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A student's perspective on the progression of a Problem-Based Learning module for final year aerospace students

Philip S. Perfect, Steven A. Kendrick, Robert A. Armstrong & Heath A. Lockett

University of Liverpool
Liverpool, England, United Kingdom

ABSTRACT: In this article, the authors describe the development of the module *Flight Handling Qualities* (FHQ) from a student's perspective. FHQ is a Problem-Based-Learning (PBL) core module for 4th year aerospace engineering undergraduates at the University of Liverpool (UoL), Liverpool, England, UK. The authors have all graduated from the UoL MEng aerospace engineering programme and have completed the FHQ module. Consequently, the authors can offer a first-hand perspective of their experiences of this module. 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. Students are presented with the theory of HQs engineering in a series of interactive lectures and work in teams of four or five to undertake a number of teambuilding exercises throughout the first semester. The teams are presented with the idea that the aircraft, with its HQs 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, and then developing fixes to any handling deficiencies identified.

INTRODUCTION

Flight Handling Qualities (FHQ) is a final year module for all students on the Master of Engineering (MEng) course in aerospace engineering at the University of Liverpool (UoL) in Liverpool, England, UK. The aim of the module is to engage students in *whole aircraft* problems – bringing together all of the previous learning that 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*), and are initially required to investigate the handling qualities of their designated aircraft [1][2]. Handling qualities were defined by Cooper and 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* [1].

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 can be assessed in two ways. Firstly, an aircraft's response to open loop tests can be assessed. The desired response is typically specified in a design standard (eg refs [3][4]), and a comparison with these shows the areas that are deficient in handling qualities. The second method of assessment is closed loop testing, which is 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 [5].

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.

In this article, the authors present a student's perspective on the FHQ module, looking at the activities that students 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. The authors also discuss 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 FLIGHT HANDLING QUALITIES MODULE

The *Flight Handling Qualities* module was first run in the 2002-2003 academic year. Those students taking the module were split up into teams and each group was assigned an aircraft to work with, which could be fixed wing, a helicopter or a tilt rotor aircraft.

Teams are given a mission, against which the aircraft is assessed to identify any deficiencies. These missions include Search and Rescue; Combat Training and Anti-Submarine Warfare (ASW), depending upon aircraft type. 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 improved handling qualities for the designated mission profile. 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 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 students for the problem-based core of the module.

Students additionally take part in a number of *teambuilding* activities (see Figure 1), including the building of a tower from newspaper and the analysis of a report on handling qualities ratings data interpretation [6].

Figure 1: Students engaged in the teambuilding exercise of a tower construction.

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

The module is assessed in three parts. The team presentation and the team report account for the majority of the module marks, while each student must keep an individual personal learning journal to record his/her learning. The learning journal is assessed every two weeks.

In order to best satisfy the needs of students, the FHQ module is continuously evolving in order to give them the best possible learning experience. The changes that have been made often come as a result of the feedback forms that all students complete at the end of the module. These forms allow students to express their feelings and experiences, both positive and negative, about the module.

One of the most important changes was after the first year when the module length was extended from one semester to two. While vastly reducing the pressure on students to complete all of the work in the required time, the increase also allowed for more advanced and adventurous changes to be made, which would not have been possible during one semester.

The introduction of a team mentor was the most significant changes in the third year of the module. Team mentors are members of the research staff in the Flight Science & Technology group, all experienced in the use of software tools and in handling qualities engineering. 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.

Other changes include modifications made to the software tuition courses given through the module, the introduction of extra lectures given by outside speakers on subjects, such as the use of the personal learning journal and on sustainability in engineering, and the addition of a team presentation shortly before the first piloted assessment. This presentation allows students to demonstrate their understanding of the task and set out their plans for the piloted flight trial.

The FHQ module has been described in greater detail by Padfield [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 students' awareness of the skills that they are developing.

The PLJ covers four key areas, specifically:

- Knowledge and understanding;
- Intellectual abilities;
- Practical skills;
- Generable transferable skills.

The knowledge and understanding section allows students to make a note of more specific technical content that 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 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 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 that 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 students must learn to utilise, the Linux-based operating system, which the vast majority of students are unfamiliar with, and many other skills that 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 and communication.

Writing the PLJ itself is a useful and rewarding experience, as most students will have never documented course information in such a manner 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 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 teambuilding 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 teamworking 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. The UoL flight simulator is shown in Figure 2.

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.

Figure 2: The UoL flight simulator.

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 that 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 among 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 a team to work effectively, it must be well led 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 manner 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 teamworking skills. As both must have elements contributed by all members of the team, it is necessary to ensure that each team member knows what he/she is required to do and when it must be achieved 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 – ie 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 that must be improved in order to complete this work. The learning journal can increase students' 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/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 reconsidering 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

The authors have considered the learning process that takes place within the *Flight Handling Qualities* module at the University of Liverpool. The module is taken by all 4th year students in 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 so as 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 the 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 engage in the following:

- 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;
- General transferable skills, such as teamworking, leadership, project planning, working within constraints and communications (both written and oral).

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