AC 2007-1054: TEACHING FREE-HAND DRAWING IN AEROSPACE ENGINEERING

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Teaching Free-Hand Drawing In Aerospace Engineering

Abstract

Computer-aided-design classes have largely replaced those dealing with engineering drafting, resulting in an often heard criticism by today's faculty that engineering students are no longer able to express themselves using simple free-hand drawings (sketches). While engineering students are expected to become proficient with modeling packages, they are seldom asked to think visually and communicate visual ideas with art-based freehand drawing. With the right instructor and short weekly exercises, however, the ability to sketch in engineering classes need not be lost. Likewise, free-hand drawing techniques can help students to develop and refine their visualization skills.

In an undergraduate aerospace engineering design class, the professor advocates the use of an art-based approach to help students think at deeper and more creative levels. By his modeling the drawing of airplanes throughout the semester, he talks through essential design components and tries to get the students to focus on seeing and visualizing. In this paper, we will describe the instructional processes he uses, the reasoning behind his approach, student drawing examples (to illustrate abilities at the beginning and end of the semester), student feedback on the drawing process and their perceptions on how it influences their learning, and suggestions on how to implement free-hand drawing techniques into your classes.

Introduction

Many faculty voice concerns that students are no longer able to sketch or effectively convey their ideas graphically. In aerospace engineering, students' depictions of aircraft and spacecraft lack detail and sophistication, revealing sketching skills at elementary levels. Yet competent engineers need to be equipped with proficient basic drawing and visualization skills.

As an engineering professor, it was painfully obvious to me that students lacked free hand drawing skills and that these skills are needed for improving their visualization and spatial orientation. Approximately ten years ago, I was tired of hearing "we can't do this" from my students, and I figured the primary reason that they lacked these skills was simply that no one had ever shown them basic drawing procedures. Since then, I have attempted to do this and have seen dramatic results that followed when sketching is taught just fifteen minutes or so weekly during the course of a semester. Initially, the goal of this effort was simply to provide students with a skill to help them understand their ideas and present them to others.

After years of intuitively teaching free hand drawing skills, I began to explore this issue further. Some research shows that creativity is almost entirely a rightbrained activity[1] and that engineering as taught is largely a left-brained activity. More accurate, however, is that the hemispheres work together for almost every task.[2] While each side does possess specialties, they are not neatly delineated sides for either logic or creativity.

I began to wonder if students' lack of expressing themselves with free-hand drawings prevents accessing thinking that is nonverbal, intuitive, and works with patterns or pictures. Furthermore, despite the many developments in computer-aided design, it is still difficult when working at conceptual stages to sketch basic ideas. Although technology is being used in place of pencil and paper, current research on cognition and the impact of technology on thinking and learning is exploring how interfacing with a keyboard and not a hand-held device like a stylus or pencil is influencing thinking. [3] Keyboards drive productivity, but not necessarily creativity. If the creative visual processing is only done through a computer, then are engineering students limiting their thinking capacity and staying restricted to thinking that is mostly verbal and rational?

At this stage in my career, I've been in the classroom close to a quarter century and I wonder if the newer professors, who have mostly learned with technology, lack basic drawing skills. For the most part, drafting and sketching skills have been replaced by computer-aided drawing and three-dimensional (3D) modeling. Considerable effort has been made for technology to reconstruct 3D information to a two-dimensional (2D) source[4] and there are artistic conventions on how 3D can be represented in 2D. Yet there is still substantial instructional merit for the formal process of decomposing a 3D object into side-, top-, and front views. In doing so, students are given the ability to spatially understand and visualize an object.

The types of drawing most of the engineering students do in my classes reflect cognitive processes needed for the bare mechanics of drawing. That is, many of their drawings are reproductions of existing aircraft, not generally a creative expression. "Perhaps the most important feature of a creative act is that it comes from within ourselves, rather than being a routine response to something in the outside world." [5] Thus the type of drawing the engineering students are attempting can be taught with rudimentary drawing skills in order to help them to think visually and communicate visual ideas.

The Process

The drawing exercises were generally undertaken during our capstone aircraft design course. This two-semester sequence is taken by seniors, who have the choice of an aircraft or a spacecraft design sequence. Students are initially asked to sketch any aircraft of their choosing. This drawing provides a baseline for both them and the professor. Next the students hear about the benefits of being able to sketch and what will be expected of them during this ungraded component of the course.

At this point, five to six exercises are begun. After the first two exercises, which deal with aircraft components, the aircraft that is to be sketched is projected for the students or given to them via a hard-copy. In all cases, the instructor then demonstrates in some detail how they go about sketching the figure. The students are then asked to practice sketching the figure over the next week or so, often after which time, they are asked to reproduce it in class. These figures are then collected, critiqued, and returned to the students. In some cases, usually with the first or second exercise, the students are asked to "try again," and the procedure is repeated.

It is somewhat typical at this stage of the process that many of the drawings will be too small. The students need to be told that their drawings should, without encroaching too much on the margins of the paper, fill the space available. Likewise, they should be told of the "golden dimensions," that is, information should be presented in blocks that are roughly proportional to three by five. These assignments are to be critiqued carefully since the feedback given at this stage should ideally bolster students to actively think visually and to be willing to sketch. If feedback is too negative, students may be demoralized since many seem to have some difficulty with the seemingly simple task of basic sketching. If the feedback, however, is all positive then it is not helpful and the students do not receive explicit guidance on how to improve. While the exercises can certainly vary a great deal and accomplish the same results, a typical set is outlined below.

Exercise 1: Sketching an Airfoil

Different types of airfoil are briefly described and sketched. These include a classical NACA (NACA 4415, for example) four-digit section, a laminar flow airfoil (NACA 63-415, Wortmann FX 67-150, etc.), a supercritical airfoil (Whitcomb), and a thin supersonic section (NACA 66-009). The steps are then described as to how, for example, the laminar-flow airfoil is sketched. The students are told that the section has a thickness ratio of approximately 15-percent. Thus, a reference line is drawn that is about six or seven times longer than the maximum thickness. The thickness construction line is located near the mid-chord point, with roughly two-thirds of it above and one-third below the horizontal reference line, as shown in Figure 1. Next the upper surface contour is basically a circular arc. It is begun slightly above and behind the leading point to allow room for the leading edge. Then, after forming the small leading edge radius, the lower surface is sketched as shown. It should be emphasized that, with practice, the lines should "flow" quickly from the right-side of the brain; not pain-stakingly drawn by mentally connecting a number of virtual coordinates that exist in ones mind.

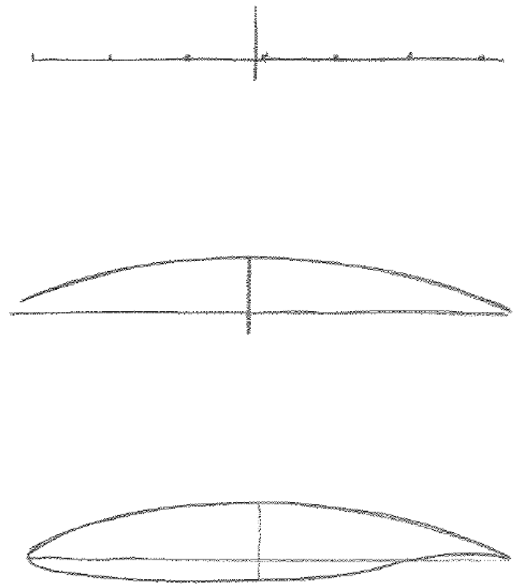


Figure 1 The Steps for Drawing an Airfoil.

Exercise 2: The Layout and Sketch of the Top and Perspective View of a Wing

Again, the sketching procedure is demonstrated for the students, beginning with the spanwise layout line, as shown in Figure 2, the vertical lines defining the midchord and the tips are positioned. The accompanying discussion should note how the relationships of these lines produces taper, sweep, the shape of the leading and trailing edges, and so forth. Multiply-tapered wings can also be described. The lending and trailing edges are then drawn, and finally the ailerons and flaps. It should be noted that the ends of the ailerons and flaps are aligned with the flow, not perpendicular to the trailing edge. Rounded wing tips can be added as well. While it would greatly simplify the exercise to use a ruler and straight edge, intuitively, it seems better to use finger-spacings, etc. for layout, and to not allow straight edges in order to help develop free-hand skills. Finally, with essentially the same procedure used for sketching the top view, a perspective view is sketched.

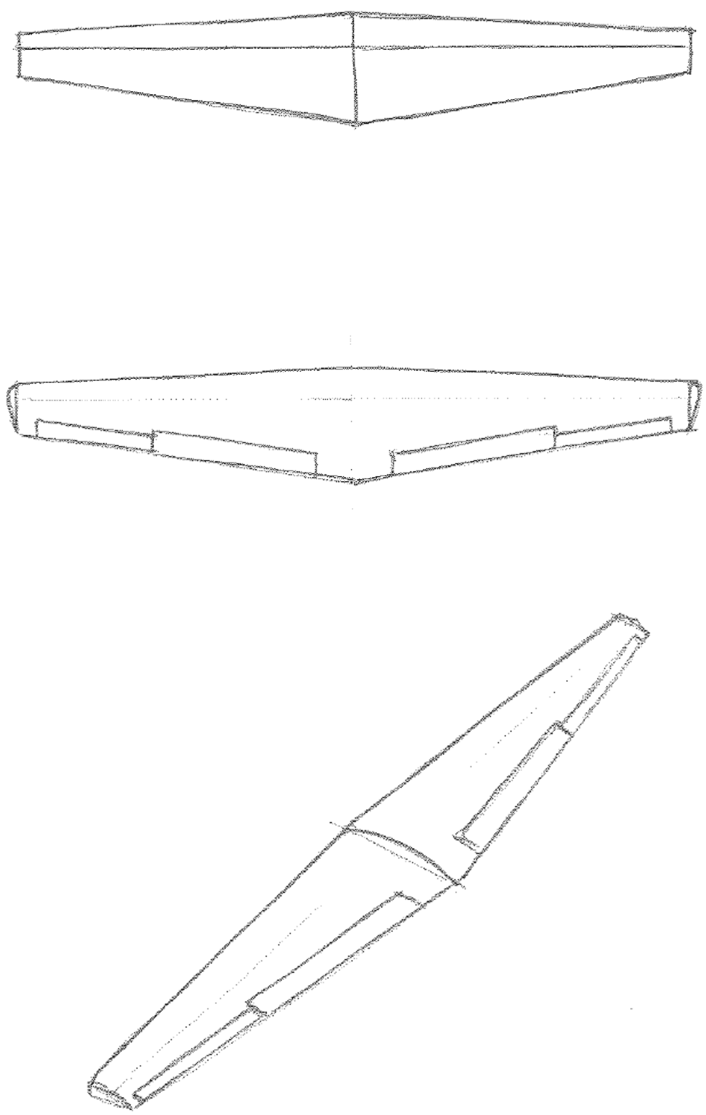


Figure 2 The drawing of a wing.

Exercise 3: Sketching the Side-View of a Fokker Dr 1 Triplane

In this exercise, the emphasis is on the relationship between the sizes and shapes of the various elements that make up the side view. The "target" of the exercise is shown at the top of Figure 3. The length, width, and lengthwise location of the maximum width are laid out as they were in the previous two exercises. Note that the side-view of the wings form a parallelogram. It should be explained that these relationships are what make the object drawing identifiable. Having each component accurately drawn, but done so with vastly different scales, will not result in a recognizable drawing; however, having these relationships done accuracy, even if each individual component is not exact, will.

To establish proper size relationships between the various elements of the drawing, the side view is "roughed out" as shown in the middle of the figure. Once this is done, the proper "lines" are drawn through the roughed out ones to arrive at the final ones. As this point, the construction lines can be erased and details, such as wing struts, bracing wires, and markings can be added to the sketch as desired, as shown at the bottom if Figure 3.

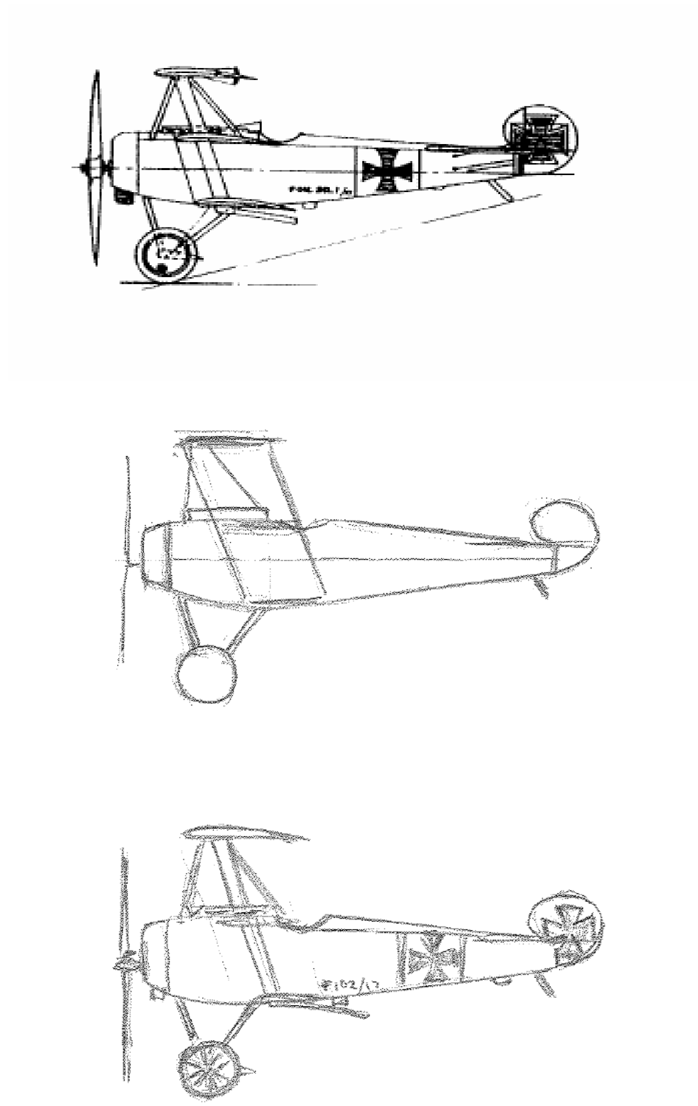


Figure 3 Side view of the Fokker Dr-1 Triplane.

Exercise 4: Another Side-View

The lessons of the previous exercise are reviewed, and then another side-view is undertaken. This time, to "balance" the old timer of exercise 3, a more modern aircraft is used , such as the Lockheed F-22 Raptor, the target of which is shown in Figure 4, while a student rendition of this target is presented in Figure 5. Of course, if there is strong student interest toward any particular aircraft, it could be used just as well.

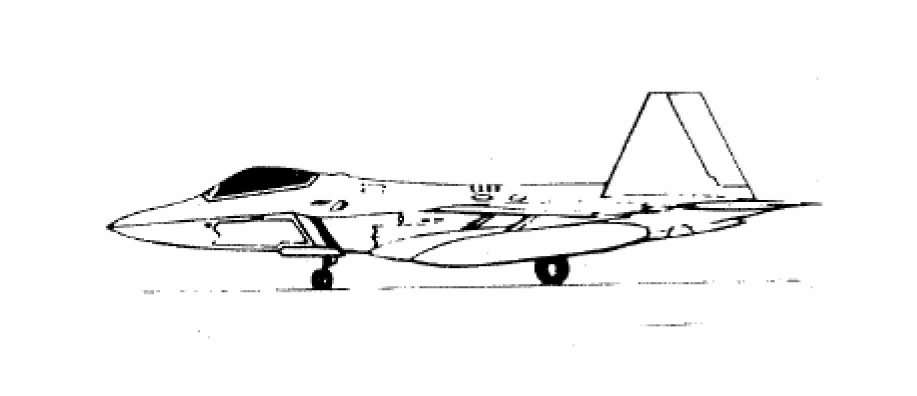


Figure 4 Side view of the Lockheed F-22 Rapture.

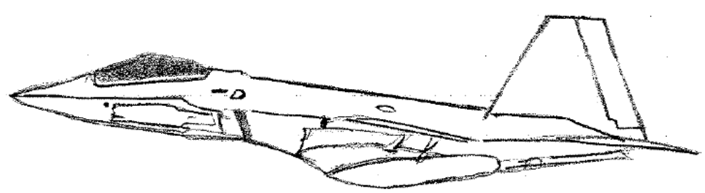


Figure 5 Example of a student rendition of F-22 Rapture.

Exercise 5: A Perspective View of an Entire Aircraft

At this point, the primary lessons of "drawing what one sees" have been presented and what remains is a perspective view of an entire aircraft. It can be fun and motivational if the target for this sketch, usually a photograph, is the consensus of the class. Typical target selections are shown in Figures 6, 8, and 10. The students are then shown how to depict the aircraft with layout lines, as already discussed. It should be noted that the procedures used in the previous exercises all apply. And, as before, once the basic relationships and views have been roughed out, the final lines are drawn through them and the constructional lines erased. Representative examples of student depictions that correspond to these targets are presented in Figure 7, 9, and 11.

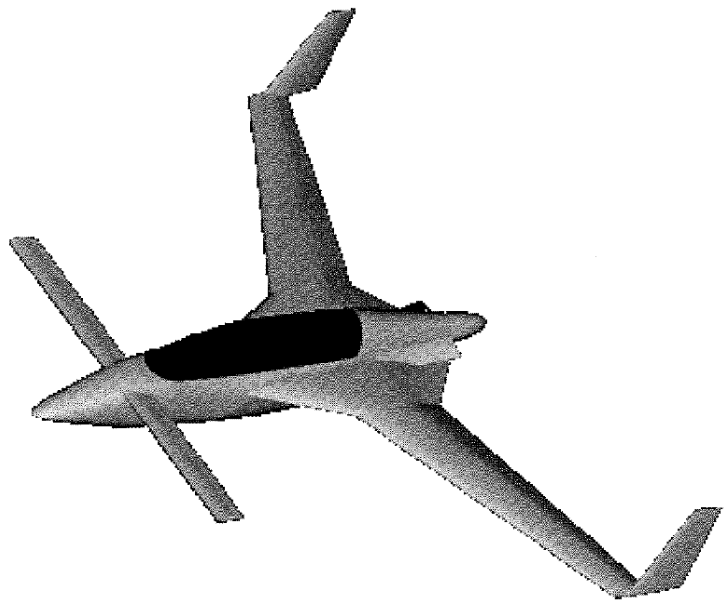


Figure 6 Target perspective view of Rutan VariEze aircraft

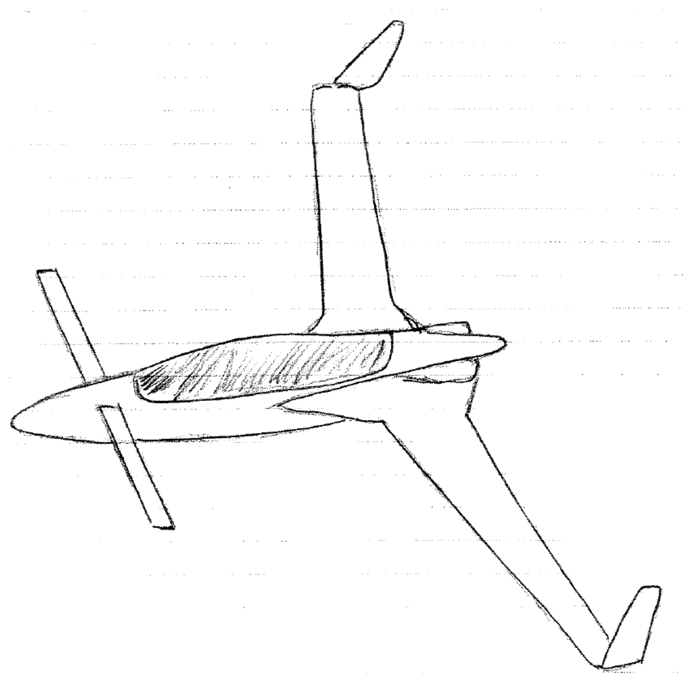


Figure 7 Example of a student rendition of the VariEze.

Figure 8 Target perspective view for Maverick Air TwinJet.

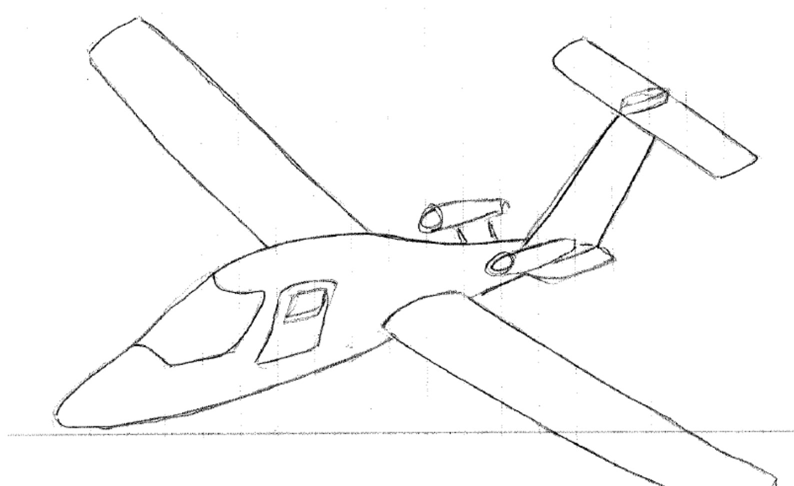


Figure 9 Example of a student rendition of Maverick Air TwinJet.

Figure 10 Target perspective view of the Bell X-1.

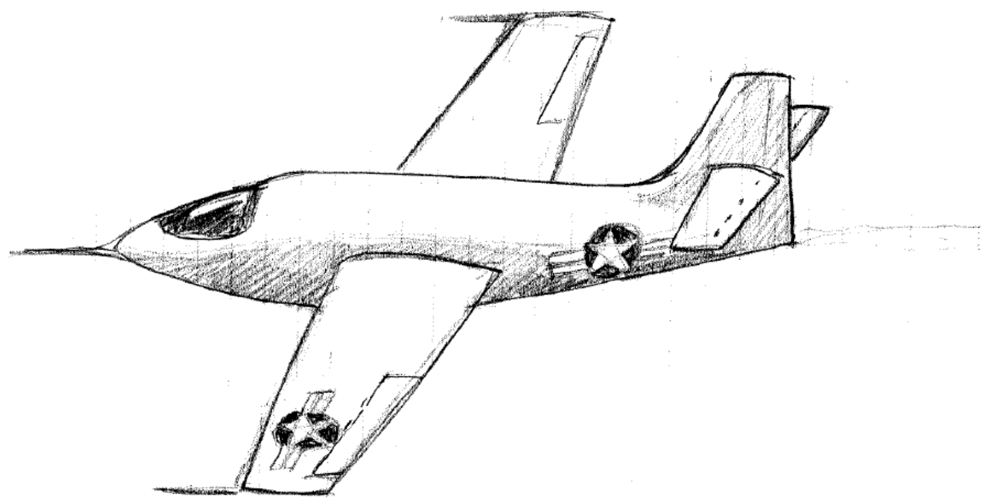
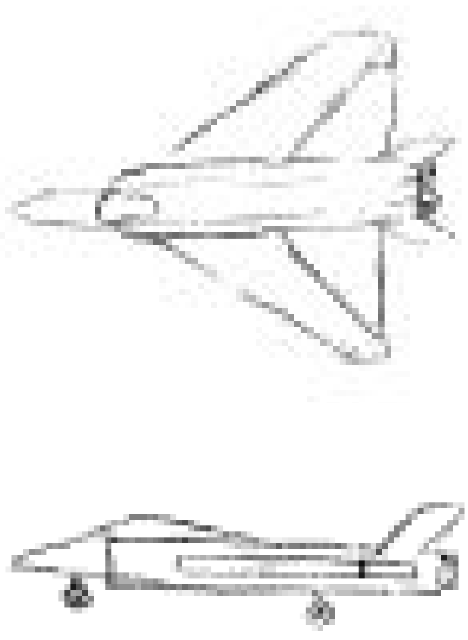
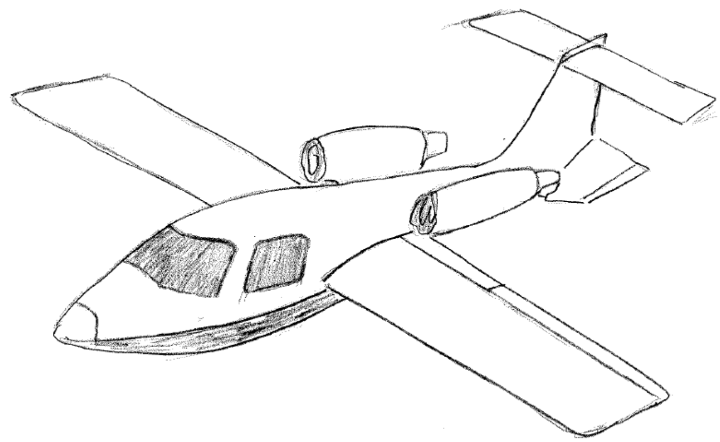


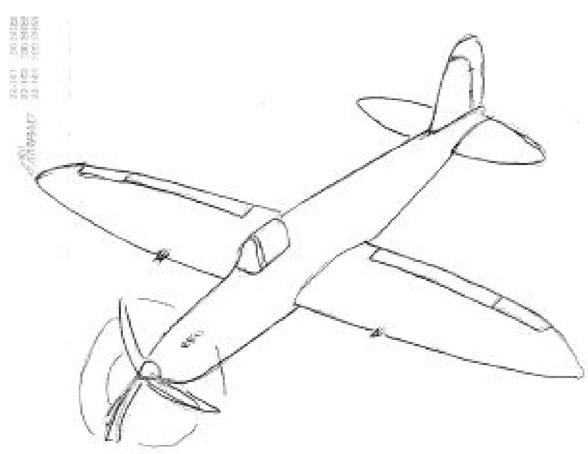
Figure 11 Example of a student rendition of the Bell X-1.

Exercise 6: Pulling It All Together

Each student selects any aircraft, and is then asked to sketch a three view (side, top, and front views) and a perspective view. In essence, it is a repeat of the initial baseline drawing, although the aircraft chosen may or may not be the same one that is selected originally. Four examples of "before and after (or later)" sketches are presented in Figure 12. On the left side of the figure are a student's initial drawing, while on the right are the same student's final (or later) drawing. The examples shown are not selected for any particular reason, other than they demonstrate different initial skill levels. In each case, however, the improvement in free-hand sketching skill appears quite evident.







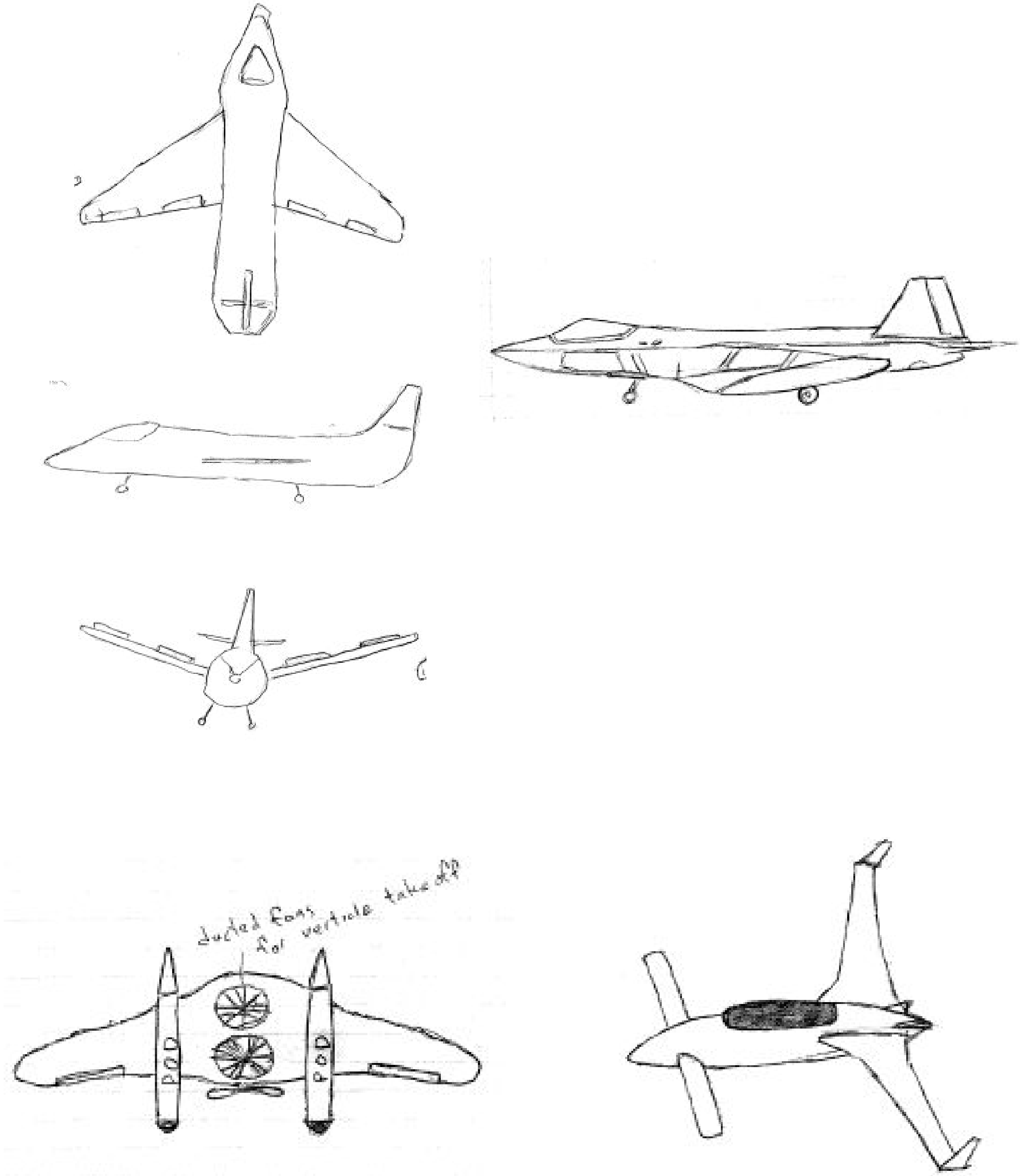


Figure 12 Examples of student baseline and final drawings.

Assessment

As it is not possible to present the initial and final drawings of every student, an attempt is made at giving a quantitative assessment of the impact of sketching activity by ranking to each of these drawings, and then averaging the before and after results. To do this, each student's baseline and final drawings were ranked on a scale of 1 to 10 by five unbiased aerospace engineers who were all provided guidelines with examples for making their evaluations. It was emphasized that it is the drawing that is to be evaluated, not the airplane, although the intention is that the student be able to sketch a realistic depiction of any real or hypothetical aircraft. An abridged summary of the guidelines with an appropriate score is as follows:

1. An attempt is made, but the result is only recognizable as an aircraft. The drawing is very elementary.

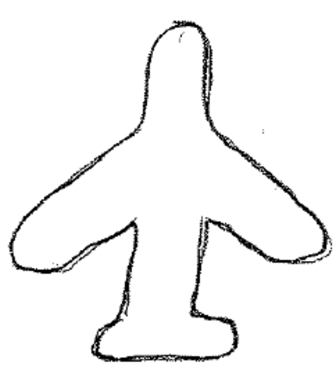
3. The major components of the aircraft are all portrayed, but lack reasonable proportion. The aircraft is somewhat streamlined, but the drawing is marginal.

5. The sketch is easily identifiable as an airplane. The major components are depicted and are roughly proportional to one another. The details of a good sketch become more important, such as line weight, intended straight lines are straight, and so forth.

7. The proportions of the major components look correct, and the depiction of the aircraft is good. Some improvement remains possible in the depiction of details, as well as with the mechanics of creating a quality drawing.

10. The proportions and details are correctly portrayed. There is like some artistry being demonstrated. Little or nothing could be done to improve this sketch.

Examples of the expected application of these rankings are presented in Figures 13-15.



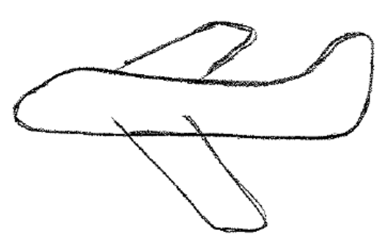


Figure 13 Example of a student drawing ranked as 1-2.

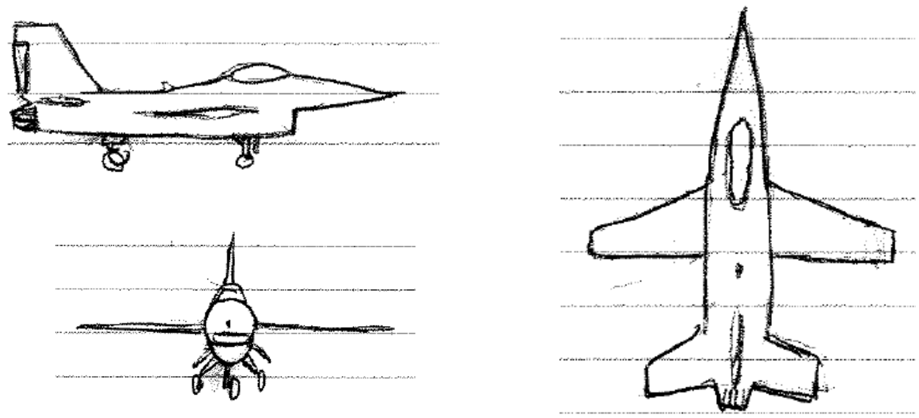


Figure 14 Example of a student drawing ranked as 5.

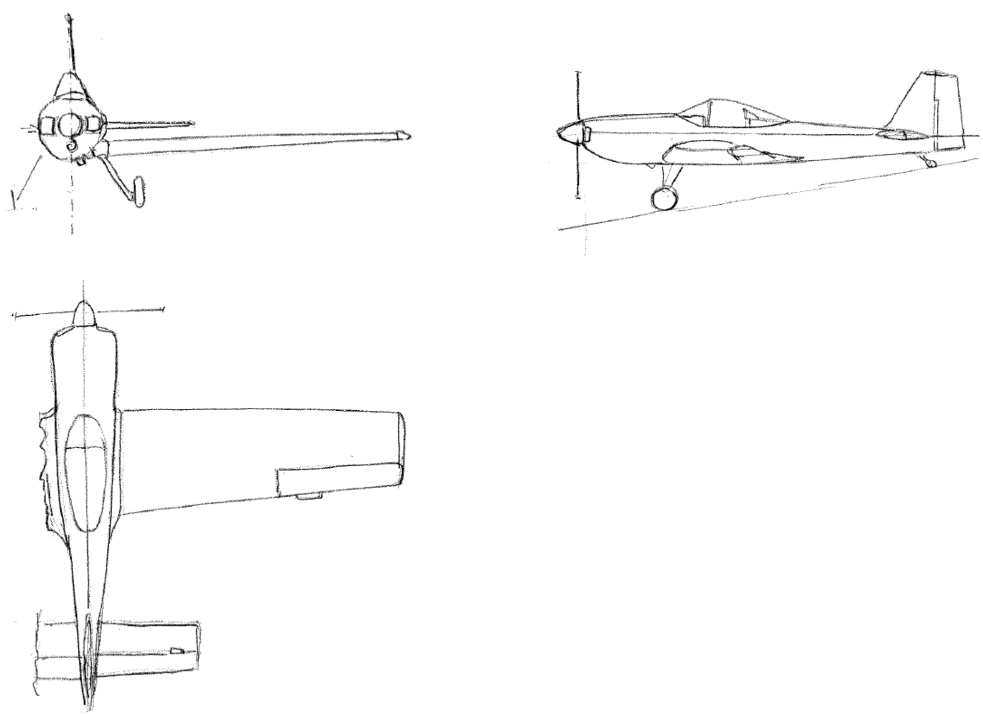


Figure 15 Example of a student drawing ranked as 10.

Using these guidelines, a combined total of 328 initial and final drawings were evaluated. The average of the rankings given to the baseline drawings by the evaluators was 3.8, while the final sketches received an average ranking of 8.0. While the actual improvement is better appreciated by actually viewing the before and after sketches, as is the case with the drawings presented in Figure 12, the quantitative result remains fairly dramatic, especially when considering how really little effort is spent in accomplishing it.

Discussion

Teaching drawing to engineering students has certainly improved the students' ability to draw, although further data is needed to ascertain what variables influence not only the students' ability, but their interest in sketching. As a preliminary attempt, last semester we assessed if students' prior drawing experience (or lack thereof) influenced their ability to draw and whether or not students perceived any instructional benefits to their hand sketching in engineering. To ascertain the benefits of sketching, a short survey was given to the students before the drawing exercises began in the fall semester of 2006. Of the 28 students who took the class, they represent a range of years in school from freshman (29%), sophomore (32%), junior (14%), to senior (25%) with 8 of the 28 female. All of the upper division students had taken an engineering drawing class while only one freshman and three sophomores had done so. Most of the students, however, had taken art or drawing classes in secondary school with one who took sculpture and two who had taken crafts classes.

Students were asked to give scaled responses to three questions. The first question asked them to rank (using a 1 "not important" to 5 "very important" scale) how important they think hand sketching is in the engineering profession. From their responses, it is clear that students think that drawing is a relevant engineering task because 57% rated it is as very important, 39% as important, and 4% were undecided. The second question had them rate their ability to draw. The majority of the students felt their ability is average and only 4% believe they have excellent drawing skills. When asked how many times sketching or drawing had been discussed in their engineering classes, half of the students circled never and the other half circled occasionally.

Students were asked to identify any benefits to being able to hand sketch in engineering. Their replies were similar in that they found it would help them communicate their ideas. One student wrote that sketching is, "faster, sometimes more accurate, easier to understand" and another agreed that "you can quickly get a point across." Three of the students noted that sketching gives "less confusion" and one stated "with sketching you are able to be universally understood." Several of the students mentioned that it is a benefit to get your ideas across without computers and as one put it, "computers can't do everything."

From this preliminary survey, it appears that students value hand sketching, but lack many opportunities to either learn or practice this skill in their engineering education. As seen in this class, when given guidance and time to practice, students do improve in their ability to sketch.

To be able to teach hand sketching, professors must be comfortable themselves with drawing skills. Given that many of the engineering professorate are not, departments will need to identify who has drawing ability and who is willing to teach it. There are resources in the popular press, such as Drawing on the Right Side of Your Brain[1] (reported to be the most widely used drawing instruction book) that can be helpful to those teaching drawing. The author of this book contends that drawing is made up of component skills. Once you've learned the components and integrate them, you can draw. Accordingly, these skills are not drawing skills, but perceptual skills:

1. The perception of edges
2. The perception of spaces
3. The perception of relationships
4. The perception of lights and shadows
5. The perception of the whole, or gestalt [6]

Given that perceptual skills are essential to engineering thinking, teaching these skills to students should not be too formidable of a task for those who are comfortable with their own drawing abilities. Drawing does require practice and both faculty and students will need to recognize that it takes time and effort to hand sketch.

Conclusion

Teaching engineering students to hand sketch has instructional benefits. Students demonstrated improved visualization and freehand drawing skills as well as exhibiting enthusiasm for the process of drawing. They were able to make the connection between the ability to hand sketch and its influence on their engineering future. The teaching of hand sketching does require some basic drawing skills, but with some training and practice, professors can help students to think visually and to communicate ideas.

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