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The Role of Radio-Controlled Model Airplanes in the Education of Aerospace Engineers

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The Role of Radio-Controlled Model Airplanes in the Education of Aerospace Engineers

Abstract

Students enter our classrooms with a wide variety of backgrounds and experience. There was a time when students came into engineering with a tinkering background (hands-on experience and familiarity with the use of tools), but today's students spend more time experiencing the world virtually. In aerospace engineering, students who have spent time flying airplanes, radio-controlled models, and/or model rockets are able to relate concepts they learn in class to things they have seen or experienced first-hand. For example, a student who is a pilot and has experienced a stall seems to have more interest in boundary layers and flow separation because of their time in the cockpit. The experience gained in flying radio-controlled models provides a degree of intuition that helps students better understand, for example, the importance of properly sizing the tail of an airplane.

In an effort to provide more students with such practical and enriching experiences, aerospace engineering students at Penn State University have been provided the opportunity to fly radio-controlled airplanes in a special projects class. This class is unique in that students are generally enrolled in it from their first-year through graduation and normally take it every semester during their undergraduate programs. This paper describes the benefit of flying radio-controlled aircraft on improving the understanding of certain aerospace engineering concepts. In order to get a better insight into the impact of this activity, students responded to a survey to gauge how they perceived the use of the airplanes and to see how their thinking about aerodynamics changed. With an emphasis on hands-on and applied learning, students are able to make deeper connections between what is being taught and how it is applied in the world beyond the classroom.

Introduction

Engineering is based on complex principles and in many of our classes, theory takes precedent over practical applications.[1] Engineering classes, however, should help enable the application of knowledge so that students can "know" and "do." Students get to do and actively construct knowledge through problem-based learning,[2] inquiry-based learning,[3] or project-based learning.[4] No matter what the label or specific instructional strategies, these approaches all fall under the umbrella of "hands-on" learning and are described as student-centered.

Teaching methods that are student-centered promote student participation and active learning. The term "student-centered" is used to describe instruction that goes beyond a "teacher-centered" class where faculty talk and students listen.[5] When the focus is on learning, rather than teaching, the attention shifts to what students do and how they demonstrate their understanding. What teachers do, however, still matters for they are the ones creating the learning opportunities, but it is the students who are the concern of those faculty using student-centered teaching. If the intention is to produce deeper learning, there is evidence that 'learner activity' and 'interactions with others results in deeper learning.[6]

The shift to student-centered learning in engineering classes is happening for a variety of reasons, including "one of the problems has been that it takes students too long to get to the real-world stuff, the fun stuff."[7] It has even been suggested that something touched is more real than something seen.[8] Instructors in the sciences often espouse that active and physical manipulation is more effective when learning complex and abstract science concepts.[9] Additionally, manipulation when it involves intentional actions on the part of the learner can be motivating and increase attention to learning.[10]

In aerospace engineering classes, building and flying radio-controlled airplanes is one way to introduce active manipulation for learning about, for example, aerodynamics, flight mechanics, and structural design. The radio-controlled airplanes, however, are often only available to students through clubs or student competitions. This paper will describe an active learning class, the Flight Vehicle Design and Fabrication Class (known by students as the Sailplane Class), in which student hands-on learning includes flying radio-controlled airplanes.

Background

The Sailplane Class has been at Penn State University since the early 1990's and was originally sponsored with funding from the National Science Foundation through the Engineering Coalition of Schools for Excellence in Education and Leadership (ESCEL). This course is based loosely on the German Akademischen Fliegergruppen (abbreviated Akafliegs, which translates to "Academic Flying Groups"). Within Akafliegs, students work on the design and fabrication of sailplanes. By participating in these groups over the course of their study, Akaflieg members acquire many of the skills needed to be a successful engineer. Work within a group setting is a powerful stimulus to education and it was thought that incorporating a similar long-term "project-centered" class into the aerospace curriculum would be a step toward achieving desired attributes, as well as help the development of lifelong learning skills.[11-13]

A traditional practice of curriculum is to have a series of courses with their own objectives and assessments. The Sailplane Class, however, uses a spiral curriculum[14] that is iterative to allow for revisiting of topics throughout a single course and over the span of multiple semesters. This approach accomplishes more than repetition, for it promotes a deeper understanding of the content. Also, in this course, with its hands-on and evolving nature, students take it multiple semesters. Ideally they take the Sailplane Class for all of their undergraduate years. This class truly is a community of learners where the students are very connected to each other and the content.

The Sailplane Class encourages students to think deeply and to actively put their knowledge of theory into practice through the design and construction of a sailplane, along with other hands-on activities. With such an expansive multidisciplinary assignment of designing a full-scale sailplane, students are keenly motivated to learn about aerodynamics, structures, stability and control, and engineering design. Despite the scope of such projects, the outcome is carefully regulated by the nature of aircraft design, customer requirements, Federal Aviation Regulations (FAR's), and in some cases, design and/or flight competition rules. Just as in the workplace, teamwork is necessary to overcome obstacles in both design and fabrication and, in this case, the magnitude of the project requires application of a number of aerospace topics. Thus the course is horizontally integrated across the curriculum. Likewise, a unique aspect of the Sailplane Class is that it is also vertically integrated, with students entering as freshman and remaining through their senior years, allowing for students to interact across their experience levels. All are required to give presentations and reports to promote both peer and expert feedback of their efforts.

While the class focus is on the fabrication of a sailplane (or, for the past several years, on a human-powered airplane), two years ago radio-controlled airplanes were introduced into the program to augment student experiences.

Course Structure

Typically, the course enrollment is approximately thirty-five students. The objectives for the course are that students should, upon their completion of the course, be able to:

1.) Complete the preliminary design for an aircraft such that it satisfies assigned specifications
2.) Design a system, component, or process that meets given requirements in aircraft systems
3.) Identify, formulate, and solve engineering problems
4.) Function on multi-disciplinary teams
5.) Communicate and present effectively the results and consequences of their technical efforts
6.) Determine what the ethical responsibilities are to themselves, to employers, and to society

The course has a lecture component as well as the laboratory sessions. The purpose of the lecture portion of the class is to support the students' design and fabrication activities. As a result, lectures are non-traditional in many ways. For example, some lecture topics are requested by the students as needed rather than as determined by the instructor. Because the students are often stuck at a point in the design or fabrication process when they make a topic request, it is imperative that the necessary information is not only presented, but understood on such a level that the students can apply it directly to the problem they are working on. On occasion this need can result in covering topics more slowly and thoroughly than in a traditional class.

One challenge specific of lecturing to the Sailplane Class is the vertical integration. It can be difficult to present information in a way that is understandable to freshmen (having limited technical knowledge), while still maintaining the interest of seniors. The instructors of the class usually handle this mismatch in background knowledge by progressing from a short lecture (15-30 minutes) on the fundamentals to increasingly complex topics. In this way, the underclassmen can learn while the upperclassmen are mostly reviewing. Although underclassmen are sometimes unable to understand the complex details of a lecture at first, repeated exposure helps to solidify concepts covered in the Sailplane Class as well as in other courses across the curriculum. In general, lectures cover topics ranging from extremely technical material, such as aerodynamics, structures, stability and control, and engineering design, to management and interpersonal material such as team building, presentation and report writing skills, and engineering ethics.

To accomplish the course objectives, in addition to attending traditional lectures, students work in groups for the design and fabrication efforts. The individual group topics and how students are placed into the groups is initiated by the instructors and the class deciding on what groups are required to satisfy the on-going needs of the project. The instructor selects group leaders depending on student preferences and experience levels. The students are then permitted to choose in which group they want to work, with the instructors interfering only to keep the groups balanced in size and experience levels.

Radio-Controlled Airplanes

In former times, model airplane building and flying was often in the background of aerospace engineering students, but more recently, this background has been replaced by more "virtual" activities. Given that the model building experiences and flying seemed to be beneficial to aerospace students (both in and out formal instructional settings), an effort was recently undertaken to recapture some of these experiences by bringing radio-controlled airplanes into the class.

The idea is that radio-controlled airplanes enable students to connect the theoretical knowledge gained from their undergraduate studies with practical application. This connection between the class work and hands-on activity is particularly evident in the students' comprehension of aircraft flight mechanics. It has been demonstrated through this activity that students who have gained proficiency flying radio-controlled aircraft possess a better understanding of the basics of aircraft flight mechanics than their counterparts not having this experience.

Students gain a theoretical understanding of aircraft stability and control, as well as handling qualities, through the aerospace engineering curriculum. Yet it sometimes seems that it is unclear to them how this theory relates to real airplanes. Furthermore, by not seeing the application of this information, they are less retentive of what they have learned. To help increase their understanding, approximately a dozen ready-to-fly radio-controlled airplanes were acquired. In order to broaden the experience, five different types of models were selected to give the students a spectrum of flying qualities and behaviors.

The students in the class who wish to participate are given the opportunity to learn to fly these models with assistance of an experienced radio-control model airplane pilot. To avoid excessive model destruction and student frustration, this instruction is accompanied with the aid of a so-called "buddy-box." This box allows an instructor to teach students in a similar manner as in a "student driver" car. The instructor flips a switch giving the student control, but the instructor can retake control at any time to prevent a mishap. This capability makes it a very useful tool when teaching and all beginning pilots are put on the buddy-box for their first several flights.

The Airplanes

Six different types of radio-controlled airplanes are being flown by the students, with each being of a different skill level to pilot. The models, which are all commercially available, are described below.

The UMX Radian by E-flight.

The UMX Radian is a good beginner airplane because it is slow and has simple controls. It is also very small and light, which make it very forgiving, both in flight and in crashes. It is a good airplane to buddy-box, and also good for making a first solo flight.

The Radian by ParkZone.

The Radian, similar to the UMX Radian, is over twice the size and many times the weight. The controls are identical to the UMX Radian, but it has more power and thus can fly at higher speeds. Its weight makes it susceptible to major damage upon crashes. This is a good intermediate airplane that is good for buddy-box teaching.

The Ember by ParkZone.

The Ember is lightweight and does not have much power. It is good for the buddy-box and early solo flights, but does not provide much learning beyond the basics.

The Fun Cub by Multiplex Modelsport USA.

The Fun Cub is a very robust airplane. It has a large wing, which allows slow flight, but is powerful enough to experiment with maneuvers. It is good for teaching aileron control and can be used to teach intermediate pilot how to use flaps.

The Corsair by ParkZone.

The Corsair is a more challenging R/C airplane. It has a much higher wing loading than the other airplanes, resulting in a higher stall speed. This can make it difficult to fly, but it does help the student better understand why an airplane stalls and how to avoid it. This airplane is fairly maneuverable, but the student must take care to maintain control throughout the maneuvers. Crashes are not very forgiving.

The DG1000 by ST Model.

The DG1000 is difficult to fly. The small ailerons limit the roll rate. The high motor creates a large nose-down pitching moment that is not easily overcome due to the small elevator. To retract the motor, the student must understand how to use the tabs built into the transmitter and must be able to use the tab without losing the airplane. It is not for beginners.

Assessment of Student Experience

The students' abilities to identify the mechanics of certain flight maneuvers and also access how various aircraft design features impact its handling qualities was correlated to their overall experience with radio-controlled airplanes. A survey of this understanding was given after they flew the radio-controlled airplanes. The students responded to questions that allowed them to check their understanding of certain flight-mechanics issues. The instructors reviewed the responses and ranked the level of understanding. All of the 39 students (5 freshman, 11 sophomores, 9 juniors, and 14 seniors) in the class responded to the survey.

To determine a student's overall flying experience, a scale from zero to three was used with the following criterion:

0: No flight experience.
1: Requires the use of buddy-box, or has limited simulation experience.
2: Needs supervision, but can handle an airplane without a buddy-box. Also could have extensive simulation experience.
3: Able to handle any airplane without help.

These experience levels were then correlated to students' understanding of what is involved in the performance of various flight maneuvers. Based on the student responses, this understanding was scored by the instructors on a scale from zero to three using with the following:

0: No knowledge of flight maneuvers.
1: Basics understanding of how to control airspeed.
2. Has an understanding of airplane control and of how to make turns and change the airspeed, but lacks more detailed knowledge of the subject matter.
3. Has a thorough understanding of how to control an airplane and complete a coordinated turn and understands the physical mechanisms needed to change the airspeed.

In a similar way, the ability to assess the flight behavior of airplanes of different types was evaluated. The students were shown pictures of each airplane and asked to judge how each would fly. They were free to discuss stability, speed, necessary controls, weight, etc.

To judge the ability to assess the airplane differences, the instructors examined the responses given and gave each student a score from zero to three based on the level of understanding according to the following:

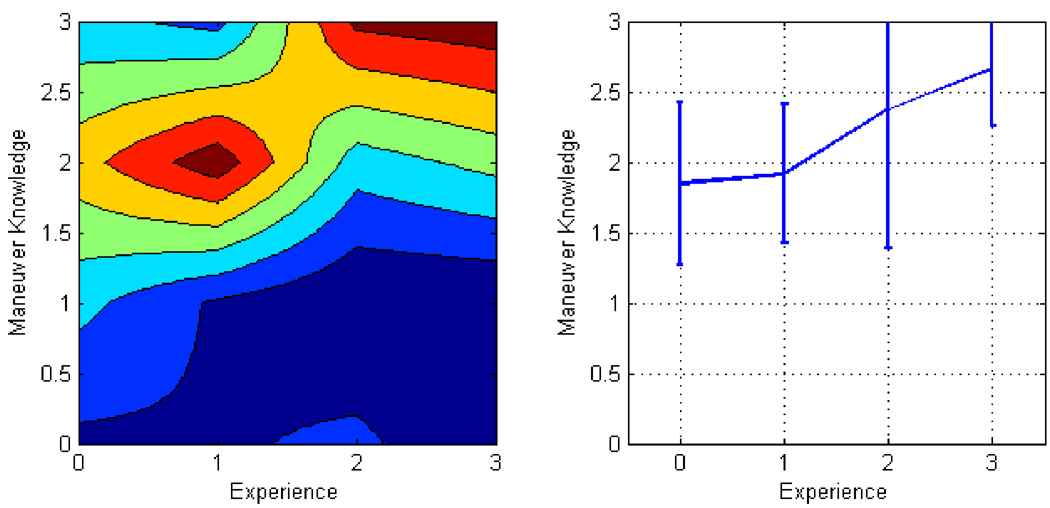
0: No idea of how the airplanes will perform.
1: Has some basic understanding of how the airplanes will performs, but does not distinguish the different flight characteristics of the different airplanes.
2: Possesses the ability to make distinctions in the different airplanes, but is missing some important details
3: Has a clear understanding of the relationship between airplane configuration and performance. Examples of this understanding being present are the relationship of wing loading and stall or top speed, how a high or low wing position affects the maneuverability, how wingspan affects the ability to roll the airplane, and how airplanes with different control surface are operated.

Assessment of the Survey Results

Upon review of the assessment surveys, several things became immediately clear. First, the students who received a score of 3.0 on the experience rating very often received scores of 3.0 for the maneuver knowledge and the airplane performance knowledge. Also, the students who scored low on flight experience likewise scored low in the other categories as well.

These relationships are summarized in the following figures.

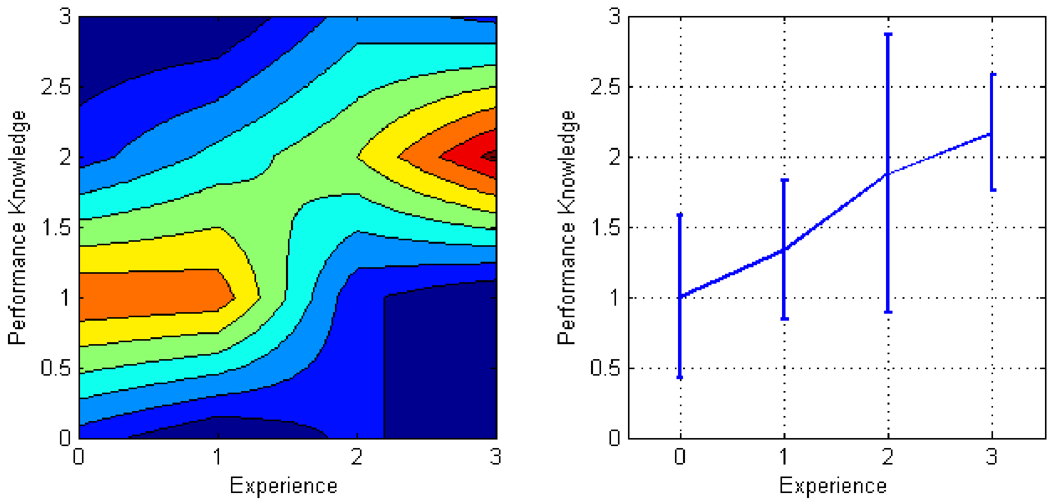
In the first figures, the effect of experience on maneuver knowledge is presented. In the left figure, red regions represent densely clustered data points (many points), blue regions represent sparse regions, and so forth. The right figure shows the average score for maneuver knowledge with one standard deviation above and below.



Maneuver Knowledge vs Experience

As can be observed in the above figures, a positive correlation exists between a student's experience and his/her knowledge of airplane maneuvers. By viewing the orange and red areas, which represent the dense regions of the data, one can see that there is a slight trend moving up and to the right. The same phenomenon can be observed in the right figure, where the average maneuver knowledge score increases with experience. A Spearman's rank-order correlation was run to determine the relationship between the students' knowledge of maneuvers and experience. There was a moderate positive correlation between the maneuver knowledge and experience, which was statistically significant ($r_s(37) = 0.38$, $p < 0.05$).

Next, the effect of experience on performance knowledge is considered. Again, the figure on the left shows dense regions of data points, while the figure on the right shows the average score for performance knowledge with one standard deviation above and below.



Performance Knowledge vs Experience

In the above figures of performance knowledge vs. experience, an even more pronounced trend than the preceding case is apparent. In these figures, it is clear that as experience is increased, so is the student's knowledge of airplane performance. This is observed in the left figure as the red, orange, yellow, and green regions shift up and to the right, and in the right figure with the increasing average score. A Spearman's rank-order correlation was run to determine the relationship between the students' knowledge of airplane performance and experience. There was a strong positive correlation between the performance knowledge and experience, which was statistically significant ($r_s(37) = 0.60$, $p < 0.05$).

The results are not surprising and support the benefit of this type of hands-on instruction. It is interesting to note that the students without flight experience only have an average rating of 1.75 on maneuver knowledge and a 1.0 on airplane performance whereas students with the highest level of flight experience in the class achieve a 2.75 on maneuver knowledge and a 2.25 on how the airplane performance is affected by configuration. Clearly, there is a strong indication that the more one flies radio-controlled airplanes, the greater one's understanding of certain flight-mechanics concepts.

Conclusions

The idea is that radio-controlled airplanes enable students to better connect the theoretical knowledge gained from their undergraduate studies with practical experience. This connection between the class work and the hands-on experience with flying models is particularly evident in the students' comprehension of aircraft flight mechanics. It has been demonstrated that students who gained flight proficiency of flight radio-controlled aircraft possess a better understanding of the basics of aircraft flight than those without this experience.

In lab classes and even in the Sailplane Lab, many students are unable to make the correlation of a good idea on paper to something that would actually perform as intended. With the experience of flying radio-controlled airplanes, this is less common; the students are not only able to generate new ideas, but they can implement them and anticipate the outcomes.

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