Freehand Sketching in the Curricula – A View From the Outside

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ABSTRACT *- Everyone has heard of "back of the envelope" sketches used by engineers. Engineers and designers who have to be at a computer to try to graphically communicate their ideas are at a distinct disadvantage to those who can make quick, clear freehand concept sketches on the spot. Industry moves fast, and ideas are often born in brainstorming or other similar type sessions. This means that someone must be able to quickly communicate their ideas, often in the form of a sketch. Unfortunately this skill is disappearing as more and more engineering graphics courses are dropping the emphasis on sketching and replacing it with 3D modeling, visualization and CAD skills development. This is not meant to minimize those skills as they are all very important. However, in order to fit everything into existing courses it is often necessary to eliminate other things such as freehand sketching.*

This paper discusses the importance of sketching in the engineering design process and the role sketching plays in a modern graphics curricula. The authors' experiences as a customer of students who have completed their graphics courses and need to apply their knowledge in a design situation is also discussed. These are students working on senior design projects or undergraduate research projects. While these students have a lot of skill in creating 3D models, they tend to lack the ability to communicate their ideas through simple concept sketches. This general lack of sketching skill tends to spill over to other areas such as creating diagrams for problems in various courses and manual plotting of data. The paper takes a look at how a few schools have worked to improve their students sketching skills.

I. Introduction

An important skill that is required of engineers is the ability to communicate ideas. This is particularly critical in the early stages of the design process. As McCormick (2007) points out, designs have inertia and resist major change once they are past the initial sketch stages. New ideas are most easily incorporated in the early going, therefore it is critical that an engineer be able to communicate his/her idea at that point or risk having it set aside. One way to effectively communicate a concept is through a sketch.

Experienced engineers use sketches for many purposes including exploring ideas, communicating ideas, visualizing how things fit together and as an overall thinking tool (Welch, et al 2000). While engineers tend to develop these skills over time, Welch also points out in an earlier paper that newly graduated engineers tend to jump directly to three-dimensional modeling (Welch, 1998). This seems to match with the authors' own experiences while dealing with students on various design projects. They are much more comfortable sitting in front of a computer creating three-dimensional models than they are making concept

sketches. Perhaps this is due to the content of their graphics courses.

This paper takes a look at the importance of sketching, the general lack of this ability in many engineering students and what some schools have done to try to correct this problem.

II. Importance of Sketching

Tipping (1993) states that "the single most important factor in developing any general design ability" is the ability to create good sketches. What is a sketch? For the purposes of this paper a sketch is an informal drawing made either freehand or with the aid of simple tools such as circle templates or rulers. Figure 1 shows a couple of simple instruments that have often been used by the author for making sketches. They might be two-dimensional or three-dimensional. They might follow a formal format or simply be pictorial. In general it is important to be able to produce sketches fairly quickly and reasonably to scale.

Figure 1. Sketching Tools

An engineering student has an additional use for sketches early in his/her academic career. Almost all engineering calculations need sketches to define a system, label variables, etc. For example, free-body diagrams are needed for most statics problems. It is my experience that many students do not focus on the diagrams, resulting in poor quality work. As they progress through school they are asked to make sketches for other purposes such as communication of ideas for various design projects. If they fall into bad habits early they tend to continue those habits, resulting in more poor quality work. The importance of sketching must be stressed early and often to get them onto the right track.

As practicing engineers after graduation the importance of sketching increases dramatically. Experienced engineers can use sketches to serve many functions. Ullman, etal. (1990) have categorized sketches by function – thinking, prescriptive, talking and storing. All of these play important roles in not only the design process, but also in the ability of the engineer to have a successful career.

Thinking sketches are used to assist in the formulation of ideas. These are often quick, "back of the napkin" pictorial sketches. An engineer might use these to organize his/her thoughts during the early stage of the design, or they might be used to communicate ideas during a brainstorming session. This is a critical point in the overall process. One, or several promising ideas are likely to be selected for further work during a brainstorming session. Engineers who can successfully communicate their ideas have a better chance of having them accepted. Quick, quality sketches provide one of the best vehicles for accomplishing this.

It is important to recognize that sketching is not just a communications tool, but that it actually aids in the thinking process during the development of an idea. It helps the designer to visualize the concept and provides an easy way to make early changes in the design. Radcliffe and Lee (1990) describe this as a form of communication with oneself.

Prescriptive sketches serve as an outline for the design process. These sketches are probably more

thoroughly thought out than thinking sketches. They show ideas in a more formal way, and help keep the designer on track.

Talking sketches aid in team discussions. Once a design or concept is being seriously considered there are generally several meetings among all the parties involved to help define the path to be taken. Sketches of this type are helpful to keep a team focused and not go off on tangents. They can be fairly quick to make, and provide a means to communicate possible alternatives or design changes.

Storing sketches are final sketches used to file ideas. These might include various concepts that were considered, notes on changes, pros and cons of various concepts, etc. It should be remembered that while this type of sketch provides a final or close to final concept, all documents, including the very early sketches should be kept on file for future reference.

So, how important is sketching? In one study Schutze, etal (2003) found that design teams that incorporated sketches as part of the design process produced significantly better solutions than teams who did not. Kivett (1998) lists three reasons that sketching is an important part of the success of the early stages of the design process:

- Almost instantaneous communications
- Small amount of time required to make the sketches
- Changes can be easily made before moving too far along.

Sketching can be used as a thinking tool, for visualization and for communication purposes, making it critical in the design process.

III. Student Abilities

Students seem to be much more comfortable behind a computer screen making three dimensional models than sketching their concepts using pencil and paper. Figure 2 shows a sketch by a student working on a senior design project who was trying to communicate an idea for a slider mechanism. It is very difficult, if not impossible, to figure out what this student had in mind. A sketch like this should stand on its own without the need for a lot of explanation. Obviously this one does not.

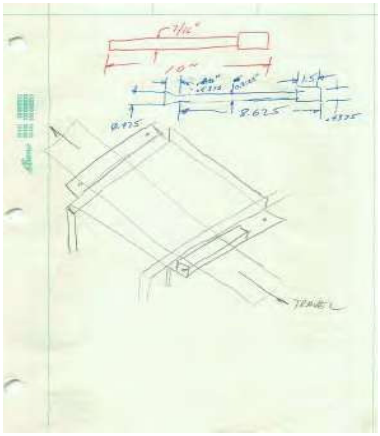

Figure 2. Student concept sketch

Figure 3 is a sketch by a student who was asked to make a three dimensional sketch of a solar powered car used for K-12 activities.

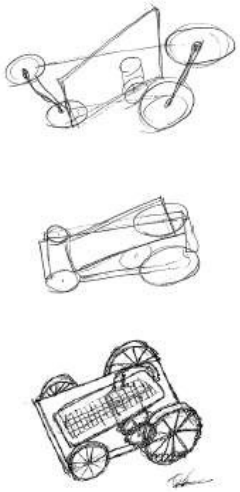

Figure 3. Progression of sketches

The figure shows a progression of sketches made by the same student as more time was given to complete the task. As you can see, the first sketch is not particularly good. Ultimately the student was able to produce a good sketch showing the part. The goal should be to be able to produce sketches at least as good as the second one on the first try in a short period of time.

This lack of skill in making free-hand sketches carries over to other areas. For example, in statics students very often cannot create quality free-body diagrams, especially in three dimensions. Even something as simple as plotting a set of data manually is very difficult for many students. Students are so use to using a spreadsheet or a calculator to make plots that they have a very difficult time when asked to do it manually. Edwards (2009) includes this lack of manual plotting skills as a general aptitude weakness for students trying to complete a fluid mechanics laboratory worksheet.

There are exceptions. Figure 4 shows a sketch made by a student working on a senior design project. While it is not three dimensional, it is neat, very well laid out and readily communicates the concept. This sketch allowed the student to easily make some suggested changes and go on to model the parts in CAD. An interesting side note is that this was done by and older, non-traditional student. The sketching skills may have been learned much earlier in industry rather than as the result of graphics instruction.

The sketch is on of the best student sketches the author has seen, and is certainly not typical. A more typical scenario encountered by the author while advising on senior projects is for the students to respond to a request for a sketch of a concept by saying that they will go model the idea and return later. They can usually get away with this in school but not in industry.

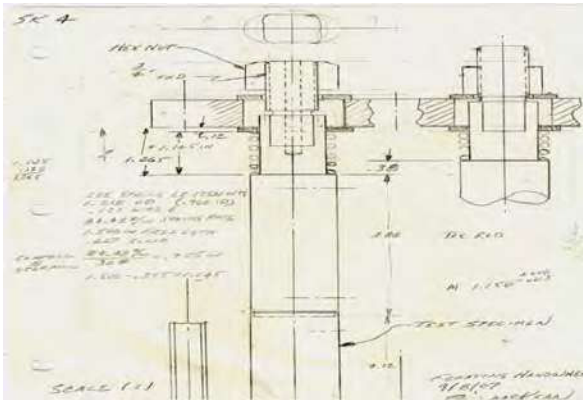

Figure 4. Sketch of a heat conduction device

IV. Improving Student Sketching Abilities

Sketching and manual drafting methods used to be a key part of an engineering graphics course. Modern courses tend to set aside the manual work in favor of including more CAD modeling. Certainly manual drafting using t-squares and triangles is all but obsolete, but many schools still include a scaled back sketching component. Much of the manual work focuses on three particular areas: three view orthographic projections, dimensioning and isometric sketches. The first two are included to teach the basic rules for making engineering drawings. The third is included primarily for visualization purposes. Concept sketches need to be more pictorial or artistic. Some schools are starting to incorporate sketching courses as part of the curriculum. Many of these focus on artistic sketching instead of engineering drawings.

Land, Seery, and Gordon (2009) describe an approach to teaching graphics at the University of Limerick which focuses on concepts. Through a seris of exercises students developed their abilities to communicate through sketches. The students' self described abilities prior to the exercises range from good to poor. In general, the students ability to communicate concepts through sketches were improved.

Watkins (2005) surveyed a group of both two and four year engineering technology programs. Part of the survey involved the role of manual sketching in the modern graphics curriculum. 52% of the respondents said that they did include some hand sketching in their courses citing a variety of reasons including communications, teaching technical drawing concepts and visualization. There is no mention of incorporating an additional sketching course into the curriculum, but acknowledges that it is an important part of engineering graphics.

Eggermont, Douglas, etal (2006) describe a first year course taught at the University of Calgary combining drawing, design, communication and teamwork. Students entering the course did not expect to have to do manual sketching. The assumed that engineering graphics were done solely on a computer. By the end of the course most of the students had shown marked improvement in their sketching ability. The realized that sketching had an important role in the design process, and their visualization skill showed improvements.

These and other schools have begun to recognize the importance of teaching sketching. The question is how to fit instruction in sketching into an already tight curriculum. It is the authors opinion that while teaching basic sketching skill as a small part of a graphics course is better than nothing, it does not provide the student with enough skills training and practice to significantly improve his/her abilities. A separate course combining visualization, conceptualization and sketching would seem to be extremely beneficial.

V. Conclussion

As an advisor on numerous senior design projects it has been obvious that most students lack the basic ability to produce good concept sketches on the spot. They prefer going to a computer and modeling their ideas there before presenting them. They may be more comfortable doing that because most of their graphics training has been in the area of three dimensional modeling. In order to successfully promote their ideas in industry they need to be able to make quality sketches. Since including only a small amount of sketching in an existing course does not seem to make much difference in their abilities, it would be preferable to include a separate sketching course in the curriculum.

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