AC 2011-515: TEACHING WITH UFO'S IN AN AERONAUTICAL ENGINEERING COURSE

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Abstract

All teachers are confronted with the challenge of presenting material in a way that enhances student's retention of the subject matter. The literature is filled with methods for achieving this goal. Most approaches are based on various learning theories that include appealing to multiple learning styles, increasing the student's emotional involvement with the material, and increasing student-faculty rapport and interaction. Many teaching techniques are designed with more than one of these principles in mind. This paper presents a technique, termed the Mystery Aircraft, that is designed to leverage multiple learning theories that increase student interest and retention of the material covered in two sequential aeronautical engineering classes. This is accomplished through the use of many visual examples of actual production and experimental aircraft. Additional discussion on the advantages of the Mystery Aircraft technique briefly cover topics such as applying the Dual Coded Theory of Redundancy and Reinforcement for cognitive learning, enhancing student cultural literacy within the field of aeronautical engineering, and support of institutional program outcomes and ABET criterion. The effectiveness of the technique in capturing students' attention, generating interest, and improving motivation is assessed through the use of student mid-course and course-end surveys. A listing of the aircraft examples and their associated topics is also presented in the appendix.

Introduction

For the last two years, instructors teaching a two course aerospace engineering sequence at the United States Military Academy (USMA) have implemented a technique entitled "The Mystery Aircraft" to enhance students' retention of subject matter. The current short course sequence in the Mechanical Engineering Department at the academy consists of two semesters, one at the junior level and the second at the senior level, that cover fundamentals of aerodynamics, aircraft performance and design, and static stability. The Mystery Aircraft technique is applied to almost every lesson in each course but with different methods and in varying degrees. The technique proved to be a very popular addition to both courses and generated positive feedback regarding its ability to increase and stimulate motivation, enhance a student's learning experience, and aid in the retention of course material. This paper describes the technique itself, reviews the pertinent literature that helped form and guide its development, and discusses the students' response to the technique.

The Mystery Aircraft Technique

In an aerospace engineering course the very nature of the subject matter and the fact a student chose to enroll in this type of course suggests there is at least some passion and motivation for the aviation industry and the aircraft that it produces. The mystery aircraft technique capitalizes on that inherent motivation in its application. In its most simple form the Mystery Aircraft technique consists of a few high quality images of specific aircraft presented to the students via projector that are real-world examples of the concepts discussed in the lesson that day. The students usually compete to see who can first identify the aircraft, and students are also rewarded if they can explain how it relates to the lesson's material. The competition helps to elevate the student's energy, and typically their curiosity is piqued as well. The subjects range from readily identifiable aircraft, where the real challenge is relating it to the lesson material, to very obscure and funny-looking aircraft, where the real story is why the aircraft was ever designed and built. What makes the technique stand out as a valuable motivational and subject matter retention tool is the way in which these images are used to apply different learning theories and how the discussion and interaction with the students that follows is facilitated by the instructor. For example, if the lesson covers lateral aircraft stability and the use of anhedral wing design, one option would be to use the Lockheed C-5 Galaxy shown in figure 1. This aircraft has a large degree of anhedral clearly visible from most angles but especially from the front view. Since this particular aircraft is fairly well-known, the instructor might choose to present it unlabeled in the middle of the lesson, hyping students up with a small reward to whoever correctly identifies the aircraft first.

Figure 1. The Lockheed C5 Galaxy
Image Sourse: http://www.aviationexplorer.com/c-5_facts.htm

The reward is typically something trivial such as a small but delicious piece of candy but can also come in the form of class participation or bonus points depending on the instructor. Varying the degree of the reward and keeping it hidden until execution simply enhances the dramatic tension. All of this offers a nice break to the lecture material as well as a change of format while still being focused on the material at hand. Agreeing with Duffy and Jones in their text "*Teaching within the Rhythms of the Semester*"[1], the variety in the classroom lecture helps keep students attention, "Never do any single thing for very long…" After several rapid guesses, with the correct identification and subsequent reward, the next slides show several other angles of the aircraft as well as key aircraft specifications or design features which the instructor can use to ask more discussion questions such as "What about this aircraft and its application possibly warrant the use of anhedral in its wing design?" or "What advantages and disadvantages accompany this design choice?", and even "What other aircraft use this design and were the considerations similar?" Answers to these questions spawn further discussion in related design considerations like the maneuverability of military aircraft and the use of high verses low wing configuration in order to accommodate the ground clearance for engines on unimproved landing surfaces etc. The instructor can facilitate the discussion for however long they choose but five to ten minutes tends to work best. These five to ten minutes of discussion inevitably build student/teacher and student to student rapport which can prove far more valuable than time that might be given to further covering lesson objectives. With an interesting discussion on a real-world application of the subject matter combined with a little competition, students more readily give their attention to the rest of the lesson material and are more motivated to learn it.

Another method of employing the Mystery Aircraft technique is to use a less well known aircraft to foster discussion about the lesson material. For example, when covering lesson concepts regarding take-off and landing distance performance, an instructor can use the ZenAir CH701 shown in figure 2. As it is a Short-Take-Off and Landing (STOL) kit aircraft, most students will not be able to identify it immediately and thus the instructor can introduce the material by building upon discussion questions such as "What do you think the primary performance goal of this aircraft was?" Further discussion on the high lift wing design and configuration can lead into the concepts governing take-off and landing distance performance. As the instructor develops governing equations on the board he can reference the images and then finally reveal the identity of the aircraft later in the lesson with a couple other video clips of STOL aircraft conducting a max performance take-off or short field landing.

Figure 2. ZenAir CH701 (STOL) Aircraft
Image Source: Matthew Rowland, MAJ, AV, U.S. Army

Literature Survey

All reputable teaching techniques are grounded in one or more learning theories. Support for employing the Mystery Aircraft comes from several different sources. Most educators are aware of Felder and Silverman's Learning Styles Inventory[2] and understand the importance of reaching out to all of the various learning styles in the course of a lecture. Although there is typically significant variety in most learning style dimensions from student to student, the one dimension that is the most one-sided is the visual-verbal dimension, as reported by Felder and Brent.[3] The majority of students report that they are strongly visual learners, and yet many instructors struggle with ways to meaningfully infuse visual presentations into their lectures.

The Mystery Aircraft not only provides a natural venue for visual media, it forces the instructor to budget the time and content of the lesson to accommodate this important learning style dimension.

While the use of high quality images during instruction obviously appeals to visual learners, the Mystery Aircraft Technique uses these images to appeal to all learners retention in an even more fundamental way than targeting and individual's learning style. Research and psychological evidence shows that the brain processes and retains verbal and visual information using separate cognitive systems. This "Dual-Coding Theory" allows for greater retention and recall of stored material. In other words, the brain can process the same information, both the verbal discussion about the aircraft and the visual image of its associated design features, at the same time without an increase in work load.[4,5] Because the Mystery Aircraft Technique presents conceptual material tied directly to a specific aircraft image at the same time, the instructor makes use of the Dual-Coding Theory for redundancy and cognitive reinforcement. Lesson material combined with aircraft images are easier to remember than just lectured words describing conceptual content alone.

Not only must a teacher emphasize visual learning to be effective, in *Mastering the Techniques of Teaching*[6], Lowman describes college classrooms as dramatic arenas that must attract and hold audience attention. The Mystery Aircraft technique is designed to do precisely that using aircraft images in a way that creates narrative or dramatic tension. Sometimes, the simple competitive moment as the student attempts to guess the aircraft is sufficient. More often, the aircraft has an intriguing story, or it represents a significant design problem that was solved by the ingenuity and hard work of aeronautical engineers. Hearing about that story and eventually learning that aircraft's identity stimulate positive emotions from the joy of its discovery. Keeping the identity of the aircraft in suspense fosters that stimulation of emotion and it also reinforces their ability to remember the material. Additionally, a good dramatic story telling tied to the aircraft can help spark an interest that might otherwise lay dormant if the only material presented in the lesson were the derivation of the relevant governing equations combined with a sample problem or two. Author John D. Anderson's[7,8] texts in McGraw-Hill's Series in Aeronautical and Astronautical Engineering provide a wealth of insight into the stories associated with various aircraft development and production. For example, in his text *Aircraft Performance and Design*,[7] Anderson tells a small story on the development of the P-38 Lightning. The Lockheed P-38 Lightning was developed during WWII as a fighter interceptor for America's efforts primarily in the Pacific theater. Several pilots were killed when entering high speed dives (something fighters are prone to do) because of unforeseen elevator control problems. Telling the story of the P-38 lightning and how the engineers who worked on it discovered the cause of its elevator problems can develop suspense and dramatic tension while introducing the topic of the day's lesson (elevator control). After covering the lesson material on elevator control effectiveness the class is finally presented with the engineer's solution of adding dive flaps to change the downwash on the elevator at high speeds thus improving the elevator effectiveness. Like most of us, students can remember images far longer than words and when combined with a dramatic story they now have emotional associations tied to the material. As Lowman suggests, instructors aid in the students' recall by pairing the drama and suspense with the abstract conceptual material.

Telling the story of an aircraft with specifics tied to the lesson material goes beyond just emotional association as an effective tool in holding students attention span. In John Medina's book, *Brain Rules*[9] he describes how the human attention span is naturally limited to about ten minutes. Rather than bemoan this fact, he proceeds to recommend structuring lectures to accommodate the students' need for "something so compelling that they blast through the 10-minute barrier and move on to new ground." He details how these "hooks" should be emotionally compelling, relevant to the class discussion, and if possible, involve some sort of narrative structure. Proper sequence and timing of the mystery aircraft technique is a great way to incorporate all three elements. This also gives both the students and the instructor a break in the otherwise interminable stretches of lecture, and elevates both student interest and learning.

Heath and Heath[10] list several properties for increasing the attention span of students and their ability to recall concepts, including leveraging the unexpectedness of an idea as well as its concreteness. Properly delivered, the Mystery Aircraft technique is a great way to generate curiosity by exposing gaps in the students' knowledge and then work to close those gaps in the discussion that follows. This can be accomplished by asking students why a certain aircraft has a particular design feature, and then filling in this information over the course of the lecture; and there is no better way to demonstrate the concreteness of a concept than by showing a picture that illustrates a principle.

Additionally, the information presented regarding the application of engineering concepts as well as the ensuing discussion during the Mystery Aircraft Technique can appeal directly to specific ABET criterion. For example, ABET criterion #3(h) states that "Engineering programs must demonstrate that their students attain the following outcomes: …(h) the broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context…" and #3(j) "…a knowledge of contemporary issues…" Use of the Mystery Aircraft Technique allows the instructor to discuss the impact the engineering solutions had on the world with the development and production of these particular aircraft. Commercial, military, and general aviation aircraft all offer a wide range of examples on how the application of aerospace engineering principles have affected our lives today. For example, the economic factors associated with making commercial aviation as efficient as possible are directly tied to fundamental performance parameters such as thrust to weight and lift to drag ratio. Solutions to military requirements for maneuverability and speed can be shown to impact the course of an entire war. Developments in general aviation engineering impact the use of aircraft in various ways to include flight training, safety, and recreational transportation. Use of recently developed aircraft allow the instructor to highlight contemporary issues, engineering challenges, and achievements such as advances in stability and control systems or new ideas regarding noise reduction and propulsive efficiency.

Finally, the use of the Mystery Aircraft technique allows budding engineers to gain a cultural literacy with the many hallmarks of aviation development that those who have been in the aerospace field for many years already know. Ideally, young aeronautical engineers should be able to identify and explain the importance of key aircraft just as easily as they can explain the physics behind the production of lift. The Mystery Aircraft gives them a familiarity with technical lessons learned throughout history that should be remembered and applied accordingly.

Student Assessment

Assessment of the Mystery Aircraft Technique was made using mid-course, and course end surveys to determine student opinion of its impact on their motivation towards and retention of the subject matter presented in class. Based on mid-course survey's targeting its perceived value by the students, the Mystery Aircraft was very popular. In fact 100% of the 32 students polled in the ME481 "Aircraft Performance and Static Stability" course had some form of positive comment regarding its use. Comments ranged from "…the mystery aircraft shows a real-world application of the material which really helps to understand it…" to "…it is fun and keeps me from falling asleep…" Additional mid-course surveys taken in ME387 "Introduction to Applied Aerodynamics" and ME350 "Introduction to Thermal Systems…", which were general in nature, yielded several positive unsolicited comments regarding use of the Mystery Technique. In fact, in ME350 33% of the students in one semester declared their enthusiasm for the technique in response to open-ended feedback. Formal end of course survey questions yielded similar positive feedback as shown below in Table 1. It is also worth mentioning that other instructors in follow on courses at the institution had students asking whether or not they will be conducting Mystery Aircraft events in their classes and if not, suggesting that they should. This is yet another indicator to the popularity of the experience and offers additional insight into how much the students appreciated the teaching technique.

Table 1. End of Course Survey for ME481 "Aircraft Performance and Static Stability"

Survey Question	Agreement Score (Scale from 1-5)
The "Mystery Aircraft" event was one of the most valuable uses of classroom lecture time for learning the subject material.	**3.8** **(86% of Students in Agreement)**
The "Mystery Aircraft" event increased my ability to pay attention in class.	**4.5** **(100% in General Agreement)**
The "Mystery Aircraft" event elevated my interest in course material.	**4.3** **(93% of Students in Agreement**
The "Mystery Aircraft" event increased my contextual awareness of course materials and their specific application to aircraft within the aerospace industry.	**4.3** **(93% of Students in Agreement)**

Conclusion

Instructors who wish to add energy and motivation to their classroom as well as improve student understanding and retention of subject material in their aeronautical engineering courses would be well suited to use the Mystery Aircraft technique presented in this paper. It has the ability to make use of various learning theories in a fun and inspirational way that directly relate to the subject matter. It is flexible and easy to apply with minimal additional preparation time and can easily be executed for short periods in the classroom. For some initial ideas and possibilities of aircraft and subject matter that can be used to incorporate the technique in future classes, please see the "Mystery Aircraft List" in Appendix A. Most all of these aircraft have several images available through websites such as www.wikipedia.com and www.aviationexplorer.com. It is the sincere hope of the authors that instructors may be able to easily apply this technique to not only improve students education but increase their motivation and passion for the field of aeronautics and the aerospace industry.

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APPENDIX A. Mystery Aircraft List

Topic	Mystery Aircraft	Application Description
Aircraft Structures and Materials	Cirrus SR22, Hughes H-4 Hercules	Composite Performance, Parachute; wood "Spruce Goose"
Airfoil Design, Vortex Panel Method	Piper Tomahawk, Neico Lancair	Use of advanced NASA airfoils, LS-0417 and NLF0315
Airfoils - Basic Lift Production	Lockheed Vega, Coanda-1910	Clark Y airfoil, mention of Coanda Effect
Airfoils: Thin vs. Thick	Fokker DR-1	Positive benefits of thickness (first airfoil with thickness)
Airplane Design: Shape and Configuration	Granville GEE BEE	Designed for Races, Tear Drop Shaped Fuselage
Airplane Design: Shape and Configuration	Piaggio P-180 Avanti	Fuselage Lift, Canard, Stability, Cabin Noise, Pusher Prop
Airplane Design: Shape and Configuration	Grumman Goose and Widgeon	Amphibious Configuration, High Drag, Specific Role: Buisness,
Airplane Design: Shape and Configuration	C-5 Galaxy	Large Aircraft Stability and Manueverability, Anhedral
Airspeed Measurement	Piper Cub, F-4, X-15	Subsonic incompressible, Supersonic, Hypersonic Aircraft Examples
Climb Performance	F22 Raptor	Climb Performance, Supercruise, T/W
Elevator Control and Elevator Hinge Moment	P-38 Lightning	Elevator Effectiveness in High Speed Dives
Elliptical Lift Distribution	SuperMarine Spitfire and Republic P-47	Elliptical Planform
Expansion Wave Theory	X-43	Hypersonic aircraft, use of expansion waves
Finite Wing Effects	MiG17, Mirage III, Annular Wing Designs	Boundary Layer fences, Delta Wings, no tip vortices
Finite Wings	YB-49 flying wing and Gulfstream350	Finite, flying wing (relationship to B2),G-350 (winglets, tip vortices)
Flaps and high lift devices	YC-14, Kaman Kmax	Blown flaps as a high lift device, helicopter that uses flaps
General Lift Distribution	Boeing Family: 737, 747, 757, 767, 777, 787	All employ taper, sweep, twist, some have winglets
Gliding Flight & Ceilings	Glaser Dirks DG-808	High Performance Glider
Intro to Stability	Beech Starship, XB-70 Valkerie	Use of Canards, lifting vs. control canards
Normal Shock Wave Theory	Polaris, Trident missiles, NASA Enterprise	Shapes that induce a bow shockwave, comparison to normal shock
Oblique Shock Wave Theory	F-104, SR-71, Aerospatiale-BAC Concorde	Extremely thin wing with sharp leading edge; adjustable "spike"
Prandtl's Lifting-Line Theory	U2, Voyager, M2-F3 Lifting Body	High Aspect Ratio, low aspect ratio
Propulsion: Turbo – Jets, Fans, Props	Antonov AN70, Progressive D27 Prop Fan	Prop Fan Application is less common.
Range & Endurance	Global Flyer by Virgin Atlantic	Max Range Aircraft
Stability and Control	Eurofighter Typhoon, F22	Advanced Stability and Control Systems
Stability and Control	Grumman X-29	Forward Swept Wing, SAS
Stall Speed & High-Lift Devices	F16XL	Stall Speed in Fighter, Active Flow Control as High Lift Device
Standard Atmosphere	Helios, X-15	High Altitude Aircraft, aircraft that "could" fly on Mars
Static Stability – Tail	Beechcraft Bonanza	V-tail, "Doctor Killer", Ruddervator
Stick-Fixed vs. Stick-Free Static Stability	Pitts Special; Oracle Acrobatic Aircraft	Neutral Longitudinal Stability, Aerobatic aircraft
Structures	De Havilland Comet	Metal Fatigue, Complex Engine Inlets, 1st Commercial Airliner
Subsonic Compressible Flow	Convair 990, F-102 & F-106, NASA TF-8A	Anti-shock bodies, Area Rule, Supercritical airfoils
Subsonic Compressible Flow	Me262, F-86 Sabre, Airbus A380	Early swept wing designs, contrail formation
Takeoff & Landing Performance	Zen Air CH701, Antanov AN-72	STOL performance, Coanda Application
Thin Aifoil Theory, Symmetric Airfoils	Beechcraft King Air, F-16, UH-60	Use of symmetric airfoils on tail sections, tails vs. stabilitors
Thin Airfoil Theory	Gossamer Albatross, MIT Daedelus, F-104	Human-powered flight with efficient wings, very thin wing
Thin Airfoil Theory, Cambered Airfoil	Wright Flyer, Cessna Citation	Unusual camber, Natural Laminar Flow airfoil
Thin Airfoil Theory, Reflexed Airfoils	F/A-117, Eurocopter Tiger (EC665)	Flying winds and Helicopters commonly use reflexed airfoils
Thrust / Power Required & Available	B1 Lancer	Variable Wing Sweep, Supersonic Bomber, Large Gross Weight,
Turning Performance, the Pull-Up, & the Pull-	F22 Raptor	Thurst Vectoring, High G-Loading / Load Factor
Viscous Effects: Friction Drag	P-51, MAV, White Knight	Laminar Flow Wing, Low Re Number Aircraft, Low Pressure Drag
Viscous Effects: Pressure Drag	SPAD 13, Global Flyer	Pressure drag from Bi-plane wires, very low drag aircraft
Vortex Flow	Flettner's Baden Baden & Hummingbird	Lift from rotating cylinders