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Learning Scale Drawing as a Tool for Industrial Design.

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ABSTRACT

Industrial designers use various types of drawings, computer illustrations and physical models to represent the things they are designing. These representations are used not only to communicate a design to others but also for the designer to evaluate and stimulate their own thinking. A design process is usually facilitated by movement between different types of representations to explore different aspects of the design.

Sometimes, however, student industrial designers appear to become stuck in their design process, favouring one type of design representation and not using another that may have been more informative at the time. In particular, we have noticed students making inadequate use of scale drawings to check the size and arrangement of the elements of a design.

This paper presents two examples of teaching and learning scale drawing that are intended to emphasise its role particularly within the early, exploratory stages of a design process.

In the first example students were required to measure the external shape of an existing product and then make a 3D model that represents the shape through a sequence of cross-sections. A scale drawing of the surface contours of the original object was a necessary step in this process.

In the second example students used 2D CAD to make a technical drawing of an object with some moving parts. The drawings were then developed into a sequence to make a "flip book" animation of the movement.

In both cases the intention was to create a design project in which measurement and scale drawing were a necessary step towards achieving a successful outcome.

The principles underlying the development of these learning experiences are discussed in this paper.

INTRODUCTION

Different forms of drawing are used by industrial designers to represent a design under development. Drawings are used alongside other types of representations of a design such as physical 3D models and computer-generated models and images. Design representations are used not only to communicate the design to others but also by designers to externalise, evaluate and stimulate their own thinking. Van der Lugt (2005), for example describes the role of the "thinking sketch" as a means of moving a general description of an idea towards depiction of a particular arrangement. Schön (1986: p76) describes drawings as virtual worlds where the consequences of various design moves can be explored. He describes a designer (in this case, an architect) as having:

> ".. a repertoire of media that enables him to choose the graphic system best suited to exploration of particular phenomena. Sketches enable him to explore global geometries; cross sectional drawings, to examine three-dimensional effects; drawings to scale, to experiment with the dimensions of design; models, to examine relations among building mass, comparative volumes, and sun and shade. He uses media selectively to address the issues to which he gives priority at each stage of the design process."

Exploring and communicating designs through various types of representations is integral to the practice of design and the teaching and learning of modelling and communication skills is therefore a necessary and significant element of design education. The different types of communication skills required could be described as part of the designer's toolkit. Part of the challenge for a student learning to design is knowing how and when to use the various tools.

The work of experienced industrial designers shows fluid movement between different modes of representation to explore different aspects of a design (Tovey, 1989). Student industrial designers, however, sometimes seem to become stuck in the design process, favouring one type of design representation and neglecting others that might be more appropriate for the stage at which they are working.

Lawson (1994, p254) observes that some design students show a tendency to repeat the same kind of drawing or even the same view of what they are drawing. The students may need to be persuaded that a different drawing or representation is needed to enable exploration of the design to continue along a productive path. Schön (1986, p127) describes such a case in his analysis of a discussion between a tutor and an architecture student. The tutor tells the student to draw her ideas out to scale and (it is implied) he does this because he expects she will discover, in the drawing, some consequences of the choices she has made so far and perhaps some opportunities she has not yet considered.

In the author's experience, there seems to be some hesitation among industrial design students to use scale drawings, done either by hand or computer, early in the design process. Instead, some students show a tendency to continue with perspective sketches, or even computer virtual 3D modelling, without having confirmed critical dimensions and arrangements of parts. It is perhaps easy for the

appearance of the representations to dominate the student designer's thinking over the need to provide for a potential future reality of the object being designed. Scale drawings can reveal inconvenient truths that a student may not see the need to confront if their designs are abstract only and will not be put to the test of being made and used. A more experienced designer would use a scale drawing earlier so that problems can be recognised sooner rather than later.

The way in which scale drawing is presented in some educational texts may lead to a perception that scale drawings are used only to precisely communicate the outcomes of a design process rather than as a tool in the thinking that goes on within the process. We have found the need to help students discover that scale drawings are well suited to investigating the size and arrangement of elements within the design, the relationship of the design to its surroundings and the resolution of detail. Additionally, scale drawing is often a necessary step when making a physical mock-up as the parts need to be designed and marked out.

Industrial design students at the University of New South Wales (UNSW) learn manual methods of scale drawing in a first year communications course. Weekly exercises are used in the course to progressively teach the principles of orthographic projection, cross sections, practical geometry and engineering drawing standards. As well as developing manual skills, the principles learned from drawing provide a foundation for later learning of computer drafting and modeling.

Students also need to experience, as they learn, ways of using scale drawings as a means of exploring and evaluating designs at all stages of development. To help students see the potential for using drawing as a tool in design, we have framed some learning activities in the communications course so that scale drawings are a means to an end in a design problem rather than being the end product of the assignment. Two case studies are presented below.

I. Project Case studies

A. Case Study 1. The "Bare Bones" Project

The first project case study is an assignment usually done in a first-year communications course in semester 1. At this stage the students have been introduced, through lectures and in-class practical exercises, to manual technical drawing techniques and practical geometry.

The project requires students to:

1. Measure the shape of a manufactured product that has a complex curved shape. Students have to devise three-dimensional reference planes in order to do this.
2. Draw, to scale, a series of regularly spaced contours to describe the shape of the object.
3. Design and construct a model that expresses the shape of the original object through an arrangement of cardboard "ribs", each representing a cross-section contour of the original shape. The "Bare Bones" name of the project is derived from the skeletal appearance of the finished models.

Examples of the models made by students are shown in Figures 1 and 2. The models are the main assessable component of the project but a good model can only be achieved with accurate drawings and thoughtful design that addresses both the appearance and construction of the model.

Fig. 1. Card model by student, Gonzalo Portas, 2006

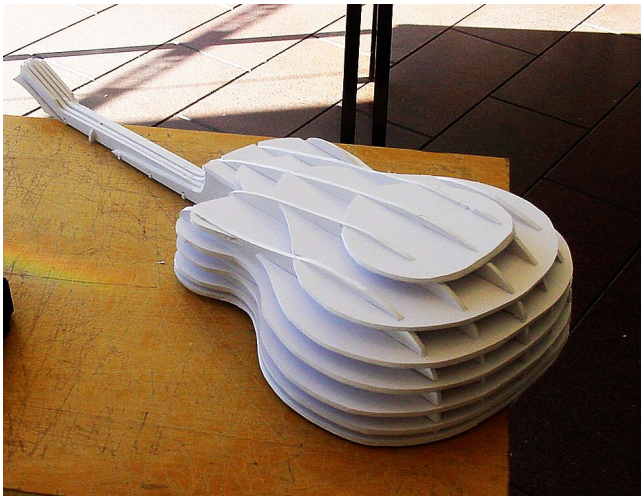

Fig. 2. Card model by student, Chern Wern Mah, 2004

B. Case Study 2: "Flip-book" animation.

The second project case study is undertaken by first-year students in semester 2, during a five-week module that introduces 2D CAD drafting. The weekly classes in this module are conducted in the computer labs and students work through self-paced tutorials that build up their knowledge of

CAD concepts and drawing tools. The project, done outside the classes, requires students to analyse and draw an object that has a simple mechanical movement. The movement of the object is shown in with alternate positions of parts drawn according to engineering drawing standards. A detail from an example student drawing is shown in Figure 3.

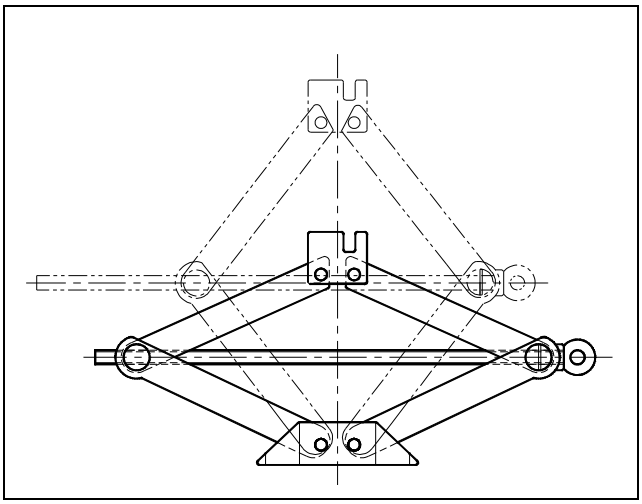

Fig. 3. Detail from CAD drawing by student, John Murdoch, 2006

This assignment has been used several times and has achieved its objective of enabling students to demonstrate their knowledge of engineering drawing conventions and standards as well as their ability to use the CAD application.

In 2006 a new requirement was introduced, to show the movement of the object by means of a flip book animation, in addition to the engineering drawing. An example is shown in Figure 4. The "low-tech" option of a physical flip-book was chosen in preference to a computer animation in order to reinforce the connections between drawing, designing and making. Determining the look and feel of the flip-book becomes a problem for students to solve with "designerly" exploration and attention is focused on a real object that is external to the computer.

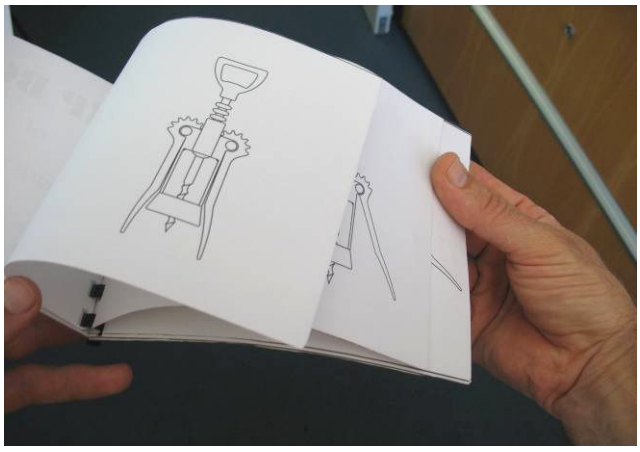

Fig. 4. Flip book animation by student, Carla Zheng, 2006

The intended learning outcomes of the project now are that students can demonstrate the ability to make engineering drawings with CAD and, with the addition of the flip-book requirement, that students demonstrate ability to use CAD drawings within a process directed toward designing and making a new object that communicates in a different way.

II. Discussion

In both projects the drawings are derived from everyday objects that the students analyse and measure. Students choose the object to use for these projects according to the degree of complexity they can manage. This means each student works with a different object and therefore solves a unique design problem. In contrast, the weekly exercises completed in class usually have students arriving at a single correct solution. These would arguably allow a shallow learning approach if used on their own. In the overall course context the weekly exercises provide understanding and practice of principles that support the open and more complex requirements of the projects.

The projects discussed have stated learning aims expressed in terms of development of particular skills and knowledge of how to do things. Less explicit, but perhaps more important, is the fact that the projects provide an opportunity for the student to learn something about designing and the place of particular skills and know-how within the process of designing.

These projects have helped to bring the learning activities of this communications course more into alignment with the overall objective of the industrial design program by presenting the skill learned as a part of a design activity. This approach follows the principle of constructive alignment discussed by Biggs (2003). Learning is constructed by the student as a result of activities aligned with the aims of the course. Assessment is also aligned with the overall objective of the industrial design program by placing emphasis on the visual, tactile and functional qualities of the objects produced rather than looking only at achievement of specific technical competencies.

The project case studies described in this paper are examples used to illustrate an approach to designing the teaching and learning of skills that support design thinking and practice. Design practice and the tools available to designers continue to change and so the learning experiences needed in design education will also change.

The examples shown will one day, perhaps soon, reach the end of their life cycle. At some time in the future even first year students may be so familiar with 3D scanning equipment and animation software that we will have to define other tools and new learning activities. However, the underlying approach to teaching and learning remains and other ways will be found to frame the learning of communication skills within design projects.

III. Evaluation and Conclusion

Experience has shown that students generally succeed in delivering the designed objects required in these assignments and there have been some outstanding examples combining high levels of technical competence with originality in design.

Feedback collected through a UNSW questionnaire known as the Course and Teaching Evaluation Instrument (CATEI) shows a strong positive response to statements that indicate these communications courses were challenging, effective for developing thinking skills and encouraged self-directed learning.

It is difficult, however, to isolate the evidence that might show these projects are achieving the objective of facilitating students' use of scale drawing as a design tool. There are many influences on students' approaches and methods in undertaking design projects in their studio courses. If these projects achieve the intended outcomes we would expect to see students making more exploratory use of scale drawing as a tool in the design studio courses throughout the four-year Industrial Design program, but this is not easily measured.

Much depends on how the learning from these projects is reinforced in the students' subsequent experience in the design studio courses. Students tend to respond to perceptions of what their design tutor expects to see, and there is a "what gets marked, gets done" factor. If the studio tutor believes a scale drawing, is a useful or necessary step in a design process then making this explicit, or making it an assessable component of the project, can be a way of guiding the student. The same could be said for any of the tools that tutors wish to encourage students to use in their exploration of design.

The learning experiences presented here as case studies may be similar to many used elsewhere, for reasons similar to those discussed. Other areas of the industrial design curriculum, such as manufacturing technology and ergonomics, also offer opportunities to frame learning experiences as design projects, and in recent years this has been done at UNSW in the courses under the control of the industrial design program. From the mostly anecdotal and subjective evidence available, the changes seem to be supporting the intended outcome of helping students integrate technical knowledge and skill with their designing processes.

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