AC 2011-1080: INNOVATIVE INSTRUCTION FOR UNDERGRADUATE AIRCRAFT DYNAMICS AND CONTROL

Praveen Shankar, Arizona State University

Praveen Shankar is a lecturer of mechanical and aerospace engineering in the School for Engineering of Matter, Transport and Energy at Arizona State University. He obtained his MS (2004) and PhD (2007) degrees in Aerospace Engineering from The Ohio State University. He has a bachelor's degree in Mechanical Engineering from Bangalore University, India (1999). His research interests are in control theory with application to intelligent/adaptive flight control and innovation in educational methods for undergraduate aerospace education.

Jenefer Husman, Arizona State University

Jenefer Husman received a doctoral degree in Educational Psychology from the University of Texas at Austin, in 1998. She served as an Assistant Professor at the University of Alabama from 1998 to 2002, when she moved to Arizona State University. In 2008 she was promoted by ASU to Associate Professor. Dr. Husman has been a guest editor of Educational Psychology Review, has served on editorial board for top educational research journals, and currently sits on the editorial board of Learning and Instruction. In 2006 she was awarded the U.S. National Science Foundation CAREER grant award and received the Presidential Early Career Award for Scientists and Engineers. She has conducted and advised on educational research projects and grants in both the public and private sectors, and served as an external reviewer for doctoral dissertations outside the U.S. She publishes regularly in peer-reviewed journals and books, and has held both elected and appointed offices in the American Psychological Association (APA) and the European Association for Research on Learning and Instruction. Dr. Husman was a founding member and first President of the Southwest Consortium for Innovative Psychology in Education. She currently serves as the elected Co-Coordinator of the Motivation Special Interest Group of the European Association for Research on Learning and Instruction.

Valana L Wells, Arizona State University

Dr. Wells is Program Chair for Aerospace Engineering and Mechanical Engineering at Arizona State University. She teaches the first course in aerodynamics, as well as undergraduate and graduate courses in aircraft design, aircraft flight mechanics, numerical methods, acoustics and rotary-wing aerodynamics. In addition to engineering curriculum innovation and reform, her interests include rotorcraft noise suppression, rotorcraft aerodynamics and high-speed rotorcraft design.

Wen-Ting Chung, Arizona State University

Wen-Ting is a doctoral Student in Educational Psychology at Arizona State University. Her research interests include teacher motivation in educational reform and students' motivation and learning.

Innovative Instruction for Undergraduate Aircraft Dynamics and Control

Introduction

Prior studies have shown that the conventional teaching methods in university engineering courses undermine students' motivation to persist in pursuing an engineering career [1-3]. This effort, supported by NASA's E.2 Innovation in Aeronautics Instruction conducted at a large southwestern university, addresses the development of an innovative approach to teaching fundamental concepts in Aircraft Dynamics and Control (ADC) to promote student motivation. A pilot study conducted in the same university identified that student's reported significantly a decrease in two key motivational constructs self-efficacy (confidence in their mastery of course material) and perceived instrumentality (belief in the usefulness of the course content for their future) when taking junior-level courses [4]. These findings indicate that the junior year coursework may be an important year to develop innovative instruction which targets students' motivational beliefs.

In most universities, aircraft dynamics and control is offered as a junior level course following a fundamental course in aerodynamics. Current teaching practice for ADC classes is in some ways more advanced than in the more "classic" areas of aeronautical engineering. Cost-effective computing and associated simulation software such as Matlab has allowed for the solution of complex problems, but the inability to visualize complicated, multi-modal aircraft motions still prevents students from in-depth appreciation and understanding of the course material. Flight Simulation/Visualization software has been utilized extensively for instructional purposes, however this has been limited to aviation schools for pilot training [5] or for teaching more advanced concepts such as control system design [6-9]. For the more fundamental courses, one example of an innovative pedagogical strategy is the utilization of a "flying classroom" [10]. However, since this involves that use of an actual aircraft, it is not easily transferable to other universities while also not being cost effective. Several colleges, especially aviation schools utilize flight simulation hardware [11], but again, this equipment tends to be expensive and not amenable to large classrooms. Our goal in this effort was to find a balance between providing ADC students with real world experience and cost effectiveness/transferability.

The rest of the paper is organized as follows. We provide a brief description of the undergraduate ADC course offered at the large southwestern university. Next, we briefly describe the software utilized and the innovative instructional process including the homework assigned to the students. The paper finally addresses the effect of the changes in instruction on students' learning and motivation.

Aircraft Dynamics and Control Course Description

Aircraft dynamics and control is offered in the spring semester of the junior year. The pre-requisite competencies expected from the student entering the course include linear algebra, state space and transfer function representation of dynamical systems and a strong grasp of Matlab/Simulink programming. Specific pre-requisite courses include aerodynamics and a fundamental course in system dynamics and control. The topics in the course include

Static Stability and Control
Static stability refers to the initial response of an aircraft to a perturbation from steady state. This part of the curriculum emphasizes how the design of the aircraft influences the stability property of the aircraft. Students learn about the effect of the size and placement of the wing, horizontal and vertical tail on the longitudinal and lateral stability of the aircraft. In addition, the effect of control surfaces such as the elevators, rudders and ailerons on the stability and trim conditions are emphasized.

Dynamic Stability and Control
Dynamic stability refers to the response of the aircraft to disturbances/inputs over a period of time. In order to understand dynamic stability, students are introduced to the derivation of the equations of motion for rigid bodies in 3 dimensions. This is followed by a simplification where linearized model for an aircraft for particular steady state/trim conditions are obtained.
1. Computation of Stability and Control Derivatives: The property that differentiates aircrafts from other rigid body motions is the effect of the aerodynamic forces acting on the aircraft. These aerodynamic forces manifest themselves as stability and control derivatives in the aircraft equations of motion. Students are introduced to the methods of computing these stability and control derivatives with respect to the aircraft configuration and flight condition.
2. Stability of Uncontrolled Motion: The effect of initial conditions on the response of the aircraft is addressed in this topic. Specifically, students are introduced to the different longitudinal and lateral modes of motion. The initial conditions that excite this mode are evaluated from theory.
3. Open Loop Response to Actuation of Controls: In this topic, students are presented with the effect of control surface deflection on the motion of the aircraft. Specifically, the effect of the step response of elevators and throttle on the longitudinal motion and the rudder and aileron deflection required to obtain specific lateral steady states are discussed.
4. Closed Loop Control: The final topic in the undergraduate aircraft dynamics and control course is a brief introduction to closed loop flight control. Some of the specific flight controllers discussed are
    a. Phugoid Suppression Controller
    b. Speed Controller
    c. Lateral Control
    d. Yaw damper
    e. Roll Controller

As per ABET requirements, students are expected to meet certain course outcomes in order to obtain a passing grade in the class. These outcomes are listed in Table 1

Table 1: Aircraft Dynamics and Control Course Outcomes

Course Outcomes	Achievement Level
Students will linearize equations of motion for an airplane	comprehension
Students will explain the concept of aircraft static stability, including the effect of aircraft design characteristics on stability.	application
Students will describe aircraft dynamic modes in terms of their frequency, damping and stability.	application
Students will calculate and describe aircraft response to deflection of control surfaces.	comprehension
Students will design simple closed-loop aircraft controllers	comprehension

Software

The United States Air Force Stability and Control Digital DATCOM is a computer program that can be used to compute the static and dynamic stability and control derivatives of fixed-wing aircraft using empirical data compiled from several configurations. Digital DATCOM requires an input file containing a geometric description of an aircraft, and outputs its corresponding dimensionless stability derivatives according to the specified flight conditions. The values obtained can be used to determine the dynamic model of the given aircraft. While the original USAF DATCOM was created in 1976 [12], we are utilizing a version developed by Holy Cows Inc. (www.holycows.net/Datcom). Holy Cows has packaged the Digital DATCOM program DIGDAT into a package called DATCOM+. Along with the DIGDAT program, there are viewers for the AC3D, XML, and LFI format output files. Data tables can easily be output to the screen or to figure files for inclusion into reports. For static stability analysis, students were also provided with Solidworks models of aircrafts in different configurations. These included variation in the airfoil, location of the wing, location of the tail and location of the center of gravity.

Software was also developed by the instructor to help in visualization of dynamic stability and control properties of an aircraft. It was created from a combination of Matlab Graphical User Interface (GUI), Simulink and FlightGear. FlightGear (www.flightgear.org) is open source flight simulation software that is freely available to users. In addition, MATLAB contains a module in the aerospace blockset that communicates with the FlightGear simulator. The Matlab GUI developed for ADC is shown in Figure 1. This Matlab GUI can load a linearized dynamic model of an aircraft into the Matlab simulation environment for a given flight condition. Initial condition for the dynamic model as well as control surface deflections can be input through the GUI. Additionally, closed loop control gains can be assigned for specific aircraft control problems. As can be seen from the Figure 1, the stability and control derivatives for the specified flight condition can be displayed on the GUI. Another feature of this GUI is the ability to modify the stability and control derivative values. The mathematical integration of the aircraft equations of motion for specified flight condition with given initial conditions and/or control surface deflection is performed using a simulink model running in the background. The parameters in the

simulink model are updated from the Matlab GUI. To visualize the aircraft motions, FlightGear simulation software is first opened using the button "Load Flight Gear with Initial Conditions". Once the FlightGear window is opened, the "Run Linear Model" button is clicked to start the simulation. Visualization of the aircraft motion can be accomplished in the FlightGear window as shown in Figure 2.
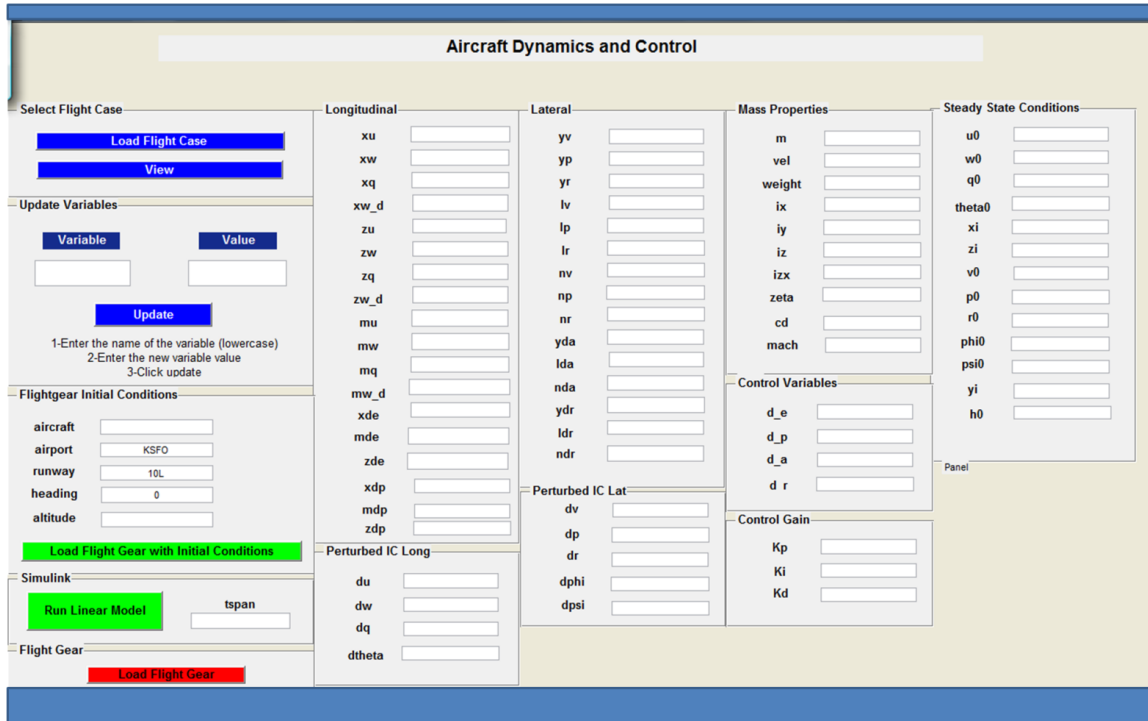

Figure 1: Matlab GUI for Dynamic Stability and Control Analysis

Figure 2: FlightGear Visualization

Curriculum Modifications

Course Instruction
The motivation behind introduction of the software into the curriculum was to determine a strategy and effect of reversing the theory to practice philosophy of teaching. Achieving the complete reversal of this philosophy however was extremely challenging. For example, the fundamental concepts involving static stability could not be taught DATCOM data analysis alone. The instructor therefore introduced static stability concepts briefly. This was followed by an introduction to DATCOM which allowed students to explore how changing the configuration of the aircraft would change the static stability properties. In comparison to the traditional method of solving numerical problems, it was expected that DATCOM analysis will allow students to test multiple configurations rapidly. It would also provide a confirmation of the conclusions obtained from theoretical analysis. For the dynamic stability and control properties of an aircraft, the students were introduced to the software developed by the instructor. The main learning outcomes expected from the students was the understanding of initial condition response and open loop response of aircrafts. To accomplish this, the instructor first introduced the theoretical analysis for Lateral/Directional motion of the aircraft. This was followed by visualization in FlightGear to confirm the results. While analyzing the longitudinal dynamic characteristics, however the method was reversed. Students were expected to draw conclusions from the visualization and present it as part of their homework. This was followed by an in class discussion involving theoretical analysis of the longitudinal motion to confirm their conclusion.

Homework Assigned
Homework 1: Introduction to rotational motions of aircraft
The first assignment in this course was assigned to give the students an introduction to the flight simulation software. The main expectation of this assignment from the students was they understand all the rotational motions of the aircraft along with what control surface affects it. Additionally, it was a simple exercise to ease the students into the curriculum.
Homework 2: Linearizing the equations of motion
The second assignment was a traditional homework allowing the students to derive the linearized equations of motion for cruising flight.
Homework 3: Longitudinal Static Stability (Hand Solved)
Students' understanding of longitudinal static stability was tested in this assignment. The effect of configuration of aircrafts including the location of the center of gravity, location and inclination of the horizontal tail on the static stability was evaluated using hand-solved numerical problems.
Homework 4: Longitudinal Static Stability (DATCOM)
Prior to this assignment, students were introduced to the USAF DATCOM software. Description of how to modify the input file to reflect the geometric configuration of the given aircraft followed by execution of the program and analysis of the data was discussed in the classroom. Students were provided with 3 wing models and 3 wing body models created in Solidworks. An example of the Solidworks model provided to the students is shown in Figure 3.
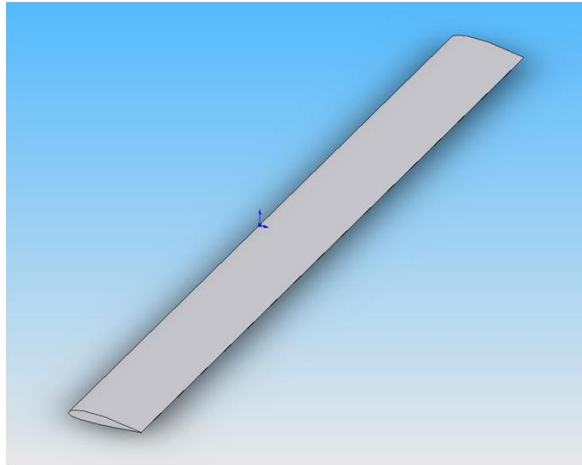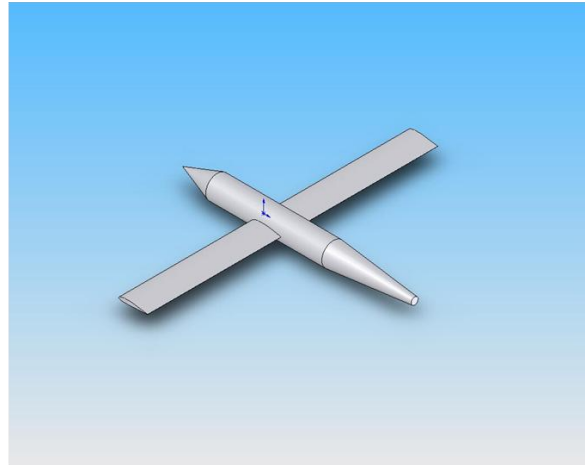
NACA 2414 Wing   NACA 2414 Wing and Fuselage Combination

Figure 3: Solidworks Files for Static Stability Analysis

A DATCOM input template file for both the wing and the wing body were provided. The students were expected to extract geometric details of the wing and wing-body and input it into the DATCOM input template file. These geometric details include the wing reference area, wing span and location of the center of gravity. DATCOM software is then executed to obtain the stability derivatives for 2 flight conditions. From the stability derivatives, students had to determine the longitudinal static stability of each model and compare it to concepts learnt from theory (Assignment 3). Additional problems added a fuselage and a horizontal tail and students were expected to determine how this changed the longitudinal static stability.

Homework 5: Longitudinal Static Stability and Control (hand solved and DATCOM)
In addition to a hand-solved numerical problem on the effect of horizontal tail and free floating elevator to the longitudinal static stability, problems utilizing DATCOM to test the same concepts were assigned. Students were provided with a DATCOM input file for the Navion aircraft. With the tail incidence angle fixed, students were asked to vary the location of the horizontal tail to determine the effect on static stability. Secondly, with the location of the horizontal tail fixed, students were expected to determine the effect of varying the tail incidence angle on the static stability. In both cases, students were asked to determine the limits of this variation i.e. determine the location and incidence angle of the horizontal tail at which the aircraft loses static stability. The final problem in this homework was the determination of the trim angle of attack for various deflections of the elevator. This was accomplished by extracting appropriate data from the DATCOM output file.

Homework 6: Longitudinal Modes of Motion Using Matlab GUI and FlightGear
Prior to the assignment of this homework, the students were introduced to the software developed by the instructor. A short tutorial on how to use the software was also provided with the homework. In class, students were taught that the choice of initial condition determines which particular mode will be excited. The specified initial conditions correspond to a particular motion variable having a significantly large normalized value as compared to the other motion variables. This analysis was accomplished in class by deriving the initial conditions responsible for the exciting the lateral modes of motion (roll subsidence, spiral and dutch roll) using eigenvector analysis. The derived initial conditions were then input into the simulator and the

students were able to visualize the lateral modes of motion on FlightGear. Students were expected to follow exactly the reverse procedure with respect to exciting the longitudinal modes of motion. With a brief background on the longitudinal modes, students evaluated different initial conditions that would excite the modes. Once they arrived at a conclusion that a particular initial condition is responsible for exciting either the phugoid or short period mode, they verified it using eigenvector analysis. Another element of the homework was to assess the effect of the center of gravity on the dynamic modes. Students determined the stability derivative (M_w) that was dependent on the location of the center of gravity. For different values of the stability derivative M_w, students excited the short period and phugoid mode. From the visualization, they determined that the short period mode was the one that was most dependent on this stability derivative. This analysis was then followed by an in-class discussion on the reduced order model of the 2 modes which showed the students that the dynamic model for the short period mode depends on M_w but the phugoid mode does not.

Homework 7: Longitudinal Open Loop Response Using Matlab GUI and FlightGear
In this homework, students simulated the response of the aircraft to step changes in elevator deflection and throttle setting. The primary objective of this homework was to identify from FlightGear visualization the short and long term behavior of the aircraft to independent changes in elevator deflection and throttle input. Students were expected to arrive at the conclusion that elevator deflection resulted in the change in the steady state velocity while throttle setting resulted in a change in the steady state flight path angle. This was then verified in class using theoretical analysis.

Homework 8: Lateral Steady State and Closed Loop Flight Control
Two types of problems were assigned in this homework. The first type was the visualization of steady sideslip: a lateral steady state motion. Students were asked to compute the aileron and rudder deflection necessary to cause a steady sideslip which is equivalent to a steady lateral velocity. By using these computed values into the simulation students were able to visualize steady sideslip motion of the aircraft. The second type of problem was the implementation of 2 longitudinal controllers: phugoid suppression and speed control. Students computed the controller gains by hand and visualized the effect of the controller on then aircraft motion using FlightGear.

Discussion
The software employed for the modification of the pedagogical approach has several advantages. The utilization of Matlab environment for the simulation simplified the learning process since all the students in the study were exposed to Matlab in at least 2 prior courses. Additionally, the software was inexpensive since the university possessed an institutional license to Matlab. DATCOM and FlightGear are freely available from the internet. More importantly, since most other universities possess similar licenses to Matlab and access to DATCOM and FlightGear, transfer of the curriculum and pedagogical approach is not expected to be very difficult or expensive to implement.

Challenges: From the instructor's perspective, the modification of the curriculum and introduction of the software posed several challenges. Firstly, it was important to develop software that would be easy for the students to learn. The main challenge however was to develop a pedagogical method and assign homework utilizing the software that would attempt to reverse the theory-to-practice strategy of teaching. The requirement of meeting ABET outcomes specified in Table 1 poses an added problem for the instructor to modify the teaching method.

Changes Being Made: The software is currently being refined to make it simpler for the students to use. In Spring 2010, students were expected to manually modify the DATCOM input file to reflect the configuration changes and flight conditions of the aircraft. Output of the DATCOM software also needed to be entered manually into Matlab for analysis. This caused confusion in students to a certain extent since DATCOM input and output files are not easy to understand. For the upcoming semester, the instructor has developed a Matlab GUI that will make it easy for the students to make changes to aircraft configuration automatically. Students will be provided with a Solidworks template file from which students can create aircrafts with multiple configurations. This model file can be imported into the Matlab environment through the new GUI which can also automatically create a DATCOM input file, run DATCOM software and import the output data into the Matlab workspace for easy analysis. The instructor is also exploring challenging and more meaningful homework to improve student learning.

Course Evaluation

Procedure and Participants
Students were recruited from two ADC courses in Spring 2009 and 2010 from a large southwestern university. There were 46 and 27 students enrolled in 2009 and 2010, respectively; 40 and 18 students who participated in our surveys, respectively. Self-reported scales were administrated to participants at the beginning, middle, and end of the semester. Students received a monetary incentive for participation. Students' grades on the final exams and their Course Grade were obtained from the instructor.
Measures
The surveys used in this evaluation were well- established scales that have generated valid and reliable responses from students in post-secondary engineering contexts [13].
Motivated Strategies for Learning Questionnaire (MSLQ)
The MSLQ [14] is an established scale utilized to evaluate students' motivation behaviors and their use of different study strategies. Only the eight-item subscale related to students general impression of their ability to be successful in the course was administered to participants of this study. Example items from this subscale are, "I am confident I can do an excellent job on the assignments and tests in XXX course". "I'm confident I can understand the basic concepts taught in XXX class," and "I expect to do well in XXX class." The students responded on a Likert-type scale ranging from 1 *(not at all true of me)* to 7 *(very true of me)*.
Engineering Self-Efficacy survey (ENGSE)
Developed by Senay Yasar [15] and adapted for use in this study, this scale follows the recommendations of Bandura [16] for constructing task-specific measures of self-efficacy. Items examined students' confidence for being able to perform the specific course objectives, and problem solving tasks within the aerodynamics course. There are a total of eleven items. Example items from this scale are, "I am confident in my ability to apply lifting-line solutions to solve for pressure, lift, and drag on wings," "I am confident in my ability to describe how airfoil characteristics affect the aerodynamic performance of the airfoil," and "I am confident in my ability use post-processing software (Fieldview) to analyze airfoils and wings using computed aerodynamic data." The students responded on a Likert-type scale ranging from 0% *(not at all)* to 100% *(completely certain)*.

SPOCK Knowledge Building subscale (SPOCKKB)

This was used to assess students' engagement in knowledge building strategies. There are a total of eight items, including, "In this class, I focus on developing my own understanding of the important ideas in what I am studying or reading.", "In this class, I set goals based on things I want to learn more about.", "In this class, I try to go beyond just what we are given in the lectures and text." The participants responded on a Likert-type scale ranging from 1 (*almost always*) to 5 (*almost never*).

SPOCK Collaborative Learning subscale (SPOCKCL)

This subscale [17] was used to assess students' perceived use of collaborative learning strategies. There are a total of five items. Example items were, "In this class, my classmates and I actively share ideas.", "In this class, my classmates and I actively work together to complete assignments.", and "In this class, my classmates and I actively work together to help each other understand the material." The participants responded on a Likert-type scale ranging from 1 *(almost always)* to 5 *(almost never)*.

Grades

Students' final course grades were measured on a 100 point grading system. The highest grade was 100 and the lowest grade was no credit (0.000).

Research questions

For self-efficacy

1. Did students report different degree of (1) self-efficacy (MSLQ) and (2) engineering self-efficacy (ENGSE) at the beginning and the end of the class?

2. Did the differences in means for (1) self-efficacy (MSLQ) and (2) engineering self-efficacy (ENGSE) at the beginning and at the end of each class vary depending upon whether students were taught in traditional or innovative class?

For engagement in active learning strategies

3. Did students who taught in traditional and innovative classes reported different degree of engagement in active learning strategies?

For academic achievement

4. Did students who taught in traditional and innovative classes performed differently and showed different degree of calibration of their self-efficacy?

Results

Self-Efficacy

A two-way analysis of variance was first conducted to evaluate the effect of two factors on students' self-efficacy (MSLQ) of their learning and performance in general in the classes (1) *Instruction type*, a between-subject factor with two levels (2009 traditional instruction and 2010 innovative instruction), and (2) *Time*, a within-subject factor with two levels (at the beginning and at the end of each type of class). The dependent variable was the averaged self-reported MSLQ scores (averaged rating between 1 to 5).

The Time main effect, Instruction Type main effect, and Instruction Type $\times$ Time interaction effect were tested using the univariate tests. The Time main effect was significant, $F(1, 56) = 6.22$, $p < .05$, partial eta squared= .10, as well as the Instruction Type $\times$ Time interaction effect, $F(1, 56) = 6.22$, $p < .05$, partial eta squared= .07. The univariate test associated with the Instruction Type main effect was nonsignificant, $F(1, 56) = .23$, $p = .64$

The significant Time main effect indicated that students' reported mean of self-efficacy was significant lower at the end of the class (after instruction) than that reported at the beginning of the class (before instruction); however, the degree of decreases on reported self-efficacy scores varied depending upon instruction types. Table 1 and Figure 1 show that although students' reported self-efficacy at the beginning in 2010 innovative class was lower than that in 2009, but their reported self-efficacy at the end in 2010 was higher than that in 2009. These results indicated that compared with students taught in 2009 traditional class, those students who taught in 2010 innovative class better retain their self-efficacy.

Another two-way analysis of variance was first conducted to evaluate the effect of two factors on students' engineering self-efficacy (ENGSE) of their learning and performance in general in the classes (1) *Instruction type*, a between-subject factor with two levels (2009 traditional instruction and 2010 innovative instruction), and (2) *Time*, a within-subject factor with two levels (at the beginning and at the end of each type of class). The dependent variable was the averaged self-reported ENGSE scores (averaged rating between 1 to 5).

The Time main effect, Instruction Type main effect, and Instruction Type × Time interaction effect were tested using the univariate tests. The Time main effect was significant at .01 level, $F(1, 56) = 76.78$, $p < .001$, partial eta squared= .58, as well as the Instruction Type × Time interaction effect, $F(1, 56) = 14.15$, $p < .001$. The univariate test associated with the Instruction Type main effect was significant at .05 level, $F(1, 56) = 4.13$, $p < .05$, partial eta squared= .07.

The significant Time main effect indicated that students' reported mean of engineering self-efficacy was significant higher at the end of the class (after instruction) than that reported at the beginning of the class (before instruction); however, the degree of decreases on reported engineering self-efficacy scores varied depending upon instruction types. Table 2 and Figure 2 show that although students' reported engineering self-efficacy at the beginning in 2010 traditional class was lower than that in 2009, but their reported engineering self-efficacy at the end in 2010 was higher than that in 2009. These results indicated that compared with students taught in 2009 traditional class, those students taught in 2010 innovative class increased their engineering self-efficacy more.

Learning Strategies
In terms of students' engagement in active learning strategies, independent-sample *t* tests were conducted to evaluate whether the mean scores on SPOCKKB and SPOCKCL of 2010 class were significantly greater than those of 2009, at the end of the classes. The results showed that only SPOCKCL of 2010 in the end of semester was significantly greater than that of 2009, $t(56)=-2.42$, $p < .05$. The 95% confidence interval for the difference in means ranged from -1.17 to -.11 (see Figure 2). The eta square index was .09, by convention interpreted as between medium to large effect size.

To examine whether self-efficacy predicted students' performance, correlation coefficients were computed for self-efficacy scores (both MSLQ and ENGSE scales taken in the end of semester, right before the final exam), the final exams, and the Course Grades. Students' confidence in their ability to do well in the course (mean score of the MSLQ subscale) was strongly and positively related to their Course Grades in both 2009 ($r= .37$, $p < .01$) and 2010 ($r=.60$, $p < .01$).

Their perception of their ability to complete the objectives of the class was not significantly related to their final course grade in either semester.

<u>Course Performance</u>

To determine if students learned more in the innovative 2010 semester than the traditionally taught 2009 semester; we compared the students final exam scores. The questions and evaluation criteria used in both final exams were the same. The results indicated that the mean score on Final Exam of 2010 (M= 79.03, SD=9.63) was significantly higher than that of 2009 (M= 67.19, SD= 9.63); $t(56)$=-3.26, $p < .01$. The 95% confidence interval of the difference in means ranging from -19.12 to -4.56 (see Figure 3); the eta square index was .16, by convention interpreted as large effect size.

Discussion

Our results suggested that students who learned through the innovative instruction which aimed to facilitate their intuitive and deep understanding reported greater confidence in performing well in the course, engaged more in active learning strategies, and performed significantly better in final exams. Also, the size of correlations between self-efficacy (MSLQ) and Course Grade indicated that students in innovative class had better calibration [18 -19] of their self-efficacy. The improvement of calibration might be explained by more feedback [18] students could gain from more interactions with their classmates and the constant use of interactive simulation programs, which allowed them to be able to better evaluate their understanding about course materials.

Table 2: Means and Standard Deviations for scores on MSLQ
Descriptive Statistics

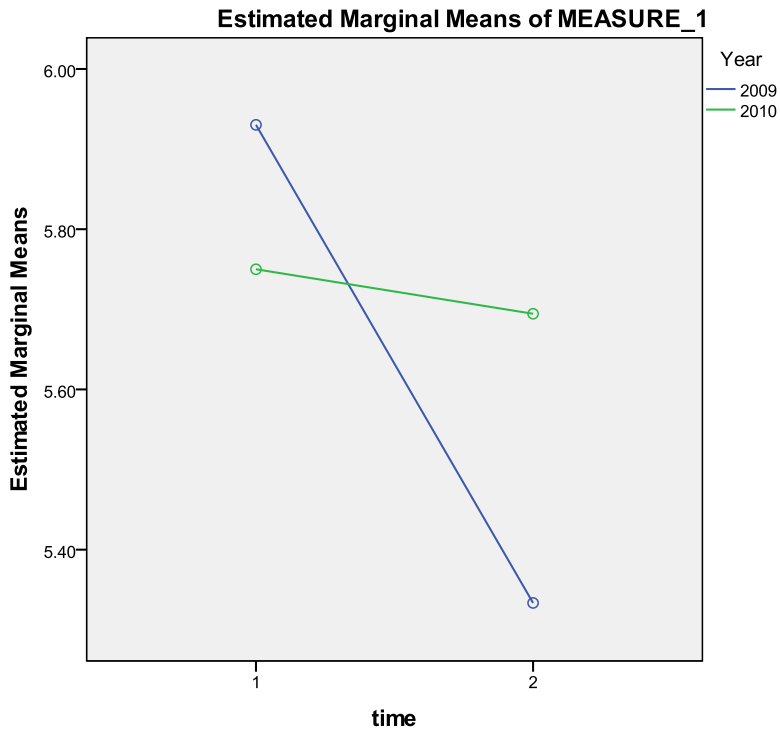|	Year	Mean	Std. Deviation	N
MSLQ_1	2009	5.9303	.74529	40
	2010	5.7500	.71999	18
	Total	5.8743	.73602	58
MSLQ_3	2009	5.3335	.94007	40
	2010	5.6944	.72662	18
	Total	5.4455	.88910	58

Estimated Marginal Means of MEASURE_1

Figure 4: Profile plot of Instruction Type by Time interaction

Table 3:Means and Standard Deviations for scores on ENGSE
Descriptive Statistics

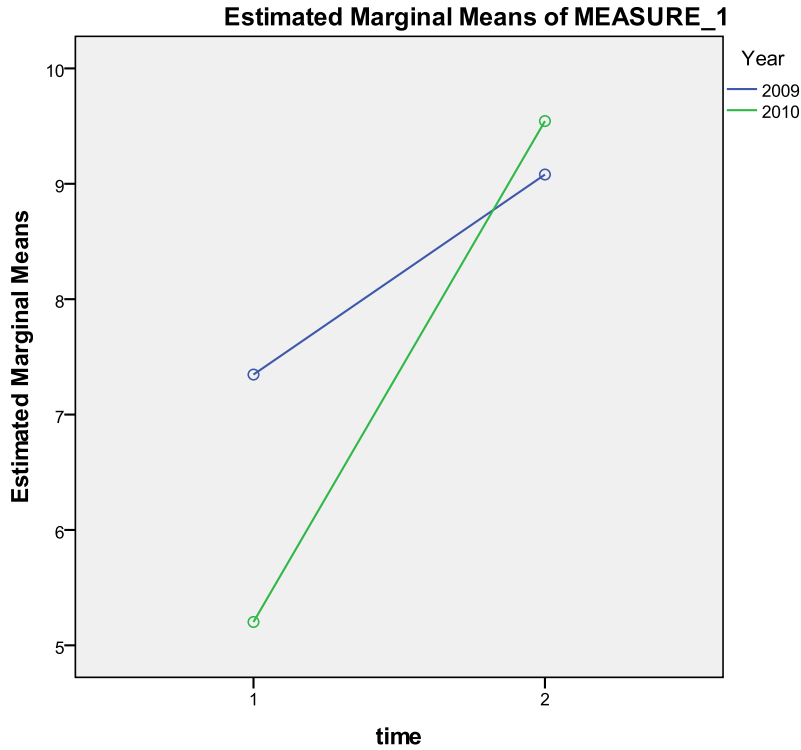|	Year	Mean	Std. Deviation	N
ENGSE_1	2009	7.35	2.162	40
	2010	5.20	2.679	18
	Total	6.68	2.518	58
ENGSE_3	2009	9.08	1.480	40
	2010	9.54	.948	18
	Total	9.22	1.346	58

Figure 5: Profile plot of Instruction Type by Time interaction

Table 4: Descriptive Statistics and Correlations among MSLQ, ENGSE, and grades for 2009 class

	Descriptive Statistics				Correlations Among Variables			
	Min	Max	*M*	*SD*	1	2	3	4
1. Self-Efficacy (MSLQ_3)	3.25	7.00	5.33	.94	-	-	-	-
2. Engineering Self-Efficacy (ENGSE_3)	3.00	11.00	9.08	1.48	.56**	-	-	-
3. Final Exam	46.00	100.00	67.19	13.96	.16	.14	-	-
4. Course Grade	57.44	98.69	72.63	9.64	.37**	.19	.86**	-

Note. ** $p < .01$, * $p < .05$. Listwise N = 18.

Table 5: Descriptive Statistics and Correlations among MSLQ, ENGSE, and grades for 2010 class

	Descriptive Statistics				Correlations Among Variables			
	Min	Max	*M*	*SD*	1	2	3	4
1. Self-Efficacy (MSLQ_3)	4.50	7.00	5.69	.73	-	-	-	-
2. Engineering Self-Efficacy (ENGSE_3)	8.00	11.00	9.54	.95	.66**	-	-	-
3. Final Exam	60.00	98.00	79.03	9.63	.35	-.03	-	-
4. Course Grade	66.04	86.60	77.66	5.40	.60**	.35	.67**	-

Note. ** $p < .01$, * $p < .05$. Listwise N = 40.

Conclusions

We present a software package that was developed using USAF DATCOM and a flight simulator to teach a junior-level undergraduate course in Aircraft Dynamics and Control (ADC). A study on the effect of implementing these software tools in improving student motivation and their confidence to learn the fundamental concepts is described. Modifications to the course instruction and examples of homework assigned using these tools is also presented. Comparison of the effectiveness of instruction between two semesters of ADC (Spring 2009 & 2010) without and with the software package is performed using extensive student surveys and exam scores. Our results indicate that students who learned through the innovative instruction reported greater confidence in performing well in the course and did significantly better in final exams. Future work is aimed at improving the usability of the software tools and developing challenging and more meaningful homework to facilitate student learning.

Acknowledgements

References

1. Guzdial, M., Ludovice, P., Realff, M., Morley, T., Carroll, K., *et al.*, "The challenge of collaborative learning in engineering and math", presented at Frontiers in Education Conference, 2001. 31st Annual, NY, 2001.
2. Kalonji, G., "Capturing the imagination: High-priority reforms for engineering education." in Educating the engineer of 2020: Adapting engineering education to the new century. Washington,DC: National Academics Press, 2005, pp. 146-450.
3. Seymour, E. and Hewitt, M. N., Talking About Leaving: Why Undergraduates Leave the Sciences. Westview Press, 1997.
4. Husman, J & Chung, W-.T. Unpublished Data, 2010
5. Karp, M, "Aviation Education for Future Pilots: An Integrated Model", the Interservice/Industry Training,

Simulation and Education Conference, 1998

6. Niemi, E, "Use of MS flight simulator in the teaching of the introduction to avionics course", Proceedings of the 2002 ASEE Annual conference and Exposition

7. Cotoi, I, Botez M, "The use of flight simulators for experiments in aerodynamic courses", Proceedings of the 2001 ASEE Annual conference and Exposition

8. Holzapfel, F., Sturhan, I., Sachs, G., "Low-Cost PC based flight simulator for education and research", AIAA Modeling and Simulation Technologies Conference and Exhibit, 2002, Monterey, CA

9. Rogalski, T., Tomczyk, A., Kopecki, G., "Flight simulator as a tool for flight control system synthesis and handling qualities research", Solid State Phenomena, 2009, 147, 231-236

10. Tomczyk, A., "The flying laboratory for aeronautics students' education", Aircraft Engineering and Aerospace Technology, 2010, 82(5), pp 320-330

11. Frasca International, Inc., "Frasca CRJ: Regional jet flight training device", www.frasca.com/pdf/CRJbrochure.pdf

12. Hoak, D. E., et al., "*The USAF Stability and Control DATCOM*," Air Force Wright Aeronautical Laboratories, TR-83-3048, Oct. 1960 (Revised 1978).

13. Husman, J., Lynch, C., Hilpert, J., and Duggan, M. A., "Validating measures of future time perspective for engineering students: Steps toward improving engineering education", presented at American Society for Engineering Education Annual Conference & Exposition, Honolulu, HI, 2007.

14. Pintrich, P. R., Smith, D., Garcia, T., & Mckeachie, W. , "Reliability and Predictive Validity of the Motivated Strategies for Learning Questionnaire (Mslq)", Educational and Psychological Measurement, 1993, 53(3), 801

15. Yasar, S., "Discourse in freshman engineering teams: The relationship between verbal persuasions, self-efficacy, and achievement", 2008

16. Bandura, A., "Guide for constructing self-efficacy scales" , Self Efficacy Beliefs of Adolescents, 2006, 5, 1-43

17. Shell, D. F., Husman, J., Turner, J. E., Cliffel, D. M., Nath, I., & Sweany, N., "The impact of computer supported collaborative learning communities on high school students' knowledge building, strategy building, strategic learning, and perceptions of the classroom" Journal of Educational Computing Research, 2005, 33(3), 327-349.

18. Brannick, M. T., Miles, D. E., & Kisamore, J. L., "Calibration between student mastery and self-efficacy", Studies in Higher Education, 2005, 30(4), 473-483.

19. Glenberg, A. M., Sanocki, T., Epstein, W., & Morris, C., "Enhancing calibration of comprehension", Journal of Experimental Psychology: General, 1987, 116(2), 119-136