Full Paper

Introduction

Traditional teaching approaches in courses covering aircraft dynamics and control typically utilize theoretical development, comprised of the derivation of governing equations followed by hand calculations of problems and/or simple simulation examples. One of the major challenges experienced by students in appreciating such teaching is the inability to visualize complicated, multi-modal aircraft motions thus leading to a decrease of students' motivation and understanding of fundamental concepts (Shankar, Chung, Husman and Wells, 2013).

Like many other engineering schools, the School of Engineering and Information Technology (SEIT) at the University of New South Wales, Canberra recognises the importance of student laboratories to complement classroom theory. As Eley (1995) and others have espoused, this is because laboratory work enables students to observe the relationship between theory and practice. Importantly, students begin to gain confidence in the application of theory by observing its practical limitations.

For this reason, in 1998 SEIT decided to develop an airborne laboratory facility. An aeroplane was acquired and it was equipped with a suite of sensors and instruments that allowed many aeroplane flight parameters to be measured and recorded. Aeronautical Engineering students and candidate pilots carried out a flight which allowed them to investigate aspects of aircraft performance, handling qualities and stability (static and dynamic) in a 1.2 hour flight. These experiments maximized the students' experience and exposure to flight test.

After an evaluation of the effort and time that academic staff required to operate the flight laboratory, in 2010 the airborne flight laboratory was discontinued. In its place there has been developed an Aviation Studio, equipped with a fixed-base flight simulator. Similar to the work carried out by Done and Neal (2012), the engineering flight simulator has been specifically designed as a versatile and practical hands-on aid to the teaching of flight mechanics and dynamics and aircraft design. Using a flight console, screens and X-Plane software, students can manipulate many aircraft characteristics.

According to Feisel and Rosa (2005) the use of technology to simulate physical phenomena most likely originated in the "Blue Box" developed by Edwin Link in 1928 (p.125). Link trainer flight simulation was used for pilot training extensively during World War II "saving millions of dollars and more than a few lives" (American Society of Mechanical Engineers, 2000 p.3). However, flight simulation for engineering training in an academic environment is a relatively recent development, (Gibbens, Dumble and Medagoda, 2010). Gibbens et al, 2010) maintain that "there is little detailed information on how flight simulators have been implemented in coursework, how effective they are in learning improvement, or how this has been assessed" (p. 429). Accordingly, the aim of this paper is to describe and compare the learning outcomes of two teaching paradigms of an aeronautical engineering course on aircraft dynamics and control - the airborne flight laboratory and a more 'contained' learning environment – the Aviation Studio.

The Flight Laboratories

The airborne flight laboratory was conducted in a specially instrumented Cessna 182RG light aircraft (Figure 1). In addition to the standard aircraft instrumentation, this aircraft was fitted with a variety of special instruments and sensors which included; an air data boom (Figure 2) providing airspeed, altitude, angle of attack and sideslip; an inclinometer to measure the inclination of the longitudinal axis of the aircraft; elevator, aileron and rudder control surface angular deflection sensors and pitch and roll rate gyros. Additionally, a computer-based data acquisition and control system, allowing up to 16 channels of data to be recorded at 100 Hz was installed. The fitting of these additional aircraft instruments met the requirements of Civil Aviation Regulation 35, (Lewis and Harrap, 2009;2010).

Figure 1: Cessna 182RG VH-CKA

Figure 2: The air-data boom mounted on the starboard wing.

A typical flight laboratory session was conducted with the academic staff/pilot performing manoeuvres and the student recording the parameters of the aircraft as they were displayed on the fitted laptop computer (Figure 3). As the flight progressed the pilot briefed that, apart from an initial control force input, the aircraft was to be flown ‘hands off’ so that the flight characteristics of the aircraft could be demonstrated. For instance, after a control input, the aircraft was allowed to take up a phugoid motion (Figure 4).

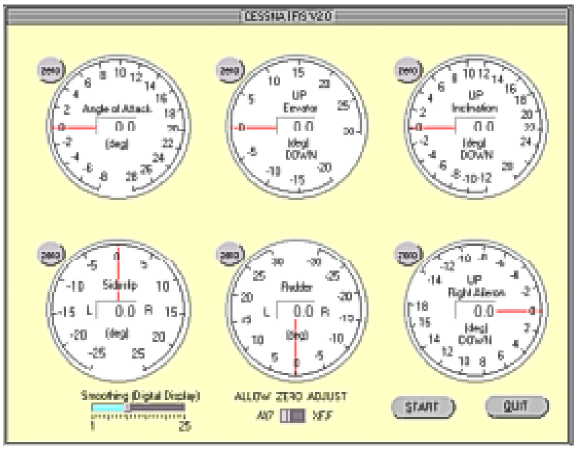

Figure 3: A typical data display using the data acquisition computer.

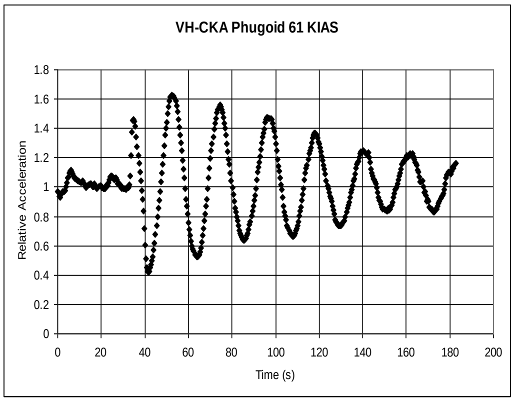

Figure 4: Long. dynamic stability: Phugoid

During the flight laboratory experiments, two students were taken up at a time. They worked as a team to observe and record data during the flight in a flight-laboratory logbook. (Figure 5). After completing the flight, they analysed their data and submitted a report in which they were required to demonstrate an understanding of the behaviour of the aircraft during each of the flight manoeuvres.

Figure 5: Student recording data during airborne flight laboratory

An important feature of the airborne laboratory was that every effort was made by the pilot to perform low ‘g’ maneuvers. This was to avoid discomfort and motion sickness and not compromise the students’ ability to observe and record information. For this reason turn performance maneuvers were discontinued as part of the laboratory as this testing often led to motion sickness problems as students tried to observe and record turn rates, bank angles and ‘g’ loadings during steady turns.

The Aviation Studio utilises a Precision Flight Controls console, screens and the X-Plane flight simulator software package (Figure 6). Students are able to ‘fly’ the simulated aircraft and manipulate many aircraft characteristics.

As in the case of the airborne flight laboratory, students record their data and submit a report demonstrating their knowledge and understanding of certain aircraft dynamics and control.

Figure 6: Aviation Studio Flight Simulator

The Aviation Studio experiments were designed to achieve the learning outcomes of the airborne laboratory: straight and level drag polar; lateral and directional static stability; longitudinal handling qualities and demonstration of longitudinal and lateral/directional dynamic modes – phugoid, Dutch roll and spiral modes.

It can be argued that both forms of the aircraft dynamics and control laboratory – airborne and studio-based – are experiential in their implied learning processes. Kolb (1984) cited in Kolb, Boyatzis and Mainemelis, (2000) maintains that experiential "learning is the process whereby knowledge is created through the transformation of experience", (p.41). Cannon and Feinstein (2005) ascert that depending on the nature of the task," experiential learning offers enormous potential for confronting students with highly complex and dynamic situations", (p350). Students must analyse what is going on in the game or exercise, synthesize solutions to address the situation and evaluate their relative merits.

What is germane to the present study is the question of whether the flight experience was too experiential. As previously stated every effort was made to ensure a smooth flight – for instance, when strong westerly winds were forecast and turbulence surrounding the designated laboratory airspace could be expected, flight laboratory sessions were rescheduled. However, it can be reported that there were many occasions when students suffered and complained of nausea which was attributed to the manoeuvres performed in the aircraft.

Evaluation of Learning Outcomes

In both the airborne laboratory and the flight simulator laboratory students submitted a laboratory report some two weeks after the laboratory session. The marked and assessed laboratory reports are a component of the total assessment for a *Fundamentals of Flight* course. A comparison of the marks and quality of laboratory reports produced in the two teaching and learning environments provided a basis of comparison for the learning outcomes of the two teaching and learning laboratories.

It is realised that comparisons of examination results and test scores are not a valid metric when evaluating the learning outcomes of different cohorts of students. However, the present study made a qualitative assessment of the submitted laboratory reports. Students who were the authors of the laboratory reports – either airborne flight laboratory or Aviation Studio flight laboratory - were matched on the basis of academic prowess. In this way some of the methodological issues when comparing the learning outcomes of two student cohorts may be overcome. The weighted average mean result (WAM) achieved by each student at the end of the previous academic year was ascertained. Students with similar WAMs and who had carried out either the airborne lab or the studio laboratory were matched and the resultant qualitative difference in their laboratory report assessed and recorded.

The laboratory reports were graded on a scale of 1 – poor attainment of learning outcomes to 10 – complete attainment of learning outcomes. The mean of the results of 10 laboratory reports resulting from the airborne flight laboratory and the mean of the results of 10 laboratory reports resulting from the Aviation Studio flight laboratory were calculated and are presented in Table 1.

Table 1: The mean of 10 laboratory reports for the airborne and the studio flight laboratory.

	Airborne Flight Lab.	Studio Flight lab
Grading	7.25	7.75

It is apparent that the Aviation Studio flight laboratory produced a marginally better result in terms of measured learning outcomes of the respective flight laboratories. However, in this study, the relatively small sample size and the methodological issues concerning the comparison of two separate cohorts of participants means that a significant result cannot be claimed. Notwithstanding the cost savings and elimination of risk, perhaps it can be claimed that the students' appreciation of aeroplane flight dynamics is not poorer by the learning experience obtained in an Aviation Studio environment.

Discussion

It must be conceded that flying in an aeroplane was an unsettling (sometimes almost traumatic) experience for some students. Rarely were they allowed to manipulate the controls. The instructor/ pilot would set the experimental conditions and then sit hands off – allowing the aircraft to enter the phugoid or spiral dive. Confinement in a small aircraft cabin and the possible undesirable effects of motion served to distract many students from the task in hand.

The flight simulator studio has none of these distractions. Students are allowed to work at their own pace and manipulate the 'aircraft'. Flight dynamic variables such as changes in aircraft centre of gravity may be changed at will and the resultant changes to aircraft stability observed in a calm learning environment.

The outcome of the comparison and evaluation of aeronautical engineering learning outcomes using an airborne flight laboratory and a flight simulator laboratory is a positive for the flight simulator laboratory given the constraints of comparing and evaluating two cohorts of learners. This finding will serve to inform the development of other learning paradigms and research activities in the flight simulator laboratory.

Recommendations/Implications/Conclusions

To an ever greater degree, teaching institutions are moving towards a virtual world where hands-on experience of equipment and artefacts are being replaced by e-learning paradigms; YouTube video and screen presentations of engineering and associated concepts. The benefits of making a comparison and evaluation of aeronautical engineering learning outcomes using an airborne flight laboratory and a flight simulator laboratory is that it may inform further development of teaching practices in a laboratory environment to better reflect a real world experience and improve learning outcomes.

For instance, the human-machine-interfaces (HMI) of many modern aircraft and unmanned aircraft systems (UAS) are rapidly evolving. Touch screens and other input devices are being integrated into the flight decks of new generation fighter aircraft; commercial airliners and the ground control stations of UAS. The ability to easily and quickly input data may significantly improve situational awareness of flight crew and ground station controllers. The new HMIs may be evaluated and experience gained in the new interfaces during Aviation Studio flight laboratory sessions.

It is expected that the Aviation Studio learning environment will produce better learning outcomes not only for existing aircraft technology but also for future aircraft. Because of the flexibility and adaptability of apparatus and software programs, novel HMIs will be able to be assessed and explored to determine their efficacy and ease of use both from an operator and aeronautical engineering perspective.

According to Wood, Beckman and Birney (2009) the use of simulations in education and training are considered to be beneficial for several reasons; "economy of time and cost savings; the benefit of neutralizing risks; exposure to different experiences that can accelerate learning and the appeal of the simulated, often highly interactive, experience" (p. 492). Thus simulations find a place when it becomes too expensive or too risky to allow students to learn in the real world. Students are allowed to explore, make mistakes and learn valuable lessons in virtual environments. As evidenced in this comparison and evaluation of aeronautical engineering learning outcomes using an airborne flight laboratory and a flight simulator laboratory, the use of a flight simulator laboratory may lead to enhanced learning outcomes.

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