must be technically feasible.

In order to ensure that the modifications to the aircraft deliver the improvements required, the handling qualities of the modified aircraft must be analysed, in the same way as the original aircraft was analysed. This analysis includes both off-line testing and piloted simulation, and the repeat nature of this work provides the opportunity to reinforce the learning that took place during the original analysis, primarily in terms of the skills required to use the analysis software, and the preparation/briefing/pilot interaction process for the simulation trial.

The preparation of the full report and the presentation require team working skills. As both must have elements contributed by all members of the team, it is necessary to ensure that each team member knows what they are required to do, and when it must be done by. For the report, there is also a requirement for editing skills, so that the report can be made to flow as a coherent whole, rather than being many separate elements. In order to produce a high quality report or presentation, the team must be capable of communicating ideas and concepts in a clear and professional manner.

Finally, there is the learning that can be accomplished through the use of the personal learning journal itself. As an entry has to be submitted for marking every two weeks, it encourages students to ensure that they have worthwhile entries to be made – i.e. to gain additional skills and knowledge throughout the course of the module, rather than to take a stop-start approach to their learning. The learning journal can also be used as a tool to analyse the progress that has been made with the overall FHQ module, and to see what still remains to be completed, and consequently the knowledge and skills which must be improved in order to complete this work. The learning journal can increase motivation to research the subjects required outside the lecture periods – in order to produce a high quality journal entry, simply recording the knowledge picked up during the lecture periods is insufficient.

One of the requirements of the learning journal is that the author should reflect on what he or she has learned during the last period. Consequently, this enables students to analyse what they have learned, and to summarise the results. This process, both of re-considering the technical knowledge provided in lectures, and thinking about the other skills that have been learned, is a useful method of reinforcing the learning that has taken place.

As the learning journal is assessed progressively throughout the module, it can provide useful feedback as to progress with the project, whether that progress is being directed appropriately, and whether or not progress has been sufficient to be able to complete the project within the specified timeframe.

CONCLUSIONS

This paper has considered the learning process that takes place within the Flight Handling Qualities module at the University of Liverpool. The module is taken by all year 4 students on the Aerospace Engineering programme, requiring students to work together in teams to perform a handling qualities analysis on a designated aircraft, in order to develop modifications and upgrades to their aircraft in order to achieve Level 1 handling qualities. In the process of completing these tasks, together with the assessment components of the module, students must learn and develop many skills and abilities. In addition to these skills and abilities, they will gain a great deal of specialised knowledge on the subjects required for this module.

While the specialised technical knowledge is useful for completion of this module, and for any students who go on to work in this field, it is the other skills that provide the real benefit to the majority of students. These skills include the intellectual abilities of being able to apply specialised knowledge to problems, problem solving, and the ability to interpret results for their real meaning; the practical skills of the use of software tools such as MATLAB and the flight trial procedure; and general transferable skills such as team working, leadership, project planning, working within constraints and communications (both written and oral).

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