THE INTEGRATED VISUALIZATION SYSTEM

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INTRODUCTION

Drawing skills represent an important tool in the skill set of the typical Industrial designer. Drawings by hand offer several unique and essential contributions to the design process (Fig.1):

- The designer's ability to converse with themselves, other designers, the client, and others in the product development group.
- A visual record of both thinking and the concept



- Aesthetic possibilities for a solution shown with a character of line work unique to that designer
- Storyboards of product-use scenarios
- Materials and manufacturing specifications for engineering
- Inspiration for the development group and the end user
- Speed and efficiency in communication

Figure 1. Concept drawing sample

Computer-aided design soft/hardware has supplanted a number of original skill sets - drafting, modeling, and rendering – with versatile visualization and engineering systems. Both are acknowledged and utilized as essential to the design process. Sketching, however, represents a primary language used continuously through the design process between members of the team.

Drawing may represent one of the most challenging skill sets the design student is required to master. Translating a three dimensional idea to a two dimensional surface requires a fluent and intuitive understanding of perspective, picture planes (plane of the visual), focal lengths (distance from the viewer to the object), and dimensional indexing (receding in perspective distance) normally attained only through years of regular practice. Learning traditional methods of perspective layout and indexing such as found in Doblin's seminal *perspective: a new system for designers* are intellectually satisfying but often prove too abstract to help the average student towards proficiency. Figure 2 illustrates some of the perspective issues that may occur even *after* such traditional lessons:

- Divergence: parallel lines diverging as they recede towards but do not share the vanishing point.
- Distortion: parallel lines converging too quickly an indication of a too-compressed focal length.
- Ellipse: a circle viewed obliquely in perspective. Visualizing the proper angle and orientation to the Minor Axis, co-linear to the vanishing point, often presents many challenges.



Figure 2. Examples of divergent and distorted perspective and ellipse configurations



Figure 3 shows equal-dimensioned objects without distortion in proper perspective. Visualization done previously with sketches, renderings or draftings may now be done digitally. Graphic (Adobe), design/engineering (Solidworks) and rendering (3D Studio Max or Keyshot) software all offer systems to accelerate different parts of the design process. A downside of ever-moreintuitive digital design tools is that students spend more time using the computer and less time practicing the craft and exercise of drawing. Where, before, the

Figure 3. Example of proper perspective

profession relied on one primary language of communication, it now relies on several. Over time education and the profession have been at odds over priorities in preparing future designers. (Brett 1986; Coutts&Dougall 2005) These challenges pose a risk of dilution of skill sets in graduating portfolios. Is it possible the students are tasked with becoming experts in too many areas before graduation?

Reduced drawing skills negatively affect the students' ability to solve problems and think in three dimensions. Research indicates a direct correlation between drawing skills and the ability to learn 3D software. (Alias et al, 2002, Ullman et al, 1990, McLaren, 2007) It seems clear that a significant hurdle in education will be to satisfy the industry demands to use the most sophisticated technology available while developing professional design drawing skills. Often the two skillsets are seen as separate tools.

AN ACCELERATED DESIGN DRAWING PEDAGOGY

As the skills needed for Industrial Design become more diverse, how may steps in the design process be sequenced and integrated into drawing pedagogy for more engaged learning and a more thorough understanding of visualization skills. At some point in their education, Industrial Design students are expected to take initiative and learn information and skills on their own. Regardless of instruction, successful comprehension is usually predicated on student initiative, drawing skills being no exception. If a system were presented that allowed the student to use various parts of the design process in a complementary and structured procedure to condense the learning effort, it might accelerate skill acquisition for the average student. The Integrated Visualization System (IVS) resulted from a configuration of four parts of the design process to increase the acquisition rate of drawing skills. The four skills - **model building, photography, computer modeling, and tracing** – separately are important elements in the design process but performed collaboratively present an independent system for students to generate grids and visual data for teaching themselves to draw in proper perspective and value. Each step generates data used later in the system to establish a clear rubric for guiding the drawing effort.

STEP 1 - MODEL BUILDING

Industrial Design primarily endeavors to develop three-dimensional artifacts for culture and society. Constructing a physical example of the design is a standard towards comprehension and validation of a concept. Additionally, the act of touching or holding an object offers a second sensory path to learning correct visualization of a form in the mind for the purposes of drawing. Research with both blind and sighted subjects showed notable success in drawing unseen objects based solely on touch. (Carvalho et al, 2012; Harty, 2012) In order to teach students how to visualize reality, they need a sample or benchmark of that reality in three dimensions to gather complete data about form, light, and perspective. Building models also helps to foster good craftsmanship, an essential trait of any professional work. Monochromatic finishes focuses attention on form, details and light without the distraction of color.

STEP 2 - PHOTOGRAPHY

For design students photography is often a curriculum standard for documentation of ideas, concepts, and models. Regardless of its separate potential for graphic design and art, photography is an ideal tool for gathering accurate visual data. Seeing with visual accuracy, however, is a challenge due to the physiological and interpretive nature of the human optical system. (Collier & Collier 1986) Photography offers undistorted visual information storage for later reference. Shooting a model(s) with a single light source offers a good primer in cinematography with referenced values of light, shading, cast shadows and reflection – valuable data for design drawing or computer rendering.

STEP 3 - COMPUTER VISUALIZATION

CAD software permits the designer to precisely develop product surfaces, minimizing interpretation during implementation. Computer Aided Design supports design evaluation and aesthetic development with the ability to make small iterative changes quickly. (Tovey, 1989) The power to visualize and compose environments aids design and presentations while providing custom perspective grids for drawing. Using Trimble SketchUp offers a quick and simple method for generating general forms with lighting and cast shadows. Screen view orientation of the form can be calibrated closely to the photographic images. Printing the screen views provides an immediate perspective underlay. Although other 3D software may be used for this step, SketchUp offers precise cast shadows and wireframes for Step 4, further defining form and allowing the designer to accurately 'draw through' the visualization. It's also free.

STEP 4 - TRACING

During training designers develop the aptitude of Visual Literacy: the ability of designers to comprehend image-based information, process it cognitively, and communicate synthesized concepts to others. (Anderson, 2002; Ullman et al, 1990; Newcomer et al, 1999) Drawing and visual literacy also maintain a symbiotic relationship: draw to acquire visual literacy and expand visual literacy to improve drawing skills. Drawing over an underlay permits a fast and effective method for the iterative design process while learning perspective. Using sample groups from outside design and art using tracing to learn to draw, Eric Anderson (1997) documented faster rates of skill acquisition, reduced frustration in learning, and better visual comprehension of form. By tracing the printed perspective from SketchUp, the designer acquires proper drawing skills sooner because the accuracy of computer-generated underlays.

EMPOWERING STUDENTS TO SELF-INITIATE LEARNING

The four IVS steps, done sequentially, offer a system for developing a form, surface information, and perspective structure for accurate visualization with less need for outside correction from instructors: students may learn design drawing skills by teaching themselves. Brooks and Brooks (1993) reveal findings that learning rates associated with traditional methods of classroom teaching effect only partial knowledge retention (5% from lectures to 75% from practice). Knowledge retention increases to 90%, however, during the act of teaching. Providing students with a system where they can teach themselves through creation of their own reciprocating knowledge base may make a significant difference in the design drawing skill acquisition rates. Using the computer to establish perspective grids helps to take advantage of both manual and digital realms symbiotically.

A VISUAL GUIDE TO THE PROCEDURAL STEPS IN THE IVS



STEP 1 – MODEL - Begin with geometric models. Construct a sphere, cube, cylinder and cone from simple materials such as paper, foam or wood.



STEP 2 - PHOTOGRAPH – Visually document the models. Arrange the models in a close pattern on a level white surface establishing light from a single source. Elevate the light 55 degrees and the camera 40 degrees off horizontal. Maintaining a focal length of about 1 meter, photograph indexed positions around the scene to document how light illuminates and illustrates from different view points. (Fig. 4)



Figure 4. Step 2: Photograph the models in composition from indexed views with a single light source.



STEP 3 - COMPUTER - Generate computer models and views.

Using Trimble SketchUp, set View parameters to Shadows and Back Edges for wireframe and shading modes. Construct and compose the geometric solids in the same size, orientation and focal length as the views from IVS Step 2. Export the views and print on paper.



STEP 4 - TRACE – Trace SketchUp views.

Using trace or bond copy paper to draw on, trace the views with line only for outlines and value in initial assignment, markers for later drawings. Reference illumination values from IVS Step 2 for rendering surface lighting. Repetition is the key to a solid

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base of design visualization capabilities.

METHODOLOGY

The study tracked the effects of introduction of the Integrated Visualization System (IVS) into a second– year Industrial Design drawing course syllabus (Design 501) at The Ohio State University. Six of 20 students from 2011 consented to participate as the Control. Sixteen of 22 students from 2012 consented to participate as the Test Group.

The aim of the research was to detect an improved rate and degree of skill development of design drawing when compared to results of prior (2011) syllabus. Lectures and assignments were sequential and cumulative in nature. The syllabi for both courses (separate from IVS assignments introduced in 2012) included 3 two-week design projects that provided primary data for the research. They included products such as a lawn mower, shampoo bottle, game controller, and power tool.

The primary variables of analysis for project drawings completed by both groups were:

- 1) **Perspective** Proper convergence of parallel lines towards vanishing points without distortion.
- 2) Ellipses Correct angle of ellipse for circular forms, viewed obliquely.
- 3) Minor axes Alignment of corresponding minor axes with respective vanishing points.
- 4) **Indexing** Proportional appearance of units of measurement in perspective.

Examples of drawing data from each sample subject's work were extracted for both Initial (First) Project and Final Project drawings. The variables of analysis were assessed chronologically through the course to observe how rates of learning progress for each group. Correct perspective grids were overlaid onto each drawing and compared to perspective conventions displayed by each drawing. Significant discrepancies were noted and tallied as error rates for individuals and in aggregate.

Shading and cast shadows were included in the test group's assignment deliverables but were not assessed as a test variable in comparison to the control group. The surface definition of the objects was displayed prominently in the photographic and computer modeling steps of the procedure to present pedagogy bases on observation versus formula.

OUTCOME/ANALYSIS

Figures 5 and 6 show two best samples of initial and final student project drawings for both Control and Test groups. An evaluation rubric of blue dot (perspective errors) and red line overlays (correct perspective grid and ellipse features) was generated by the author, a senior designer.



Figure 5. Samples of Control Group drawings, initial and final projects.



Figure 6. Samples of Test Group drawings, initial and final projects.

ANALYSIS, ASSESSMENT OF PROJECT DATA FROM CONTROL, TEST GROUPS

Analysis of the drawings from both groups include the following findings:

- 1 Error rates for the **Control** Group averaged 2.16 per Initial drawing improving to 1.5 per Final drawing: an **improvement rate of 31.6%** between initial and final drawings.
- 2 Error rates for the **Test** Group averaged 1.75 per Initial drawing improving to 0.69 per Final drawing:

an improvement rate of 60.5% between initial and final drawings.

The reduction in the rate of design-drawing discrepancies indicates that the Test Group did, in fact, improve their design-drawing skills at a faster rate than the Control Group over the same course time period. Also as predicted drawing skill acquisition rates were accelerated on both individual and aggregate levels.

SIGNIFICANCE

What is a most effective pedagogy for drawing in Industrial Design education? Given industry demands for broader skill sets – digital modeling, graphic languages, drawing, prototyping, and designing skills – it is little wonder that many students' efforts may not be focused enough to become expert in any one discipline, especially drawing. One objective behind the study was to find opportunities to synthesize the disparate subject matter required within the curricula to maximize educational returns or, in essence, make education more efficient. Assessment of data generated within this study indicates a promising link to accelerated design-drawing skill development within the context of a prototypical Industrial Design education.

Other benefits of the IVS if implemented into design education may be:

- 1 a higher base level of visual literacy: research points to traditional two- and three-dimensional creative activities as classic drivers of visual literacy. (Sless, 1984; Anderson, 2002; Flood et al 2004; Felton, 2008) While the individual steps of the IVS are not unique to the design process, the particular sequence and integration of information gathering are the primary drivers of a better understanding of three dimensional form, perspective and surface lighting.
- 2 More effective product visualization in computer rendering by using photographic references for cinematographic composition.
- 3 Student portfolio evidence of more integrated design processes.

On a macro-level, the Integrated Visualization System offers a practical pedagogy for Online Education. None of the four IVS steps require prior experience to complete. A major factor in effectiveness of online education is managing the implementation of course materials and assessing the quantity and quality of the individual output and learning process. The IVS, with its built-in self-check/self-assess sequential procedures, provides a flexible system for a range of instructor involvement while minimizing the impact of absence.

During implementation of the IVS in the Spring of 2012, it became obvious including design projects in each assignment was important to maintain student interest and inspiration, both critical to the learning process. Although available as a stand-alone pedagogy, the Integrated Visualization System, based on two studies (pilot, Winter, 2012, research, Spring, 2012), appears most efficient in conjunction with an existing design drawing syllabus.

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