VISUALIZATION IN THE DESIGN PROCESS: INTRODUCING TWO AND THREE-DIMENSIONAL SKETCHING TECHNIQUES TO ENHANCE CREATIVE THINKING AND COMMUNICATION

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ABSTRACT

Visual literacy, for three-dimensional designers is a critical skill for thinking, understanding, exploring and communicating physical concepts. In contemporary design education and practice, there is an increasing reliance on digital technology to provide "virtual" visual experiences. As a result many design-education programs have diminished or abandoned support for traditional methods of two-dimensional and three-dimensional sketching (drawing and desktop modeling). However, while new technologies provide a degree of visual assistance to the designer, studies by McGown, Green and Rogers [1] et al show that digital tools alone do not provide the cognitive connections or support for visual thinking that is inherent in those traditional tools. Further when digital technology is used as a dominant tool throughout the design process it may adversely affect cognition resulting in diminished perceptual understanding, confidence, and opportunities for innovative solutions. Industrial design educators globally have begun to witness this cognitive decline and are rediscovering drawing and modeling as valuable means for stimulating visual thinking and innovation.

Research at the Carnegie Mellon University School of Design, by one of the authors (Anderson), has resulted in the development of flexible teaching strategies and methodologies that respond to the visualization needs of early students [2]. This approach has consistently helped students to communicate their ideas visually through techniques that increase confidence, enable understanding, stimulate creativity, and are efficient and economical. Having proven valuable in the area of industrial design, this research sought to broaden its scope to include undergraduate engineering students. Described here is a first effort at introducing these methods to senior–level engineering students in the context of a product design class. The collaboration between the industrial design and engineering was a natural opportunity to introduce and assess this approach.

Keywords: visualization, sketching, modeling, form generation

1 INTRODUCTION

Visualization is a process of mentally constructing, shaping and understanding information and the ability to externally communicate it. This process extends beyond simply representing in visual terms – using manual activities such as drawing, imaging (photography, collages), or making skills. Rather it relies on these abilities as methods for thinking, conceiving, exploring, and proposing ideas. In essence visualization is the pathway for design [Anderson].

In today's knowledge driven economy, those who successfully engage in the visualization process are more often able to shape complex information into new opportunities. Historically, drawing and making were key tools in this process stimulating cognitive connections between the mind and external representation. This allowed for a more fluid process of analysis and problems-solving through creative exploration. This was particularly important in education where students understood drawing and making as a value and expectation. However in recent times these proven skills have been challenged by new and emerging technologies. Programs in both industrial design and mechanical engineering are seeing an increased number of students lacking in visual literacy and creativity yet are proficient with multiple software programs.

Technology has proven valuable in several areas of the design process. However the reality is that while there are many software programs entering the market seemingly daily, and under many guises including simplicity, flexibility and expediency, current software programs are not found to be as useful and effective in the creative and development phases as they are in the final. McGown, Green and Rogers (1998) write "Most researchers have chosen to ignore the earlier stages of design including the conceptual phase, in favour of developing expert systems for supporting the latter stages. These latter embodiment and detail phases utilize an enhanced quality of information that is more amenable to computer support than that available in the ill-defined and complex conceptual stages." They further write, "Knopp et al agree that computer support of the latter stages of design is easier to achieve since the product description is already well known. They contend that the technology push, coupled with a poor understanding of the design process, has led to the current lack of support for the conceptual designer"[1]. They go on to say that freehand sketches have several advantages over computer systems including greater speed, ease of use, immediacy, more expressive qualities, and are only constrained by the designer's imagination.

2 VISUAL THINKING AND REPRESENTATION

Effective visual thinking begins with having tools that allow an uninhibited exchange between mind and matter. Ideally, one negotiates between sketching and making to formulate, verify and modify representations of thought. This activity helps in making a cognitive connection to both purposeful and discovered information. If student abilities are limited in either area – can only draw or only make - then the kinds of information that will be understood and the possibilities that can be generated are diminished. Because making requires more preparation, varied materials and tools, and is not as nimble or economic as drawing, it is often most effective in the supporting role. Consequently, drawing has emerged as the dominant tool in visualization, particularly in the early phases. Of the multiple drawing systems available, perspective, a universal system of representing the illusion of three-dimensional information onto a two-

dimensional surface, is the one that comes closest to naturally representing how we see and understand physical information. For this reason it is the primary tool that industrial design uses for thinking and communicating. It is also the most difficult system to grasp, especially when describing complex forms.

2.1 Approaches to perspective drawing
There are three major approaches to perspective drawing: art, science/technology, and design. Most design students are introduced to perspective drawing from a fine arts position. These approaches use varied techniques to teach the drawer how to observe and represent information using surfaces, and spaces and takes years for students to master. Others learn perspective from a technical point of view gaining a proficiency in representing defined information accurately. However neither approach addresses drawing well as a tool for thinking, creating, and managing complex information. Design drawing is the third approach typically offered in programs of Design and in particular industrial design. As industrial design is often referred to as the merger of art and technology, so are the principles of design drawing. Design drawing borrows from art and technical disciplines offering a balance of style and clarity. Its driving principle is form construction – cognitively building information through the understanding of structure with line. Its purpose is as a tool for thinking, managing and communicating information.

3 UNDERSTANDING VISUAL NEEDS
Drawing is an innate ability that is typically suppressed in early childhood. The consequence is that adult students tend to be fearful of drawing because of an often misplaced notion of goals. Typically when one thinks of drawing it is thought of from either the artistic or technical approach. The images of beautifully illustrated works of art or highly specified documentations often come to mind. However the goals of many who desire to communicate visually fall between these extremes. Design drawing offers an approach that is better supportive of their goals. By placing drawing in the context of a tool for thinking and effective communication, the clarity of the idea becomes paramount enabling one to express information without overly critical assessment of artistic or technical merit. This allows inexperienced drawers to gain confidence and ability in visual thought and expression.

3.1 The challenge for the visual novice
However important, communicating effectively through drawing is not as simple as selecting the right approach. Learning how to see two-dimensional and three-dimensional information, understanding its complexities and interpreting from varied points of view is necessary. This requires quality instruction, patience, practice, desire and most importantly commitment – buying into drawings role and understanding its value. This is a challenge for the new student of design and engineering who has varied but shallow visual experiences. This student can range from being quite insensitive to the physical world around them (having little desire to investigate because of readily available virtual information) to having specific but narrow experiences. Coupled with a limited opportunity for applicable drawing instruction, a false sense that software has replaced such needs, and discipline norms, achieving effective visualization in education has become increasingly difficult. Absent a clear strategy for addressing these challenges and inclusion as part of a strategic pedagogical framework, visualization through activities of sketching and modeling will remain inconsistent and unsustainable.

3.2 Understanding the goals of engineering students

In order to have value outside of industrial design, the process of visualization must be a flexible structure that appropriately adjustment to pedagogical goals. To understand the needs of engineering more clearly, a pilot study was conducted with two graduate students using Anderson's approach. Consistent with his other studies, the engineering students were able to quickly and confidently construct and represent product information using perspective drawing. They further developed multiple alternatives and expressed enthusiasm in their creative efforts. Through survey, interviews and artifacts, helpful information towards defining an appropriate teaching approach for this group was discovered. One point of information strongly suggested that the lack of perceived value of perspective drawing be addressed. Prior to the drawing experience both students understood the idea of perspective, appreciated how industrial designers communicated through perspective drawing, but had not seen the value for themselves. This quickly changed as examples and demonstrations were shown to illustrate value at the multiple levels of their design process.

3.3 Accelerated visual learning

Perspective drawing can be a time intensive system of representing the physical world. Students typically struggle with issues of accuracy, proportions, and spatial relationships when describing information, particularly when the "eyeball" approach is used, and quickly became discouraged. However, Anderson's approach uses pre-established perspective grids (figure 1) in a unique system that quickly raises confidence, increases understanding, and promotes fluid visual thinking. When used, this approach offers a rapid means for developing structured forms that are accurate in proportion, perspective yet can be sufficiently flexible (figure2). By placing and securing tracing paper over the grid, students can shape information into coherent statements of intent and effectively modify their thinking (design) to create better proposals. Tracing paper creates a translucent layer that allows the drawer to correct or change prior or developing information, quickly. Tailoring this approach to accommodate different needs has shown to accelerate drawing skills in a fraction of the time of traditional methods.
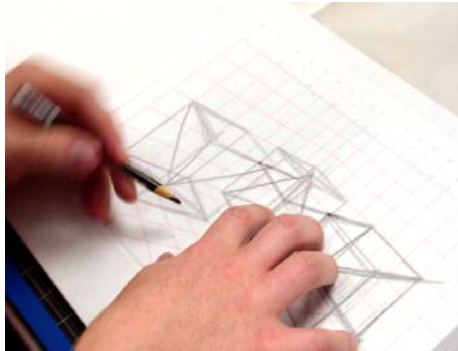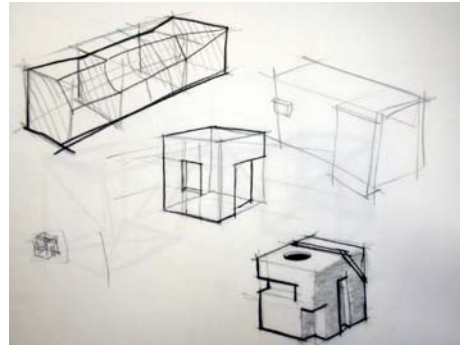

Figure 1 – Using the grid tool

Figure 2 – Basic form development

4. NEW STRATEGIES TOWARDS EFFECTIVE DRAWING

There are three major types of drawing in the design approach: conceptual, development, and presentation (figures 3, 4, & 5). The conceptual drawing captures initial and often spontaneous thoughts using loosely structured lines. The development responds to clearer defined directions and is more structurally accurate with increased details showing specific intent. Each of these types of drawings responds to active mental and external negotiation of ideas and therefore is not executed linearly. The presentation drawing however tightly controls and presents all aspects of the idea through a realistic rendering.

As a thinking tool the conceptual stage of drawing is most valuable and attainable for the visual novice. It allows idea fragments to be externalized and formulated into coherent concepts. Once the idea has been formulated students shift to development where multiple have options for support exist, such as the computer and other forms of imaging. Yet development drawings continue to have a valuable place in the design process. As a refined skill it remains quicker, more economical and offers greater support in stimulating ideas than current technology offerings. However, when managed well, both drawing and technology compliment each other and deliver creative solutions more quickly. In the latter stages of visualization, digital drawing tools offer a greater support of defined ideas and in most instances has replace the manual drawing in presentation.
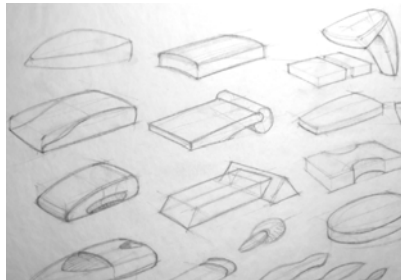

Figure 3 – Conceptual Sketches   Figure 4 - Develop   Figure 5 - Pres

5 INCORPORATING VISUALIZATION – A 6 HOUR STUDY

Can the average student enhance their ability to think and represent visual ideas in six hours? This was the question posed in shaping this study. The challenge was to teach two sections of engineering students how to effectively visualize using drawing and making techniques in three class sessions that met once a week over three consecutive weeks. Most students had no prior drawing experience before beginning the workshop and of those with experience few understood perspective drawing. In a class that was 110 minutes long, careful orchestration of the assignments and lectures was critical. This approached included lecturing and demonstrating the principles of perspective drawing, introducing grids and short-cuts to effective representation. Modeling was introduced as a desktop sketch activity for informing and confirming.

5.1 Shaping meaningful assignments

The assignments needed to respond to several challenges that included having only instruction and feedback during each 110 minute class (outside support was not available); a different meeting environment for the two class sessions – one was a

computer lecture lab and the other a general classroom with work tables; and students with a range of backgrounds and experiences, few visual. Assignments had to be constructed with minimal resources and consider the space in which students had to work. They also had to consider reasonable outside expectations for the development of work between each of the three sessions. And finally they had to be interesting and challenging enough to stimulate student interest and desire to develop independently.

Considering the timeframe of three short sessions, an objective was to quickly engage the students in meaningful activity. This was achieved by creating a project scenario that required them to immediately begin the process of problem solving, communicating only through drawing with an occasional text call-out to identify major features. The scenario was to design a personal organizer using a 3.5" cube that supports 4 personal items. This product had to be stackable vertically and horizontally. Students had to further consider issues of human interaction and human factors. Throughout each class group critiques were facilitated to increase awareness, promote understanding and enhance ability. This structure enabled students to quickly transition from the drawing system to focusing on the ways to solve problems.

5.2   Strategies for idea representation and exploration

The drawing format was 11" X 14" tracing paper. This size provided a compromise between smaller formats where often it is difficult to explore details, and larger formats that are difficult to fill. In the initial phase students were challenged to move beyond single solutions and explore a broad range of opportunities. Several strategies were employed to assist students in this endeavor including beginning with 25 thumbnail sketches in perspective (see figure). From the thumbnails they were required to select one direction and make a quick but proportionately accurate sketch model out of foam-core or similar material to test their concept. A major discussion was had about drawing and modeling and how it could better support their design activity. As a result their selection became the final direction because of time. The next phase was to transform loose concepts into a meaningful design. This was achieved through the construction of more accurate drawings that communicated clearer intent using tracing paper overlays to develop the design. The final deliverable was a detailed perspective drawing of their organizer, a foam-core model that held the four defined contents and a sequentially bound process book showing the complete evolution of their concept. A quick overview of this process is provided in the chart below.

Table 1 - Description of activities

Day one	Introduced perspective; perspective grids; strategies on object development; techniques for visual impact; examples of effective 3-D sketches; and gave assignment. Homework expectations included developing 25 thumbnail sketches and at least one sketch model capable of holding defined contents.
Day Two	Group critique of assignment; strategies on exploring broader concepts (design); issues of interaction; issues of human factors; strategies for presentation
Day Three	Final presentation - each student pinned up their drawings, presented their sketch & final models, & submitted the process book

6 ASSESSING THE RESULTS

Students responded remarkably well to the tools, lectures and projects presented. They quickly developed the skill to represent reasonable drawings of basic forms and then effectively shift to use drawing as a tool that reflected their thinking. Most impressive was their evolution evidenced by their process books. In most cases their drawings were fluid and their ideas were varied. They realized in a short period of time that they were capable of expressing multiple concepts through drawing, and in fact had documented a significant amount of work as evidence. Their final concepts were expressive, fun and convincing as concept proposals. Examples of work are shown in figures 6 -9.
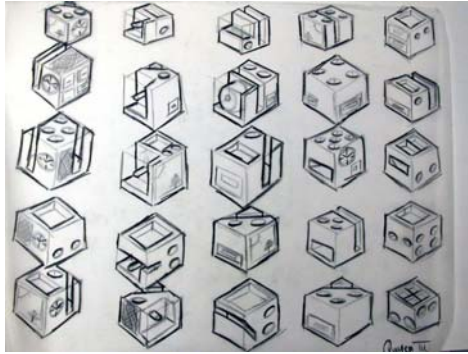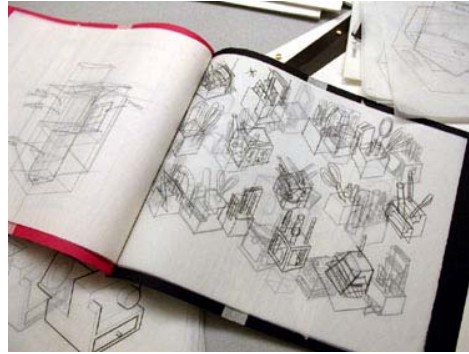

Figure 6 – Thumbnail sketches
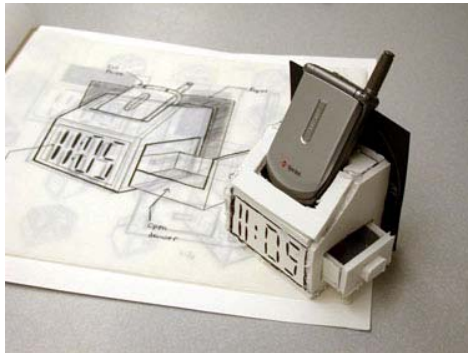

Figure 7 – Process book

Figure 8 – Final drawing & model

Figure 9 – *Class models*

7 SUSTAINABLE DEVELOPMENT

Clearly, an experience such as the one described here is valuable only to the extent to which the students take something meaningful away from it. While it is not possible at this point to know what long–term effects this exercise may have on the ability of the students in terms of visualization and ideation, through observation, assessment and experience, the effect over the near term is predicted to be positive. After the three–week instruction period, the students were assigned to three–person teams and asked to conceptualize and prototype a lighting system appropriate to a college dormitory room. While space limitations here preclude a full examination of this project, included are some representative sketches completed by students in the course of this second project (figures 10 & 11). These sketches showed an ability to think and express three–dimensional concepts at a much higher level than that shown by students in other terms. Students in previous quarters typically created sketches at a very rudimentary level,

almost always in two dimensions, and rarely with any sense of scale or proportion. The sketches shown here, which were done by several different students with no further coaching, clearly show a good sense of scale, an ability to think in three dimensions, and an ability to apply advanced visual techniques such as varied line weight to add emphasis to the drawings. While these drawings were slightly better than average, they are by no means atypical of the work done by the majority of the students. At the end of the term students were specifically asked to evaluate the drawing instruction they had received. The responses were overwhelmingly positive (37 out of 40 students made positive comments) with several of the students remarking that they had already used their newly acquired skills in other classes, or were planning to use them on their jobs.
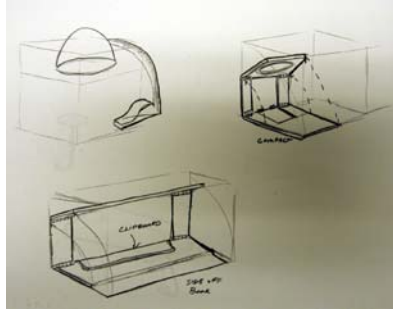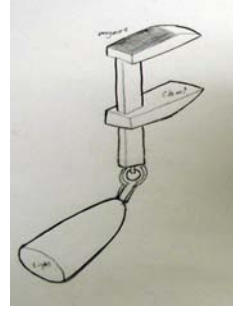

Figure 10 – Lamp concept 1

Figure 11 – Lamp concept 2

8   CONCLUSION

The focus of this first collaborative effort between Carnegie Mellon University and The Ohio State University was to aide engineering students in thinking visually by engaging them in activities of drawing and modeling. By borrowing and appropriately applying techniques used in industrial design, particularly in the conceptual and development phases, engineering students can enhance their ability to stimulate new thinking and offer greater support in the design process. Further, if expanded beyond a three week experience to be fully inclusive in a program, the impact of visualization can be greater.

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