AC 2009-72: ENGINEERING SKETCHING REFINEMENT: GESTURE DRAWING AND HOW-TO VIDEOS TO IMPROVE VISUALIZATION

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Engineering sketching refinement: gesture drawing and 'how-to' videos to improve visualization

Abstract

Engineering sketching, in our course, functions as a tool for creativity, design, and analysis rather than strictly for technical representation. This component is taught by an artist-in-residence and is worth one-third of a full-year course grade. The technical drawing components (orthographic, isometric, etc.) are developed as supporting elements to the evolution of ideas rather than as an end in themselves. Students are taught how to convey ideas quickly by sketching on paper quickly and correctly. Sketching used for ideation is integral to creativity. As a design tool, engineering sketching is being used to visualize engineering concepts such as movement, forces, and stresses. During the latter part of the course students are asked to use their newfound drawing abilities to explore projects ranging from biomimicry, inclusive design, design for development to the history of design, and design styles. The students are shown how to construct these drawings during 'live' drawing sessions. The students are taken through the steps required for drawing complex objects (ranging from hand-tools to an IC engine – Fig. 1). The start of each drawing lecture simulates gesture drawing commonly seen in Fine Arts: students are shown slides of objects for roughly one minute and are asked to translate these objects into perspective or isometric sketches. A series of videos have been developed to reach all 750 first year students – making drawing 'help' available in the middle of the night when most students are finishing their work. The videos were made available this Fall in DVD format with an accompanying booklet.

This paper describes the sketching process in depth and why it is being used before students learn a CAD package ("the use of software may in fact encourage the students to go straight into their finished work without going through the critical and creative thought period"), the changes that have been made over the past seven years and the new components introduced the past two years. It will also include examples of student work.

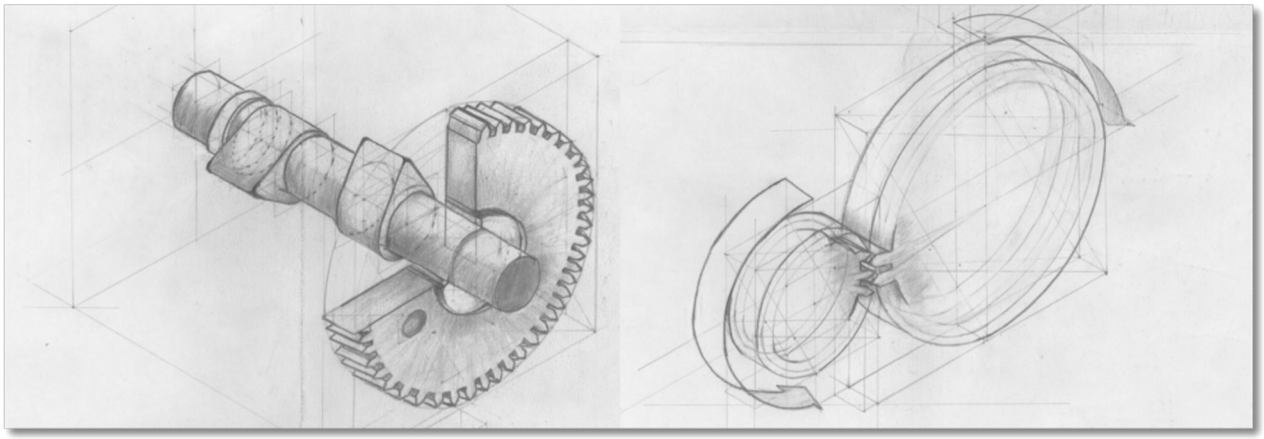

Figure 1: Cam and gear ration drawing - first year engineering communication and design

Introduction

Sketching and drawing are not exclusive to expert artists and creatives. In the words of Merrit and Moodie these marks can include "…unschooled and highly refined mark-making, loose-limbed mind's eye impressions and carefully scrutinized studies from life."[1]

Usually recognized for its ability to communicate an idea, sketching is seldom fully acknowledged for the role it plays in creative ideation. The ways with which designers and engineers communicate significantly influence their inventive processes. It is essential that engineers can effectively communicate an idea to each other, their peers and their clients. Visual modes of representation such as sketching and drawing are recognized for their ability to facilitate the exchange of ideas between people. However, within the process of design it is equally important that the designer/engineer can effectively externalize an idea for his/her own reflection and evaluation. In this case the role of sketching extends beyond the exchange of ideas; this tool becomes an individual's way of thinking, - ideating.

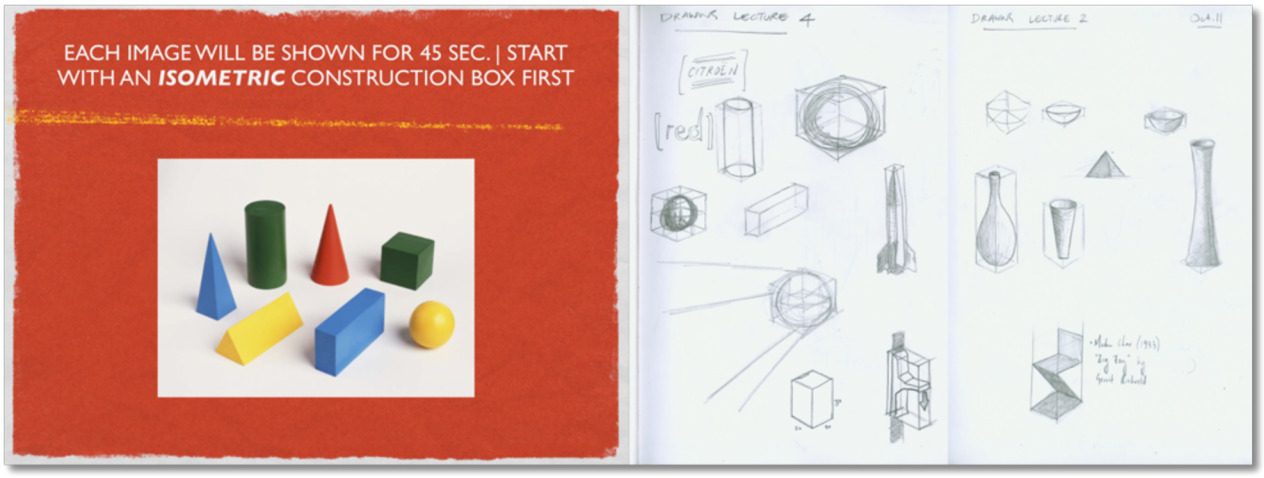

Figure 2: Sample lecture slide and student sketches

Sketching

The reasons for creating a sketch are diverse. The resolution, detail and accuracy of a sketch vary with the designer's objective and the intended audience. As a tool that is used throughout the process of design, sketching is versatile. From facilitating idea generation to facilitating detailed refinement, sketching is not limited by particular materials or locations, although, it can be influenced by them. As a record, sketching can be used to loosely capture ideas in rapid succession as they are generated. It can be used to visualize intangibles such as forces, movements or stresses. As an exploration, sketching can be used to work out the complexities within a design problem.

In his book *Engineering and the Mind's Eye* [2] Ferguson outlines three main modes of sketching:

- *Thinking sketch:* supports the non-verbal thinking process. Like thinking aloud these are often incomplete descriptions of the designers thoughts.
- *Talking sketch:* created spontaneously to supports group discussion or communication.

- *Prescriptive sketch***:** communicates design details to those outside of the immediate design process. Used to communicate with draftsmen or machinists these sketches are characteristically more detailed and accurate.

Although Ferguson's sketches are not universally inclusive of all sketches they do begin to demonstrate that sketching is not simply a means of representation. Sketching has a multitude of purposes and is often summarized or categorized based on them. In his introduction to the book *Design Sketching* Niklas Andersson uses the headings– investigation, exploration, explanation and persuasion to describe the varying purposes in which to engage the process of sketching.[3] However, to begin sketching one does not need a specific purpose or goal; sketching can be used simply as a way to *engage* the mind. Most importantly, sketching facilitates *thinking*, like the process of designing, sketching is a process without a predetermined outcome. The hasty gesture sketch that captures an idea, or the developed technical drawing used to refine an idea, both posses a greater objective beyond their own end.

The Design Sketch - Ideation

When visually depicted, ideas are more able to inspire new ones. Sketching can be a way to express sight and the imagination however when used for creative ideation the designer/engineer's sketch is not typically an exercise in transposition or duplication. This is because the idea has yet to exist in a tangible form. The sketch resembles thinking out loud, giving form to a vague thought. As Andersson describes, "one of the basic cognitive benefits of sketching is that the mere acts of formulating a mental image in a concrete way on paper makes it possible for the designer to reflect over the concept at once and almost instantly develop it further into a new concept, a so called iteration."[4] Acting as a placeholder the sketch gives form to uncertainty and provides the designer/engineer with something that can be evaluated, revised, redeveloped or dismissed. As an approximation the single sketch is not final or finished but in progress. The simple transfer of an idea from the mind to paper allows it to develop.

The Sketch as Process - An Integral Part of Creativity

Each new sketch represents a progression in thought. As Goldschmidt says, design sketching "is not merely an act of representation of a pre-formulated image; in the context we deal with, it is, more often than not, a search for such an image."[5] The very process of creating a sketch plays an active role in shaping thoughts and ideas. The activity of sketching involves a process of constructive critical questioning. The placement of each mark and line involves a series of evaluations. These marks and lines are not determined but discovered. Sketching is a process that evolves and responds from various elements of its context. Beyond an individual's preferences and sketching style this process of discovery is influenced by external factors such as the materials.

Materials can facilitate or even inspire but they can also be very inhibiting. It is important to understand that materials can have effects that go beyond the resulting marks. Sketching allows the opportunity to be creative without being overly critical. The low investment nature of sketching materials finds room for mistakes, revisions and rejection. Using materials and tools that are immediately at hand, allows engineers and designers to capture ideas at any time or in

any location. Napkin sketches are common receptacles for creative ideation as designers and engineers are not always seated at a desk or in front of a computer when they develop an idea. As one becomes familiar with his/her sketching materials, and what works best for their process one's own language of sketch develops. A large part of this language is formed by how one sees and by how one learns to see again.

Ways of Seeing

An individual must develop their own process and sketching style; their own way of internalizing and externalizing information. "People who sketch extensively are aware that drawing effects the way they see and that the way they see is an important factor in the effectiveness and quality of their drawings. Similarly, what you see critically affects the way you think. This relationship between sight and thought provides each of us with unique ways of drawing and thinking creatively. For these reasons, seeing and thinking should be viewed as an integral part of sketching."[6]
Before a student can create forms from nothing (without a visual stimuli) most students must learn how to see what exists before them. Further, they must be able to see beyond what they think they see. When used to visually explain an idea (to themselves or others) the sketcher must be able to create 3-dimensional forms on 2-dimensional surfaces. Orthographic projections, isometric projections, exploded views, and perspectives form a common visual language within the fields of design, engineering and manufacturing. These techniques provide ways to understand and communicate spatial relationships. It is the ability to truly see a form and to find the essence of form that helps the sketcher to later develop a formless idea into one with form. A sketch simplifies, the sketcher must chose what to include and what to omit, what is important and what is not. Gesture sketching exemplifies this; it encourages students to capture the essence of form. The ability to capture ideas in haste is essential to design ideation as ideas are often generated faster than they can be visually realized. Speed also facilitates transitions in thought, taking advantage of the minds ability to complete incomplete forms. The resolution of a sketch changes not only with the sketcher but also with the viewer. It is highly dependant on the knowledge and any common visual language held between the sketcher and the viewer. When communicating to someone outside of the design process the intention of the sketch will change. Usually this results in more emphasis being placed on the result.

Reading a Sketch

Goldschmidt suggests, experienced sketchers "infer meaning from a sketch."[7] They are able to read as much information from a sketch as they invest in it. Creativity is often stimulated through circumstances that prompt questions. Although sketching can provide order and tangibility, another benefit is actually found in the sketches dissimilarity to what it represents. Ambiguity stimulates reinterpretation. The very lack of clarity in a sketch is considered one of its greatest creative qualities.[8] Ambiguity can come in the form of multiple lines to define an edge, blank spaces or openings in the sketch, or missing contour lines. Through the use of "untidy indeterminacies"[9] the sketcher is able to see relationships, forms and possibilities that help to develop an idea. This process takes advantage of the human minds ability to make sense of incomplete forms and facilitate shifts in thinking.[10]

Why sketching for first year engineers?

Most students entering their first year in the Engineering faculty do not expect to be drawing with pencil and paper. They have convinced themselves that they do not draw, cannot draw, and will not draw in their future career. Instead, they expect to be given a software program that will do everything for them: idea generation, visualization, and construction.

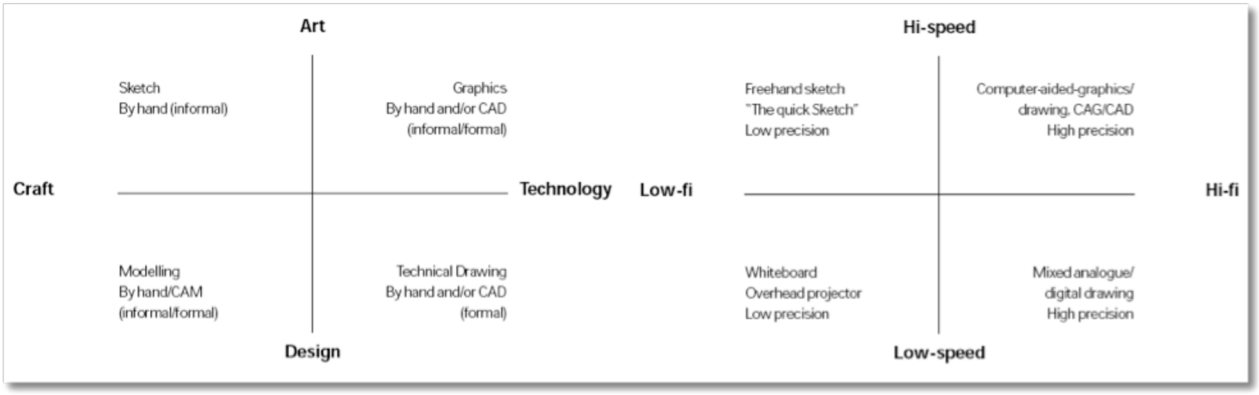

Figure 3: Placing sketching and the speed of sketching[12]

The danger of starting with a software program in first year design engineering is that it becomes a part of 'the jumping to solutions' culture. Novice designers need to explore the design problem/need thoroughly via sketching before jumping to a 'brilliant' solution. Software creates images that are so perfect that they could be easily confused as the final product rather than initial ideas. The use of software may in fact encourage the students to "go straight into their finished work without going through the critical and creative thought period".[2] The emphasis of the drawing component is on visualization, which will enable the students to use 3-D modeling software with more efficiency. If a student can 'see' the object in advance, the software can be exploited to a much greater extent; the student will bring his or her own creativity, not being limited to the creativity of the programmer. As Ferguson notes in Engineering and the Mind's Eye: "if designers use commercial computer programs… they turn over all the small and tiny decisions to the programmer, who is more likely to be an 'engineering scientist' than an experienced designer".[2]
Our students work on four-person design teams for eight months, during which they change design partners five or six times. They spend the majority of their time designing solutions to real world problems (Rube Goldberg machines, Engineers without Borders, Inclusive Design, Solar Decathlon, etc.). Sketching is seen as a form of visual communication on a team and the students are expected to sketch their ideas during team meetings. Figure 4 places the sketching activity in an Art/Craft quadrant as an informal activity. Students in our course move clockwise through three stages of this figure: sketch, graphics and technical drawing (all by hand). They perceive drawing by hand mostly as an artistic and craft-type activity – the current digital culture puts sketching in a low-fi, tenuous, and slightly old-fashioned position.

By the end of each year however the vast majority of students are able to produce drawings of 'good' to 'very good' quality. Students show improved visualization and sketching skills, and an appreciation for the role of drawing in the design process.

Gesture drawing in art

If drawing is 'learning by doing' and 'learning by making', gesture drawing has been described as 'learning by being'. When creating a gesture drawing, according to Kimon Nicolaides in *The Natural Way to Draw*, 'you should draw, not what the thing looks like, but what it is doing. You need to "sense" the thing that you are drawing. Is it fluid and soft, or spiky and hard? Is it coiled like a spring, or off-centre and asymmetric, or is it solid and balanced?'[11] The 'sense of the thing' or form of an animate or inanimate object is a consequence of being (a)symmetric and/or (un)balanced, basically a consequence of force (Fig. 5). We can perceive these forces when we see, for example, a dancer jump across a stage or a bridge across a gorge. One might use the

SELECT Elements of drawing:	**COMBINE** Combinations of elements produce:	**COMMUNICATE** Combinations stand for physical and emotional experiences of the world:
point line shape (2D) texture tone colour plane	contrast proportion scale pattern rhythm	spatial depth force direction movement volume, mass, weight balance symmetry structure form (3D) surface properties observer's position(s) /mood, attitude

Figure 4: Drawing to perceive and communicate engineering concepts [12]

word 'leap' to describe the manner in which the dancer jumps and the manner in which the bridge spans from one side to the other. Gesture drawing gives form to such an insight. It relies on 'empathetic sensation: a capacity to share the physical sensation of another person or of an inanimate thing'. [13]

Gesture drawing in a large engineering design class

One of the changes made this year is the introduction of gesture drawing sessions. This session is similar to model gesture drawing classes in the fine arts. In Fine Arts, to get students to 'warm up' and be less self-conscious about their mark making, a model will do a series of short poses and will hold each pose for as short as 30 to 60 seconds and up to 5 to 10 minutes. Students

attempt to get an approximate shape, contours, and feel of the model on paper within this time period.
The majority of students in the engineering school are sequential learners who are quite precise, linear, and thorough. While these are necessary qualities for an engineer, they tend to hamper students' ability to 'go with the flow' and to be less self-conscious in a drawing setting. The gesture drawing sessions in our course are slide shows where basic and more complex shapes are shown in rapid succession.

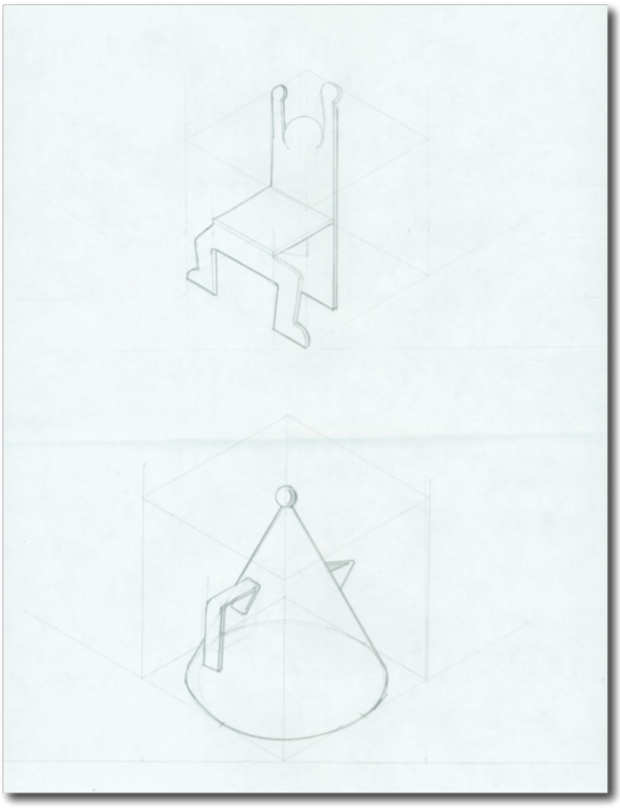

Figure 5: '10-minute' student sketches.

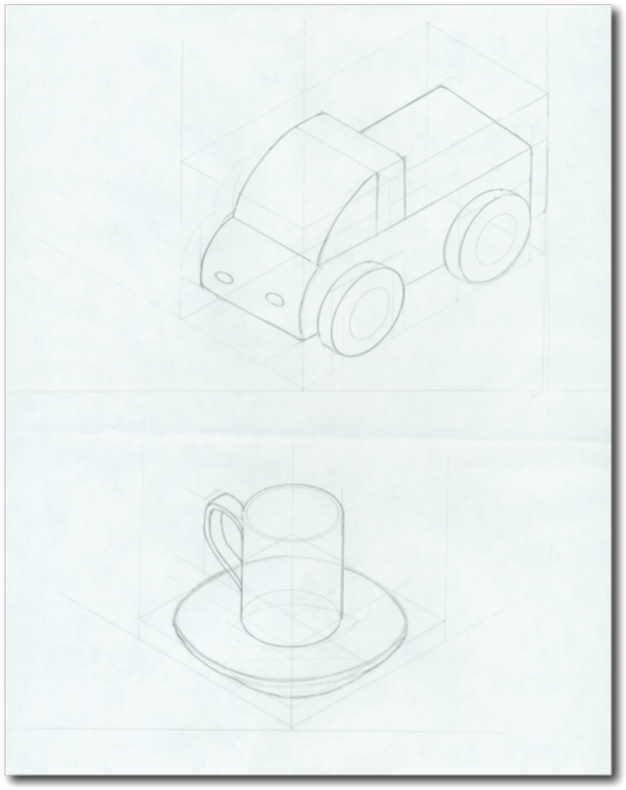

Figure 6.: '10 minute' student sketches

The computer, not the instructor, 'times' the slides (which to the students is somehow more acceptable). Students have to translate perspective photographs into isometric drawings (Fig. 2). The translation of the perspective images is encouraged at this stage.
It allows students who are not visually literate to 'sequentially' go through the building of an object. The translation phase allows students to place the objects inside a 3- dimensional grid that centers the objects and allows for 'logical' construction. Students can ask themselves: 'Where do the edges of the object meet the construction box? Is the centre of the object in the centre of the drawing envelope? Are the parallel edges of the object parallel in the sketch?' The short time periods during which these images are shown, forces the students to think and draw rather than decide whether they like their drawing or not. The most important aspect of this exercise is the speed of drawing and the opportunity to be less self-conscious.
Students are given a drawing test at the end of the term, during which they draw 5 objects and are given ten minutes per object. Before the test they are given a list of objects that may appear during the test, so they can practice in advance. Figures 6 and 7 are examples of the 10-minute

sketches. Students were given a take home assignment after the in-class drawing test. Some felt, if given the time, they could do a much better job. The take home ('good' copy) portion allowed them to prove this (Fig. 8).

Changes made

The engineering sketching component in the design class is in its 7th year. One of the big changes is the introduction of an isometric sketching video. The video starts with the basic shapes (cube, cylinder, pyramid, and sphere) and moves to more complex shapes, shows sectioning and an exploded view. The video allows students to practice on their own time, allows them to start and stop the videos to see lines created and the movement of the hand. In a large class, this year a record 740 students, one instructor can only hope to reach all students. The drawing video has made a big difference in the general drawing level of the entire class. All students are able to practice and get to a competent drawing level. The video has over 80 minutes of drawing material. Currently student and instructor manuals are in development to suggest different exercises for the various videos.

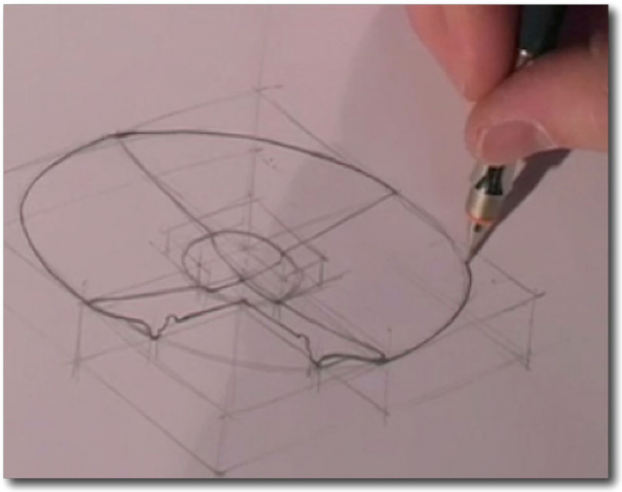

Figure 7: Sketching video - 'sectioned' saucer.

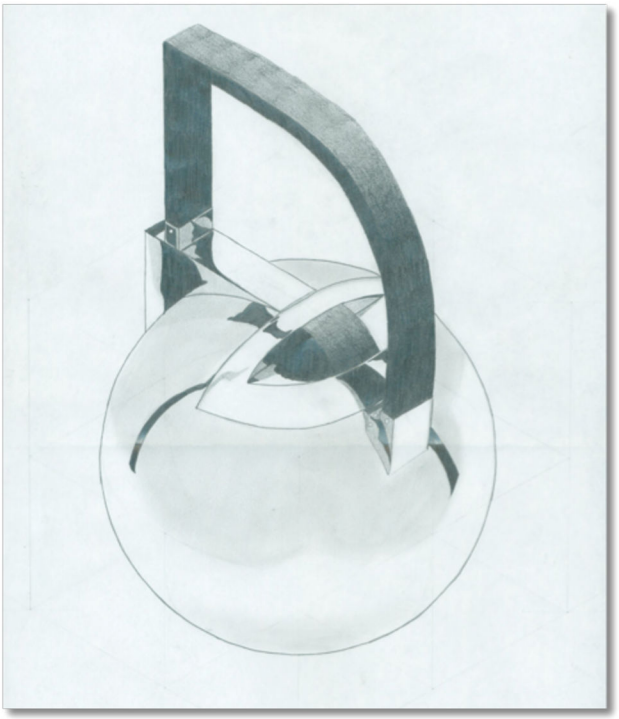

Figure 8: Student drawing - 'good' copy.

Conclusion

The goal behind sketching in our first year design course is not only to allow our student to understand and communicate spatial relationships, but to also give them a way to innovate. The very process of creating a sketch plays an active role in shaping thoughts. The activity of sketching involves a process of constructive critical questioning. The ambiguity of a sketch opens the door to new interpretations and therefore new ideas.
Sketching in our course is teaching our students first and foremost to 'see' again and as Teilhard De Chardin (paleontologist/geologist) said: 'The whole of life lies in the verb "seeing".

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