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Using a Low Cost Flight Simulation Environment for Interdisciplinary Education

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Abstract

A multi-disciplinary/inter-disciplinary education is increasingly being emphasized for engineering undergraduates. However, often the focus is on interaction between engineering disciplines. This paper discusses the experience at Tuskegee University in providing inter-disciplinary research experiences for undergraduate students in both Aerospace Engineering and Psychology through the utilization of a low cost flight simulation environment. The environment, which is pc-based, runs an off-the shelf software and is configured for multiple out-of-the-window views and a synthetic heads down display with joystick, rudder and throttle controls. While the environment is being utilized to investigate and evaluate various strategies for training novice pilots, students were involved to provide them with experience in conducting such interdisciplinary research. On the inter-disciplinary level these experiences included developing experimental designs and research protocols, consideration of human participant ethical issues, and planning and executing the research studies. During the planning phase students were apprised of the limitations of the software in its basic form and the enhancements desired to investigate human factors issues. A number of enhancements to the flight environment were then undertaken, from creating Excel macros for determining the performance of the 'pilots', to interacting with the software to provide various standardized flight conditions based on the experimental protocol. These enhancements involved understanding the flight model and performance, stability & control issues. Throughout this process, discussions of data analysis included a focus from a human factors perspective as well as an engineering point of view.

Introduction

The 'Programs Outcomes and Assessment' detailed in Criterion 3 of the ABET2000 document [1] for accreditation of engineering programs is a template for educating well-rounded engineers. This criterion arises from an awareness of the need for today's graduates to have skills for success and competitiveness in a global and highly interactive work environment. In order to fulfill the requirements of this criterion, educators are now consciously designing and delivering their educational materials [2].

Interdisciplinary research is considered to be an effective method for exposing students to the skills outlined in Criterion 3(a) – (k) of Reference [1]. Such a research environment when properly structured provides the students with opportunities to develop collaborative, technical and communication skills. The added advantage is that students actually are able to see a practical application of the skills they are acquiring and have a sense of accomplishment. The 'Calpoly Interdisciplinary Monarch Butterfly Nuptial Flight Research' [3] is an interesting example of interdisciplinary research in which students of behavioral ecology, molecular and cellular biology, statistics and aeronautical engineering are attempting to determine characteristics for a successful mating. The Mind Project [4] of Illinois State University is designing 'simulated persons' using artificial intelligence and robotic devices. Although the project is aimed at cognitive research, it has involved students from a variety of departments.

The authors have been conducting research at Tuskegee University in the area of flight simulator based training methodologies. These investigations have been directed towards novice pilots as the volunteers for the research are students with no flying experience. Some of the factors that have been studied are the impact of above-real time (a scenario in which events are presented at a higher speed than normal) training strategies, various forms of feedback, and team interactions etc. [e.g. 5,6]. Currently, an interdisciplinary research effort towards determining training strategies utilizing a low-cost flight simulation environment for ab-initio or novice pilot training and minimizing flight instructor interventions is being undertaken.

This research has provided excellent opportunities for interdisciplinary experiences for students in aerospace engineering and psychology [7, 8]. Interdisciplinary research, however, needs to be carefully structured for student involvement. Differences in specialist jargon and execution methodologies between disciplines require considerable effort in educating students and faculty alike. . Reference 9 for example notes that 'established means of facilitating working relationships among social and computer scientists are currently lacking'. Faculty must exhibit the establishment of collaborative working relationships. The development of project concepts and plans requires faculty to exhibit willingness to adopt concepts and techniques outside of their own discipline. Often, these interdisciplinary relationships must be forged individually for each unique case, but are essential to provide a model for the students to emulate during development of their own interactive and communication skills as an inter-disciplinary team

The remainder of this paper will discuss the experience at Tuskegee University in providing interdisciplinary research exposure to students. The paper will include a discussion of the structure, student contributions and the benefits of interdisciplinary experiences, and future plans.

The Inter-disciplinary Research Environment

The environment for the inter-disciplinary experiences detailed in this paper involved an investigation whose objective was to determine an effective training strategy on a flight simulator for learning to land a light aircraft using a straight-in approach. The faculty research team consisting of the authors identified a group of psychology and aerospace engineering majors students interested in the research who were invited to the preliminary planning meetings. These planning meetings provided a structured environment for the students to be exposed to different terminologies, concepts, and perspectives in problem solving, and provided modeling of collegial interactions between faculty members of the two disciplines.

The initial meetings established the tasks and timelines to achieve the research objective. The students were then given various responsibilities based on the tasks outlined below.

(a) Establishing the flight simulation environment
(b) Determining orientation, training and evaluation maneuvers
(c) Coding automatic performance grading
(d) Designing the experiment
(e) Recruiting volunteers
(f) Establishing experimental protocols
(g) Conducting the experiment
(h) Analyzing & evaluating the data

Establishing the Flight Simulation Environment

The first objective for the aerospace engineering students was to establish the low cost flight simulation environment. During the planning meetings the various required characteristics of the environment were discussed. The students brought some useful psychological observations to the table regarding problems encountered in previous simulator research in maintaining the interest of volunteers in the research. An important observation was the need for a realistic and interesting flight simulation environment. The student experimenters had noted the waning interest of the volunteers after a few flights with the previous simulator which utilized a bland desert scenery.

Since the earlier simulator had proprietary software which was inaccessible to the research team, a decision to establish a more user friendly simulation environment was taken. The establishment of the flight simulation environment then was an exercise in systems engineering as the objective was to use off-the-shelf software and hardware. The public domain FlightGear Flight Simulator and the commercial MicroSoft FS2002 Professional software were evaluated by the students to determine its ease of use, sensitivity, realism etc. For the current investigation the MSFS2002 was determined to be a suitable engine. However, to use it effectively a number of enhancements were needed. One of the requirements of 'realism' for the environment was to have a multiple monitor out-of-the window display. An extensive internet search was conducted by the students to determine availability of software extending the capability of the MSFS2002. The WideView [9] software was found to provide exactly this capability. The multi-monitor capability of WindowsXP software however was used for configuring the various parts of the synthetic instrument display.

Determining orientation, training and evaluation maneuvers

Previous research by these investigators has established a methodology for most experiments consisting of three phases. This methodology is based on psychological practices in the arenas of human factors and motor skills learning. Because of the individual differences exhibited by participants, orientation flights have been utilized a) to provide basic instruction in airplane controls, b) to screen participants for their aptitude and c) to ensure they are equivalent in skill level to each other at the start of the experiment. As a screening mechanism, a criterion was set below which a pilot was discontinued from the study, and above which was allowed to continue into the training and testing phases of the experiment. The criterion had its basis in the Federal Aviation Administration's requirements for a private pilot license. Both the psychology students and the aerospace engineering students flew orientation flights and discussed the merits of elements of the criterion.

The research team meanwhile considered various potential training techniques for investigation. The impact of the use of a visual cue of flying through a 'tunnel in the sky' on the landing approach versus a standard visual & instrument scanning technique was chosen for investigation. The influence of 'fading' of the visual cues was also included. The concept of fading of cues was explained to the team and the reasoning behind the planned sequencing of flights as a fading technique. The logic of the design of the experiment was also part of this discussion. The aerospace engineering students were thus exposed to discussion/debate regarding the merits of various training techniques and the development of a research hypothesis.

Coding Automated Performance Grading

Since one of the objectives of the research was to minimize the involvement of a 'flight instructor' in the learning process, an automated grading to inform the student pilot of his/her performance had to be established. This required the comparison of the actual with the desired flight parameters; hence data extraction software was needed to interact with the simulation engine. Again an internet search was conducted and the 'FltRec82' [10] was determined to be an appropriate software. However the data extracted by this utility had to be manipulated to determine the 'performance' of the 'pilot'. An Excel macro was therefore written by the students to calculate and provide a quick answer to the student researcher as to whether the 'pilot' had passed or failed the flight maneuver during the orientation/screening phase. A similar procedure was subsequently used so that the pilot could determine his/her training progress and identify weaknesses. To be able to determine the pilot's 'performance' the students studied the various performance metrics used in previous investigations. During these previous investigations the students had conducted a comparative study of various grading strategies with grading by flight instructors [8]. While the aerospace engineering students were at ease with the discussion of the rationale for including certain flight parameters while excluding others, the psychology students were exposed to the practical applications of concepts like that of kinetic and potential energy interchanges which they had studied in physics courses.

Designing the Experiment

One important concept for the engineering students to learn from the psychology faculty and students was the concept of human variability and individual differences. Humans are inherently more variable than machines, and are susceptible to many more individual differences and chance variations than machines. This issue repeatedly came into play during the course of this research. Psychologists have extensive methodologies developed to handle such variability, both during an experiment, and in the context of data analysis. Thus, the engineering students were able to see practical applications of concepts learned in theoretical statistics course of statistical analyses and in recognizing individual differences in human observers. For example, when designing the experiment, the question of how many participants to evaluate in each experimental condition had to be determined. The psychologists provided useful insights into the reasoning behind sample sizes to be confident that results were not due to chance fluctuations. The engineering students developed an understanding that a single human being can not be representative of all humans in the same way an engineering prototype may represent future models.

An aspect of experimental design was whether to have one group of participants complete all the different training conditions, or to have groups of participants who were subjected to different training. Thus, the engineering students learned about different experimental designs, and became familiar with concepts like ‘between-subjects’ and ‘within subjects’ designs.

Recruiting Volunteers

As the investigation would utilize volunteers, the University’s requirements for research involving human subjects had to be fulfilled. The students were thus exposed to the regulatory aspects of research which required that details of the research had to be provided to the University for approval. The students developed an understanding of the ethical considerations involving research with human participants. For instance, when conducting research with human participants, issues of informed consent must be considered. The students learned that human research participants may behave differently when they are given full information regarding experimental hypotheses. Thus, research must carefully consider the practical aspects of conducting sound research while protecting participant rights.

Another aspect of ethical treatment of volunteers involved how to invite and encourage them to participate. The students learned that although incentives can be used, they must not be coercive in any manner. Finally, the students realized that a well thought out research plan was essential because after the approval of the plan by the University any changes would have to be referred again to the Human Participants Review Committee causing delays in the investigation.

Establishing Experimental Protocols & Conducting the Experiment

To ensure consistency in the manner of interacting with the participants, and since the research was to be conducted with volunteers who had no flying or flight simulator experience, effective protocols for conduct of the experiment had to be designed. These included standardized briefings on simulator operation, orientation flights, training and evaluation maneuvers and in providing post flight feedback on performance. This process required intensive teamwork between the engineering and psychology students and involved role-playing (of the volunteer and experimenter briefer.) The students realized the importance of adequateness of instruction. In addition the emphasis of the psychology faculty and students about thoroughness, consistency and relevancy of instructions to minimize bias between experimental conditions was practically observed by the aerospace students. During this process the student researchers were exposed to the important aspect of being sensitive to the volunteers' response to the evaluation of their performance/skill. Students also learned about concepts of attention span and information overload when providing instruction. The need for demographic and other relevant parameters e.g. exposure to video games for was determined as part of the research. Subsequently appropriate forms were designed by the students to collect demographic information and coded data.

The requirement of standardized orientation, training and evaluation flight scenarios was met by understanding the Adventure Basic Language on the MSFS2002 so as to appropriately modify a canned straight & level flight and landing lessons already programmed in the software. Since the orientation flights were primarily straight & level flights, the aerospace engineering students gained a practical understanding of the interactions between the altitude, throttle setting and speed to establish the desired flight parameters. This also provided an opportunity for the psychology students to understand the basic aspects of flight mechanics.

The students then presented their protocols and demonstrated the experimental procedure to the faculty team members. The students then conducted final 'dry runs' evaluated by the faculty to ensure the experimental procedures were correct and to determine the durations for the various phases of the experiments. An elaborate schedule usually involving pairs of aerospace engineering and psychology students to conduct the experiments was then developed by the students. Data was then collected on a number of participants.

Analyzing and Evaluating Data

Another area in which the issue of human variability came into play was in the context of data analysis. Again, when a single pilot produces a certain performance, the tendency on the part of the aerospace engineering students was to presume that the performance was representative of the effect of an independent variable on the behavior of the pilot. The expertise of the psychologists was utilized to understand the statistical significance of the data when drawing conclusions about the effects of experimental conditions on human performance.

Summary & Conclusions

A team of aerospace engineering and psychology majors was involved in an interdisciplinary research project involving the use of different training strategies to train novice pilots on a flight simulator. The research provided the students an opportunity to function as a closely knit team along with their faculty mentors. They were exposed to:

(a) Participation and interaction as a research group
(b) Establishing tasks for achieving research objectives
(c) Time and effort management
(d) Interdisciplinary academic areas
(e) Literature searches
(f) Formal presentations of results

As a consequence, the aerospace engineering students developed a better understanding of human factors, experimental design and data analysis. The main elements of success were primarily a high level of motivation of the students due to the opportunity of learning of concepts not covered in their major areas, and being given responsibility of tasks with practical impact on the investigation and planning and actual conduct of the experiments with minimal supervision. However, it is essential that for interdisciplinary student research teams, the faculty mentors have a well-structured research plan so as to minimize the potential of overwhelming the students. Regular meetings to provide well defined tasks are an important element of the structure. This model will continue to be used by the authors. Future research plans include enhancements of the flight simulation environment to incorporate visual and audio cues for enhancing the performance of the 'novice pilots' based on flight techniques of experienced pilots for realistic self-instruction. In addition, the authors are exploring the integration of interdisciplinary research experiences as part of the standard curriculum for both aerospace engineering majors and psychology majors.

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References

1. http://www.abet.org/criteria.html

2. Pimmel, L. R., 'Student Learning of Criterion 3 (a) – (k) Outcomes with Short Instructional Modules and the Relationship with Bloom's Taxonomy,' Journal of Engineering Education, Oct. 2003
3. http://biosci.calpoly.edu/BioSci/MonarchFlight/
4. http://www.mind.ilstu.edu/
5. Ali,S. F., Khan, M. J., Rossi, M., Crane, P., Heath, B., Knighten, T., Culpepper, C., ' Effects of Self-Instruction Methods and Above Real Time Training on Maneuvering Tasks on a Flight Simulator, Final report NASA NAG203, 2003
6. Khan, M. J., Rossi, M., Heath, B., Ali, S. F., Crane, P., Knighten, T., Culpeper, C., 'Effect of Above Real Time Training and Post Flight Feedback on Training of Novice Pilots in a PC-Based Flight Simulator,' Proceedings of the Hunstsville Simulation Conference HSC2003, Hunstsville, AL, Oct. 30-31, 2003

7. Knighten, T., 'Analysis of Demographic Variables as Predictors of Performance on Various FlightTasks Using a PC-Based Simulator,' Proceedings of the 4th Annual Undergraduate Science & Engineering Conference, NSF(CREST, AGP), Tuskegee, AL, Nov. 14-16, 2003
8. Heath, B., Crier, T., 'Comparison of Different Methods of Grading a Level Turn on a Flight Simulator,' Proceedings of the Hunstsville Simulation Conference HSC2003, Hunstsville, AL, Oct. 30-31, 2003
9. Fostering Research on the Economic and Social Impacts of Information Technology: Report of a Workshop http://www.nap.edu/readingroom/books/esi/ch4.html
10. http://www.wideview.it/\
11. http://www.avsim.com/hangar/utils/nav/

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