VISUALIZATION AS A MEANS TO CRITICAL AND CREATIVE THINKING

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1 Introduction

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. Anderson defines visualization as a process of mentally constructing, shaping, and understanding varied information, and the ability to externally communicate it. This process extends beyond simply representing information visually using activities such as drawing, imaging (typography, photography, collages), or physical making. Rather it relies on these abilities as methods for thinking, conceiving, exploring, and proposing ideas[i]. In essence visualization is the pathway for critical and creative thinking, and its communication[1].

Historically, in the United States, art and design education has led in the area of visualization – training highly refined visual shapers and interpreters. However as society has become more visually driven, the skill of visualization is emerging as a need and powerful tool for non-artist and non-designers. Yet there are few meaningful resources capable of supporting this new student – one who has an interest in developing visualization as a complimentary skill. And, because many art and design programs remain deeply rooted in traditional pedagogy, there is little room for effective and

[1] Anderson here has evolved his definition to broaden the scope of visual information

efficient learning by those who seek knowledge from these disciplines. Moreover, in industrial design education, an area of study known for managing complex visual information, the motivation of students applying to programs and their values have expanded beyond the tradition of aesthetic form giving but now encompasses visual strategy in the broader sense. In programs like Carnegie Mellon, there is an increased enrollment of intellectual students who are attracted to industrial design but have limited visual experiences. The program is structured to support this type of student because they express a clear interest in learning the thinking of design; it's methods, and exhibit the potential to contribute broader and valuable perspectives.

2 New Opportunities for Teaching Visualization

Visualizing information is an innate desire that is witnessed in early childhood. Whether it is drawing pictures or representing thoughts through abstract tools such as sticks and sand, children often find creative ways to express themselves visually. However with a reduction in nurturing and support, as witnessed in primary public art education in the United States, fewer children are provided the attention and pathway to develop into mature visual thinkers. By the time these children reach adulthood they have become fearful of expressing their thoughts through drawing and modeling activities[2] and believe themselves to be inept. This can be reversed however by properly aligning visual goals and instilling confidence through approachable strategies and methodologies.

There is a tremendous opportunity for new strategies and methodologies that respond to new student of visualization, one who represents a rapidly growing segment of society. Research at the Carnegie Mellon University School of Design, by Anderson, has sought to respond to shifts in visual interest and learning. His research investigates the performance and perception of industrial

[2] Drawing is referred to as mark making on paper or flat surface. Modeling is referred to as the physical shaping of information through paper, board or other materials that offer volume.

design students in undergraduate programs across the United States with respects to visualization. This research has resulted in the development of flexible teaching strategies and methodologies that approach the needs of early students differently than traditional art approaches and expands on those of design. It 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 has broadened its scope to include engineering students and others through university course electives and visualization workshops with undergraduate and graduate engineering students.

3 Understanding Visual Needs

Drawing and modeling are key tools in the visualization process and often thought to be tools that result in artistic or technical representations able to withstand high levels of scrutiny. The images of beautifully illustrated works of art or highly specified documentations and artifacts often come to mind. In these areas of study students learn to use varied techniques to observe and represent information with mastery of skill often the goal, which takes years to achieve. Yet the goals of many who desire to communicate visually fall short of these extremes, and neither approach addresses the dynamic opportunity of visualization as a tool for thinking, managing, and creating complex information. Design is the third approach to visualizing information. It is typically offered in programs of Design but often seen more immediately in areas such as industrial design because of the constant negotiation of two and three-dimensional information.

As industrial design is often referred to as the merger of art and technology, so are the principles of visualization in design. Visualization approaches used in design borrows from the art and technical disciplines to shape a flexible framework that offers a balance of style and clarity. A driving principle is form construction – cognitively building information through the understanding of structure with line, plan, and volume.

This framework of offers an approach that is better supportive to a range of visual learners. By placing drawing and modeling in the context of a tool for thinking and effective communication, the clarity of the idea becomes paramount rather than the artifact. This enables one to express information without overly critical assessment of artistic or technical merit and allows inexperienced visualizers to gain confidence and ability in shaping and expressing visual thought.

3.1 Understanding the Visual Goals of Engineers

In order to have value across disciplines, the process of visualization must be a friendly and flexible structure that appropriately adjusts to pedagogical goals. It is also helpful if the group to be chosen for further testing and development has visual needs that can be address through these methods. Mechanical engineering was selected because it offers the most natural opportunity, outside of design, to enhance how its students and professionals engage with visual information. To understand the needs of mechanical engineering more clearly, Anderson has conducted several studies using his visualization methods. Through prior pilots, surveys, interviews and artifact reviews, helpful information towards defining an appropriate teaching approach for this group was identified and executed. In each case engineering students were able to quickly and confidently create and represent product ideas using perspective drawing and basic modeling techniques. They further developed multiple alternatives and expressed enthusiasm in their creative efforts. One study is shared in detail within this paper.

4 The Advantage and Challenge of Drawing

Effective visual thinking begins with having tools that allow an uninhibited exchange between mind and matter. Ideally, one negotiates between two-dimensional and three-dimensional sketching to formulate, verify and modify representations of thought. This activity helps in making a cognitive connection to both purposeful and discovered information. This Anderson refers to as design drawing. If student abilities are limited in either area –

can only work two-dimensionally as in manual or digital drawing, or only three-dimensionally as in physical or virtual modeling, then the kinds of information that will be understood and the possibilities that can be generated are diminished. Because three-dimensional modeling requires more preparation, varied materials and tools, and is not as nimble or economic as manual drawing, it is often most effective in the supporting role. Consequently, manual drawing has emerged and remains a dominant tool in the early phases of visualization.

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 visualization who often 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 drawing and modeling needs, and discipline norms, achieving effective visualization in education has become increasingly difficult. Absent a clear strategy and suitable methods for addressing these challenges, and its inclusion as part of a strategic pedagogical framework, visualization will remain inconsistent and unsustainable.

4.1 **Design Drawing Strategies**

In design, drawing performs as an output for active negotiations between conceived (mind) and perceived (external perception) information, which shape fragmented thoughts into ideas through non-linear development. This Anderson refers to as design drawing. There are three major strategic approaches to design drawing identified here: conceptual, development, and presentation (figures 1, 2, & 3). The conceptual drawing captures initial and often spontaneous thoughts using loosely structured lines. The development drawing responds to clearer defined directions and is more structurally accurate with increased details showing specific intent. And the presentation drawing 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 in ways other tools cannot achieve, including digital. McGown, Green and Rodgers in writing about digital drawing tools state "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 utilized an enhanced quality of

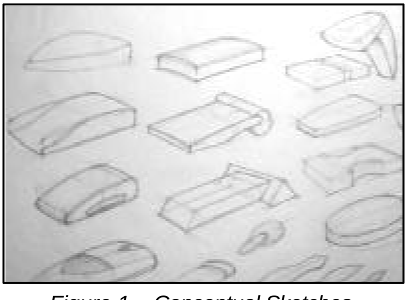

Figure 1 – Conceptual Sketches

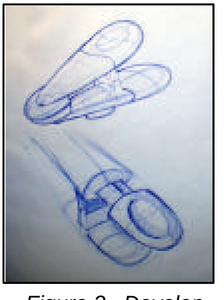

Figure 2 - Develop

Figure 3 - Pres

information that is more amenable to computer support than that available in the ill-defined and complex conceptual stages.[ii]" They further state that currently there seems little reason to attempt to replicate freehand sketching by computer methods. However, when managed well, both manual drawing and digital technology compliment each other and stimulate creative solutions more rapidly than either alone. On the other hand, in the latter and presentation stages of visualization, digital drawing tools offer greater support of defined ideas and in most instances has replaced manual drawing.

Although this strategic approach to conceptual, development, and presentation stages of visualization is discussed with a focus on drawing, the same framework can be applied to modeling.

4.2 A Method for Accelerating Visual Cognition

Successful concepts are built upon the experience that the student has with the information being realized. As a tool, drawing construction helps the student to visualize the structure of an idea, process it line by line, and provide a fluid means of confirmation through the use of simple tools (e.g. pencil and paper). Exercise and practice enhances visual literacy and through supportive modeling further strengthens cognitive understanding of forms, details, and potential applications.

There are numerous drawing systems one can use to develop visual information. However, perspective, a universal system of representing the illusion of three-dimensional information onto a two-dimensional surface, is the one that comes closest to representing how we naturally see and understand physical information. For this reason, it is the primary system used in industrial design. It is also the most difficult system to grasp and can be time intensive, especially when describing complex forms. Consequently, students typically struggle with issues of accuracy, proportions, and spatial relationships when describing information in perspective, particularly when the "eyeball" or intuitive approach is used. This can cause them to quickly become discouraged. However, Anderson has an approach that incorporates pre-established perspective grids[3] (figure 4) in a structured system. This approach quickly raises confidence, increases understanding, and promotes fluid visual thinking. When used properly it offers a rapid means for developing structured information that is accurate in perspective yet support the initial conceptualization phase (figure 5). By placing and securing tracing paper over a printed grid, students can shape information into coherent statements of intent and effectively modify their thinking

[3] Perspective grids are pre-established lines typically printed on paper that provide a guide to drawing objects within this visual system

(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 and support model construction in a fraction of the time of traditional methods.

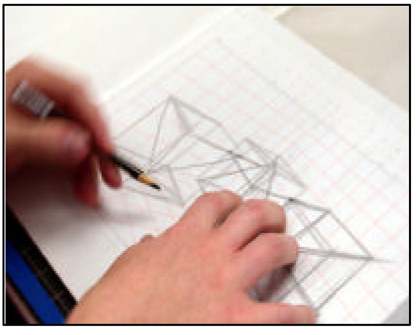

Figure 4 – Using the perspective grid

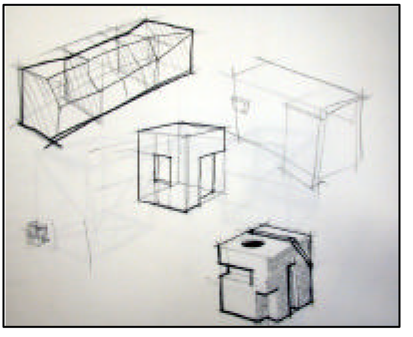

Figure 5 – Basic concept generation

5 Integrating Visualization in the Classroom in 6 hours

Can the average student enhance their ability to think and represent visual ideas in six hours? This was the question posed in shaping a visualization study with mechanical engineering seniors at The Ohio State University, USA. The challenge was to teach two sections of engineering students how to effectively visualize using drawing and modeling techniques within three class sessions. Each section 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 perspective grids and short cuts to effective representation. Modeling was introduced as a desktop sketch activity for informing and confirming.

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. Reasonable expectations had to also be considered for outside development of work between each of the three sessions. And the assignments 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.

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 6). 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, and in the interest of time, their selection became the final direction. 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.

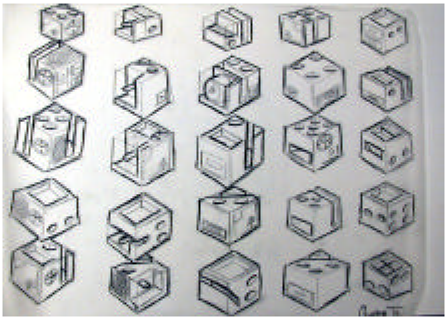

Figure 6 – Thumbnail sketches

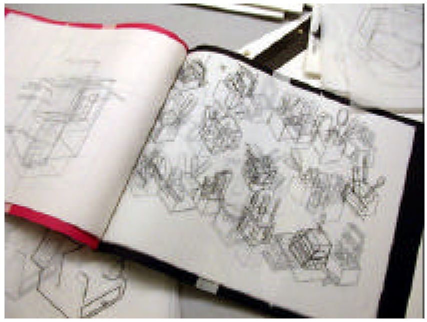

Figure 7 – Process book

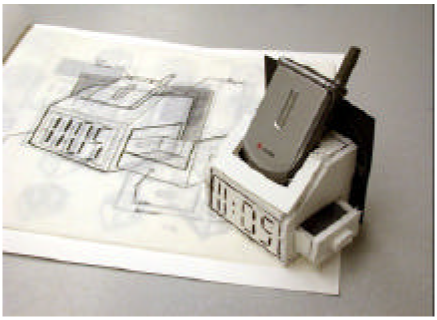

Figure 8 – Final drawing & model

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. For this reason it was important to include remarks by the professor of record for the course, and engineer Dr. Blaine Lily on student performance beyond this experience. He writes "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."

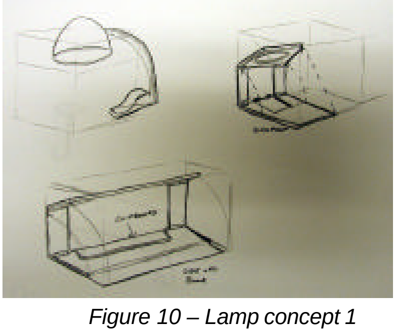

Figure 10 – Lamp concept 1

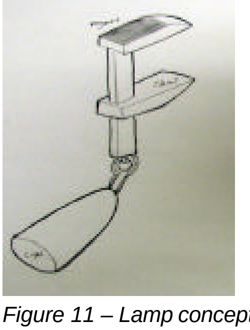

Figure 11 – Lamp concept 2

8 Conclusion

Visualization for the industrial designer is critical skill used for thinking, understanding, exploring, and communicating concepts. It is the ability that allows designers to reason with complex information using varied methods in order to shape environmental and behavioral conditions. This definition does not imply that designers necessarily need to master various methods, but rather that they are proficient enough with them to offer intelligent responses. By understanding the essential methodologies that designers employ in their visual thought process, new teaching models for visualization can be shaped that benefit neighboring disciplines, such as mechanical engineering, and the public at large. The collaborative effort between Carnegie Mellon University and The Ohio State University demonstrated a successful model that has enabled engineering students to enhance their ability to visualize, communicate complex information, stimulate creative and critical thinking, and enrich their design process through tailored drawing and modeling experiences.

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