Reflecting on Professional Practice: capturing an industrial designer's expertise to support the development of the sketching capabilities of novices

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Abstract
This paper reviews the importance of sketching to designers and clarifies the key techniques used at different stages of designing. The analysis of the author's sketching expertise is described and a survey of undergraduate perceptions of sketching was carried out using the Nominal Group Technique (NGT) and a questionnaire. A revised strategy for the teaching and learning of sketching to first year industrial design and technology undergraduates is outlined and early observations of its implementation are reported.

Key words
sketching, industrial design, teaching, learning, professional practice

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Introduction
Sketching remains a vital skill for professional designers and its teaching at undergraduate level needs to be constantly under review. In the UK, the recent introduction of Computer Aided Design (CAD) systems such as Pro/DESKTOP into many schools and colleges will inevitably have had secondary consequences on the time available to develop sketching skills. However, the relationship between manual sketching techniques and CAD is a key international issue. Good pedagogical practice concerning drawing for designing is quite properly the subject of on-going debate. It is in this context that this paper sets out to review professional practice as exemplified by the author's experience and the continued development of effective teaching and learning strategies for undergraduates relating to sketching technique.

The paper starts by establishing a 'state of the art' based upon the author's industrial experience and a basic literature review relating to sketching in a design context. Secondly a small scale survey of the perceptions on sketching of a cohort of first year undergraduate industrial designers is presented. Thirdly the findings of a reflective account of the author's teaching, using the principles outlined by Schön (1983) and Moon (2001) is juxtaposed against a small scale survey of the student first year cohort. The author then describes and discusses the teaching and learning approaches being developed in the 'Drawing for Design' module for first year undergraduates in the Department of Design and Technology at Loughborough University. Finally conclusions are drawn.

The 'state of the art'
The value of sketching to designers is reviewed through a discussion of the literature and the author's experience.

The author has ten years experience in the product design industry. He has designed a wide range of transportation, military, consumer and industrial products, both as an independent consultant and as part of design teams. This provided the opportunity to work with both novice and expert designers, experiencing their sketching techniques and the ways in which they use sketching within design projects. The author's experience in a consultancy showed that when selecting applicants for design posts the applicant's ability to explore a design task using rapid sketches was more illuminating than their ability to produce highly rendered presentation drawings. The consultancy needed designers who could express and develop ideas quickly and efficiently. In this respect early sketches provide a valuable snapshot of designer's thinking processes and thus the potential of the applicant is made more apparent.

Designers need to generate, communicate and discuss new concept ideas, both to themselves and to the other stakeholders involved in the development of new products (Griffin and Hauser, 1996). These stakeholders may be from a range of specialisms within an organisation and external participants such as focus group members and end users. A typical design project may involve: engineers, project managers and designers, as well as marketing executives, accountants, and end users. To

facilitate effective communication and understanding between stakeholders, various graphical and physical representations of new product concepts are used. Söderman (1998) points out that sketching is one of the product representation techniques central to providing this understanding.

Sketches may be used for idea generation, communication, problem solving, and the development of functional and aesthetic solutions. Sketches can be quick and inexpensive to generate (Tovey et al, 2002), require very little equipment and can be created in most environments. Romer et al, (2001) report that 96% of a sample of designers still use sketches to develop new concepts. Powell considers drawing skills to be 'indispensable in the resolution of complex form' (1990: 6.)

The author used sketching in a range of roles in industry, from the creation of new concepts to facilitating the communication of complex solutions. The ability to sketch realistically and rapidly was very apparent in this industrial context. The author sees the ability to sketch quickly as important for a number of reasons. Firstly in a commercial context (time = money) there is pressure to speed the process of new product development. Secondly, in meetings sketches are a valuable and flexible means of communication and discussion. They add an extra dimension to the discussion in that points can be clarified 'in real time', however, this means that the sketches need to be made very quickly if the discussion is not to be 'bogged down'. Finally there are indications that the ability to explore concepts rapidly promotes the flow of ideas much in the way that brainstorming should be carried out (Buzan 1985; De Bono 1983).

To illustrate the above, a survey of design consultancies reported on the Core 77 design resource website reported that graduate designer's 'sketching and freehand drawing ability have to be excellent... designers have to be fast and fluid, not slow and considered' (Core 77 1998) In the author's experience, the ability to rapidly generate many design solutions is an essential requirement for employment in a design consultancy. Designers usually worked in small groups, aiming to build a synergy. This was supported by rapid sketching in conjunction with discussion. Initially the designers aimed to produce a wide range of initial concepts freely. The sketches produced at this phase were very loose and would probably mean nothing to an outsider; essentially the sketches were tied into context with the verbal discussion at the time. The designers would then use this visual brainstorm to develop a smaller number of concepts for a process of internal review; i.e. more realistic sketches are now employed. The production of a large number of 'thumbnail' sketches allowed many styles to be explored. Internal review rejected and conflated the proposed concepts into a range of solutions that could be further refined and presented to the clients and stakeholders in the form of highly realistic presentation drawings for further review. Thumbnail sketches offer minimal investment in time but require a level of familiarity and experience to 'read' accurately.

A wide range of rapidly and inexpensively produced concept sketched provide a fertile arena for discussion between designers while concepts which are difficult to articulate are clarified. For example, the client may want the product to be 'more in the Ferrari style' rather than 'Audi'; such concepts are difficult to discuss with words but possible if sketches are used in addition. In this way the designers could develop, relatively quickly, concept drawings to a level of detail and realism for them to the interpreted by a client and other stakeholders. When working on functional solutions, fewer solutions would be sketched and modelled, although as the more developed solutions required proving in three dimensions, rapid work was still required.

The exact mental processes that occur when creating new design concepts are not yet known. Various methods are available to express the internal discourse that occurs when attempting to solve a design problem. Keywords, thumbnail

sketches, annotations, brainstorming and talking to yourself, all may help to externalise the internal discourse without requiring extensive effort. However, sketching in particular is cited as having a further use other than merely a medium for recording ideas. Verstijnen and Hennessey (1998) propose that design tasks are typically too complex to resolve entirely without externalising some elements. They consider that during design activity, elements of the solution are processed in small bites, by a part of the brain that operates at high speed, but has limited capacity. Sketching and self-conversations may allow partially resolved elements of the design task to overflow, be logged and lined up for further processing.. The use of sketching during this phase provides a useful store of instances in the progression of the design whilst possibly freeing the brain to process the next stage effectively expanding working memory (Purcel and Gero 1998). The role of sketching in expanding working memory is a common theme in the literature.

The act of sketching allows shapes and ideas to evolve on paper very quickly, when they are still somewhat unresolved in the designers' head, thus allowing concepts to emerge that might otherwise be missed or discounted if a more laboured medium was used. In contrast a typical 3D CAD system requires much more detailed input to model an idea, and as such the pace of development may hinder chance discoveries.

Emergence can be defined as the discovery of unintended concepts or ideas through the interpretation or combination of unresolved or ambiguous sketches. For example a line out of place may hint at a new proportion. Emergence is also a common theme in the literature (Garner 1990; Goldshmidt 1991). Lund and Stenholm (1994) consider that sketching should be used to generate the chaos from which a solution is to be found, although the exact wording may be lost in translation; this appears be a reference to emergence. The generation of concept ideas goes through a cyclical process of sketching, analysing and reflection which Goldshmidt (1991) refers to the use of combination and reinterpretation of the emerging ideas to allow further design solutions to surface.

Sketch development phases

Following the discussion above, it is useful to analyse sketching into three distinct stages, although the boundaries of each stage are blurred. The first stage of sketching in the context of new product development tends to produce what are often referred to as 'thumbnails'. These are the first marks on paper, proposing initially very unresolved and in some cases very random forms and ideas that are a result of visual brainstorming or 'brainsketching' (Van der Lugt 2002). Goldshmidt (1991) points out that these represent the first externally recorded links between the subconscious processing of the designer's mind and the design problem in question. Thumbnails are a very rapid sketch of a proposed physical form or mechanism that answers elements of the design brief. Goldshmidt (ibid) considers that these thumbnail sketches, indicate a two way discourse, with the designer both generating and responding to the sketches. The ideas contained in the sketch are transient; representing a snapshot of the designer's thought processes. These often intentionally ambiguous sketches do not necessarily 'fix' the design, but hint at a solution (Garner, 1990) allowing various interpretations to be made of the information presented, both by the designer and other members of the design team.

The relatively unfinished and simplistic nature of thumbnail sketches, as illustrated in Figure 1, allow many ideas to be logged quickly. At the early stages of a design project, influences from the designer's own experience and from collected inspirational material may be being combined to generate these ideas. The short amount of time invested in each sketch gives twofold benefits; an improvement in confidence as each sketch becomes less precious, hence more original and unusual ideas can be explored quickly; and possibly closer links to unconscious thought processes are represented. The unfinished and ambiguous nature of the sketch makes them inappropriate for communication with anyone other than experienced designers (Gyi et al 2003)

Figure 1. Thumbnail sketches.

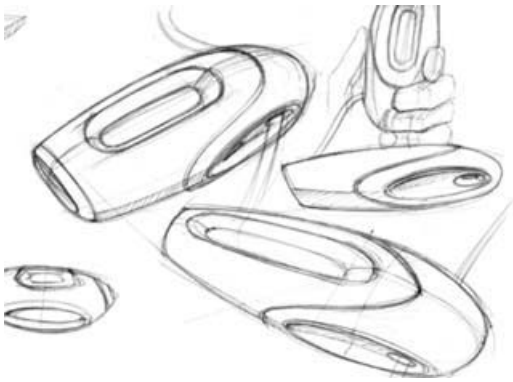


Figure 2. Semi-detailed sketch.

Figure 2 illustrates the next identifiable sketching stage, the semi-detailed sketch. This will typically resolve more design elements and present them using reasonably accurate perspective views or elevations. Although this stage requires more investment of time, the improved realism should allow more colleagues, possibly from other disciplines, to understand and evaluate the design work

The final presentation drawing stage, illustrated by Figure 3 involves a high degree of realism and detail development. A range of form, colour, texture, engineering and ergonomic solutions may be presented within the same drawing. The improved realism over the aforementioned other forms of sketching allows more people to understand the design and thus offer more accurate feedback, at the expense of requiring much more time to create.

Figure 3. Presentation drawing.

Although these three types of sketching/drawing have been presented in a linear fashion, use is often made of each type throughout a design project, as various obstacles are encountered and resolved.

Undergraduate perspectives on sketching

This section aims to explore new undergraduates' perspectives on sketching. This survey used Nominal Group Technique (NGT) (Lomax and McLeman 1984) with a small sample (n= 18) of students to establish an agenda. This was then used to design a questionnaire which was administered to the cohort of 120 first year Industrial Design and Technology undergraduate students taking the Drawing for Design module. The survey method is described and the analysis indicates four general areas for further discussion.

The NGT method was used because it generates issues which are important to the respondents rather than those identified by the researcher. In this case a sample of 18

volunteer first year students were asked to individually mind map their perceptions of the 'Drawing for Design' module. Secondly a 'moderator' from among the group collated the individual mind maps on a sequential basis, listing them on a flipchart for all to see. This continued until all perceptions were logged. As the overall mind map evolved students were allowed to add further comments as ideas were 'sparked off'. Thirdly, group discussion generated an agreed series of statements derived from these perceptions. These statements were put into positive or negative form so that it was possible to respond to them using a six-point scale of agree/disagree (prevents 'fence sitting'). Each student then responded to each statement on that six-point scale. The results were collected and collated to give a score for each statement. Finally this set of results from the sample of 18 was used to generate a questionnaire, which was administered to the whole cohort of 120, of whom 98 replied. It should be noted that whilst these techniques generated numerical data - i.e. weightings against given statements, they were, nevertheless, based on qualitative data. The results of the NGT exercise, questionnaire and the author's reflection logs were compared and contrasted.

Analysis of the survey of undergraduates generated many interesting issues, which can be discussed around four main areas: perspective and related issues, speed/accuracy, confidence, and efficiency. The specific results of the NGT exercise and the questionnaire were qualitative in nature and, therefore difficult to present in conventional format concisely. The author has, therefore, embedded the results as appropriate within the discussion below.

Discussion

The author, in contrasting the survey results with the literature and his own reflective practice has identified three key areas for discussion: perspective and related issues, speed and accuracy, confidence.

Perspective and related issues

Industrial designers tend to work in teams during concept development stages, using rapid sketches, words and annotation to facilitate communication and emergence. These sketches need to be fast and realistic enough to advance thinking whilst remaining easy to manipulate. At this stage simplicity and a degree of ambiguity can be valuable (Garner 1990). In contrast observation of new students' sketch work showed evidence of slow mark making and a failure to understand the principles of perspective. It was evident that many students could not 'see' errors in perspective. This translated into considerable lack of confidence amongst the sample.

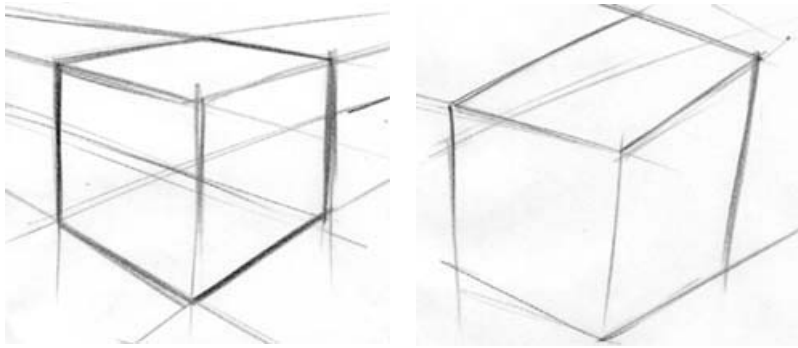


Figure 4. Shows a cube sketched using freehand two point perspective on the left and an example of common errors on the right.

The survey showed that 18.5 % claimed they were not taught perspective drawing at school and had always used isometric techniques. When they were taught perspective, the average age this was done was 13.7. Most were taught by drawing cubes and 'buildings' in two-point perspective. Whilst 34% reported they experienced no problems with perspective during the first undergraduate year, observation indicated (Figure 4) that many could not 'see' errors. 21% reported problems with perspective drawing of ellipses and curves; observation indicated the real percentage was higher. It was evident that this caused significant problems with drawing more organic, curved shapes.

Observation and reflection on student performance and the survey findings indicated a limited grasp of the principles of perspective. Common problems included an inability to derive the correct placement of vanishing points and the inability to use perspective without rulers/aids. These factors were causing effects such as poor sketch quality, inaccuracy and lack of confidence. It can be argued that students were spending most time struggling to generate sketch forms and were not, therefore, able to use the technique as intended: to develop concepts. Revisiting the driving analogy, in the early stages of driving the learner tends to look at the gear lever when changing gear. Later the process becomes ingrained and the driver can focus on the overall task: driving.

Media
Observation and the survey indicated that students tended to be initially very precious with each sketch. They would use pencil and spend time rubbing out perceived errors and correcting. This initially slowed the concept development phase, preventing rapid solution generation and slowing or limiting the design process and range of solutions explored.

Mark making
Students tended to be only able to use one intensity of line, whichever media they were using. This means they were unable to use subtlety of line to indicate distance/depth, development or to establish the position of a line without frequent erasing. Students were introduced to sketching with Biro. This media prevents rubbing out and yet enables a range of line quality to be produced. Experience showed biro sketches to be less precious and freer. Many students reported this new found freedom, but also being told not to use Biro by teachers in schools.

Form description
Observation and the survey showed that students had been taught, in schools, to use shading techniques to give 'body' and depth to sketches. Whilst this technique works, it is relatively slow and inappropriate for concept level work where speed of development is important.

Sketching and CAD
In schools there have been considerable developments in CAD systems and software, notably Pro/DESKTOP. This raises two broad issues in relation to concept level sketch work. The time available for teaching design subjects in schools has not increased and the introduction of CAD must have impacted on the time available for teaching hand sketching techniques. Secondly Pro/DESKTOP presents images in isometric rather than perspective. This means students are less likely to have experience of using perspective which remains a key technique in consultancy type industrial design. Isometric techniques are suited to structural drawings but are limited in terms of aesthetic representation.

Speed/accuracy

During the first 'Drawing for Design' session students are asked to sketch a fairly complex object such as a mobile phone as a diagnostic exercise. Initial observation showed students to be slow at sketching, with a reliance on aids such as rulers. Much time would be spent erasing and repeating lines with time spent more on details, rather than establishing the overall form. In consultancy, speed is a necessity and initial sketches sacrifice accuracy to promote speed. Confidence and practice have a significant impact on speed. A lack of ability in understanding perspective, line quality or form description will slow down sketching. At the early stage in their design careers many students lack the necessary ability in these areas.

It must be recognised that sketching from observation is quite a different skill to creative sketching. Although the same mechanical skills are in use, observational sketching involves the recording of form in two dimensions. Slow progress in observational sketching can be explained as a lack of skill or application. However when sketching new objects that only exist at some level in the designer's 'mind's eye' the question must be asked is poor performance due to a lack of ideas or a limited ability to express them? Brief studies by the author into the difference in apparent sketching skills between observational and creative sketching assignments indicate that the students tend to be better at observational sketching than creative. At an early stage in their design careers students may not be confident enough in their own design decision making to create form quickly. The author considers that successful creative sketching and designing requires a body of knowledge to base new ideas upon. Particularly when developing aesthetic design solutions, a mental and graphical library of existing products and inspirational images can be combined and restructured to provide various initial 'start points.'

Confidence

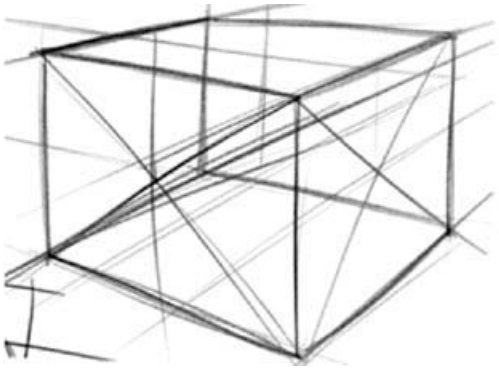
Many of the points above relate to the question of confidence in design sketching. There are two broad issues here. Firstly, teaching and learning quality enabling students to develop both technique and confidence to sketch quickly and efficiently. Secondly, observation shows that many students are increasingly concerned about 'what staff want?' They seek simple examples of good practice, often not realising that there are many levels/ issues involved and that skill comes only with considerable application and practice.

A revised teaching and learning strategy for undergraduates

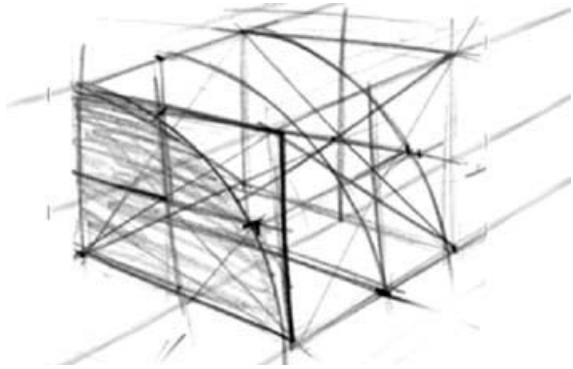
Analysing the author's sketching techniques

Sketching is such a central part of consultancy work that for the author it became an almost automatic activity. Using the analogy of driving a car, it is easy to explain the various car control techniques to a learner driver on a simplistic level. However the nuances and finesse of an expert driver take a great deal of reflection and analysis to identify, and communicate. Similarly when decanting ten years of almost unconscious sketch activity into an undergraduate module there are issues both of identification and communication to resolve. To prepare the new Drawing for Design module considerable time was spent analysing the author's sketching techniques. Observational and creative sketching exercises were undertaken and recorded both by video camera, and by scanning the sketch at regular intervals. This allowed the sketching process to be reviewed repeatedly. Many different techniques emerged, with often a range of methods employed within the same sketch. Essentially three main methods were used to describe form, referred to here as: crating, primitives and sections. These methods provided the foundation for the emerging revisions to the undergraduate module.

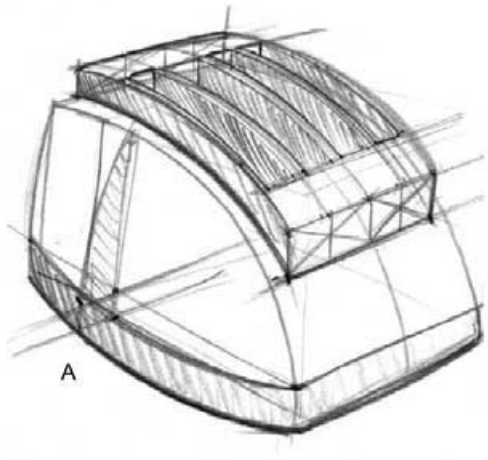
Figure 5. Brief analysis of the techniques involved in sketching a toaster from observation. Particular attention is paid to establishing the correct perspective and sketching from basic geometry rather than outline or negative space.



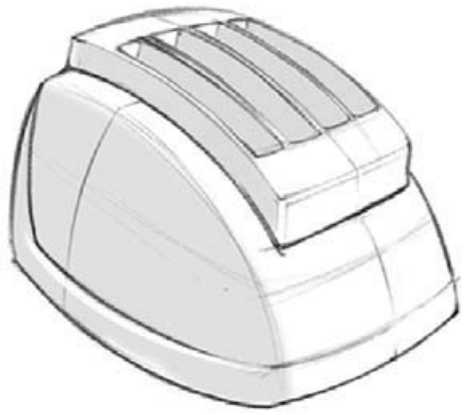
i) Perspective grid generated and a crate is sketched corresponding to the extremities of the product.



ii) The basic quadrant shape is roughed out within the crate.



iii) The toast slot area is added by projecting upwards from the top surface of the quadrant sketch. A section is used to define the curve on the product sides at A.



iv) Line work is tidied up and basic shading according to a light source added.

Curriculum developments in the Drawing for Design module

A library search will return many books on the theory of perspective. However finding very simple 'starter perspective' guides is difficult. The basic idea that objects appear to be smaller as the distance from the viewer increases is a relatively simple concept to communicate to the students. However applying this to sketching products is a difficult skill to master. The author aims to demystify the concept of perspective in the modules by presenting three, albeit established methods of sketching in a specific manner:

- crating
- primitives
- sections.

The minutia of the module is not reported in this paper, however an overview of the methodology follows.

The perspective sketching element of the course begins with the analysis of images to illustrate foreshortening. A range of objects and viewpoints are analysed to illustrate how to express scale and create interest by manipulating the position of vanishing points and the horizon line.

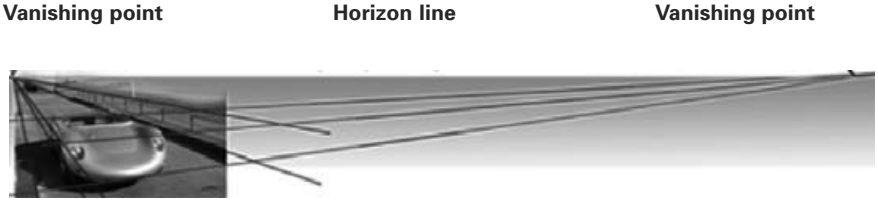


Figure 6. An example of a perspective grid derived from a photograph

The three methods all require a basic perspective grid as the foundation for the sketch. Figure 7 illustrates three stages in generating a series of perspective gridlines, radiating from two vanishing points on the horizon. For clarity the vanishing points are shown on the same page as the sketch, however in reality this produces an exaggerated view, and the vanishing points are normally located outside of the paper area. It is not intended to present highly accurate measured perspective, but to provide a simple and quick system to help sketch generation at a 'good enough' level

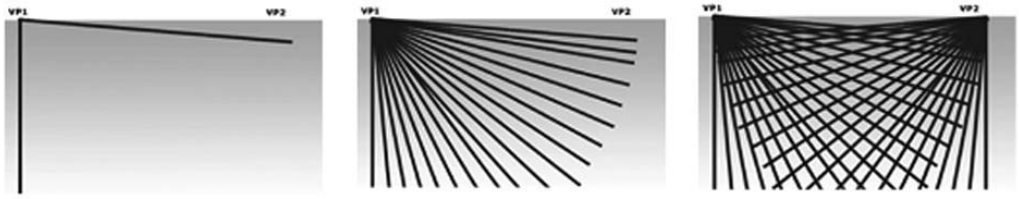


Figure 7. Stages in the creation of a perspective grid.

Figure 8 shows how, through the use of the grid, rectangles can be created in perspective. Then by adding vertical lines, and connecting the gridlines, it can be a relatively simple process to create boxes in perspective.

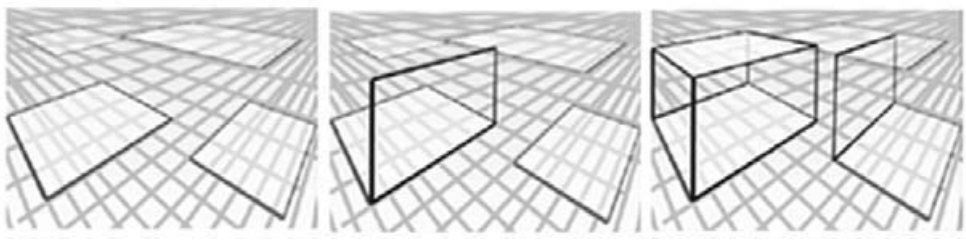


Figure 8. Perspective boxes or crates, created using a perspective grid

Crating

These boxes form the basis of the first method, crating. Crating may be the most common form of taught perspective sketching technique, and is reportedly taught in most schools within design and technology courses. It involves creating boxes or crates in perspective that correspond to the external dimensions of the object in questions. Each face of the crate corresponds to the elevations of an orthographic drawing of the object in question. Almost all students are capable and confident of sketching a side view of any object

Side elevation of a chair

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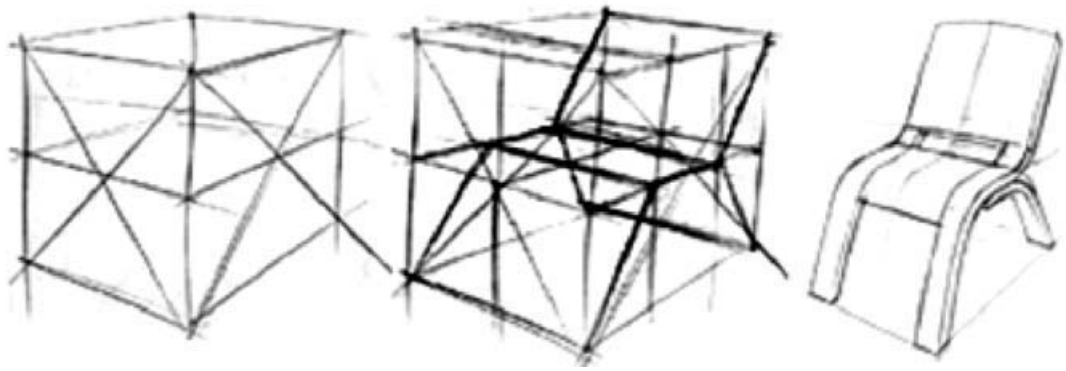


Figure 9. Stages in sketching a chair using crating.

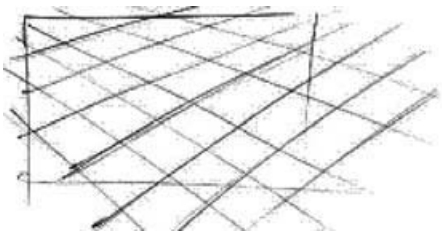
The example shown in Figure 9 shows stages in creating a sketch of a chair using the crating technique. It illustrates how to create a convincing perspective view from a side view. The side view is sketched and enclosed in an appropriate rectangle, subdivided into quarters. A corresponding crate is sketched using the perspective grid, and diagonal lines from corner to corner locate the centre of each face. In this case, the side elevation is sketched onto opposing faces of the crate and the two elevations connected. A clean sheet of paper is then placed over the crated construction lines and the sketch refined. Although this is a relatively simple example, crating can be employed to sketch more complex objects by subdividing the object into a number of crates.

Primitives

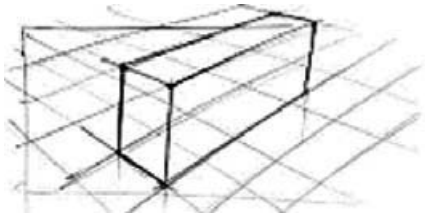
The second technique involves analysing complex objects and simplifying them into a number of primitive shapes. Additive or subtractive combinations of spheres, cylinders, cubes and cones are sketched on a perspective grid to describe the geometry of the object in question.

Figure 10. The four basic primitives.

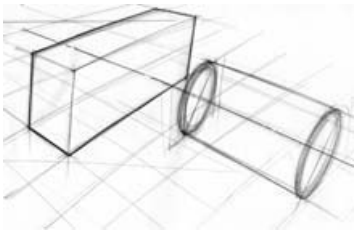
The following example illustrates the process involved in sketching a camera using primitives:



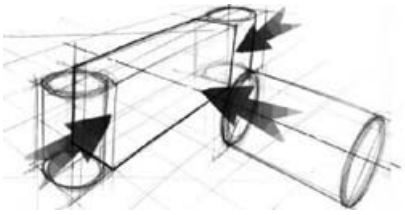
i) Begin with a suitable viewpoint and sketch perspective gridlines.



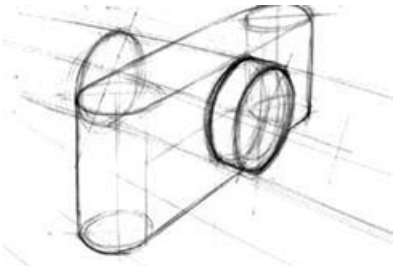
ii) Sketch a cuboid shape corresponding to the main body of the camera.



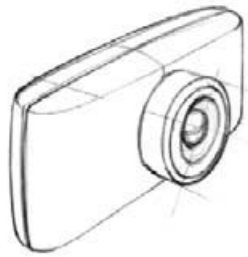
iii) Add a cylinder corresponding to the lens area, notice how the central axis of the cylinder aligns with the gridline.



iv) Construct cylinders to define the ends of the main body.



v) Lightly sketch in the vertical cylinders in the correct position to create the curved end surfaces.



vi) Trace over the construction sketch-work, picking out the correct lines.

Figure 11. Stages in drawing a camera using the primitive method

Sections (contour lines)

The third method uses sections through an object and surface contours to describe form. The previous two methods crating and primitives, could be used to sketch a complex curvaceous form, such as a sports car, however the sections method in particular offers benefits when representing organic form. It involves imagining slices through the object and arranging them in order along perspective gridlines. The sections method forces analysis of the surface contours of the object; which may benefit subsequent CAD or physical modelling activities. Figure 12 Illustrates the process of sketching a car using the sections method.

A series of sections are arranged on gridlines. The sections are connected using surface defining contour lines. Finally the sketch is traced over and refined.

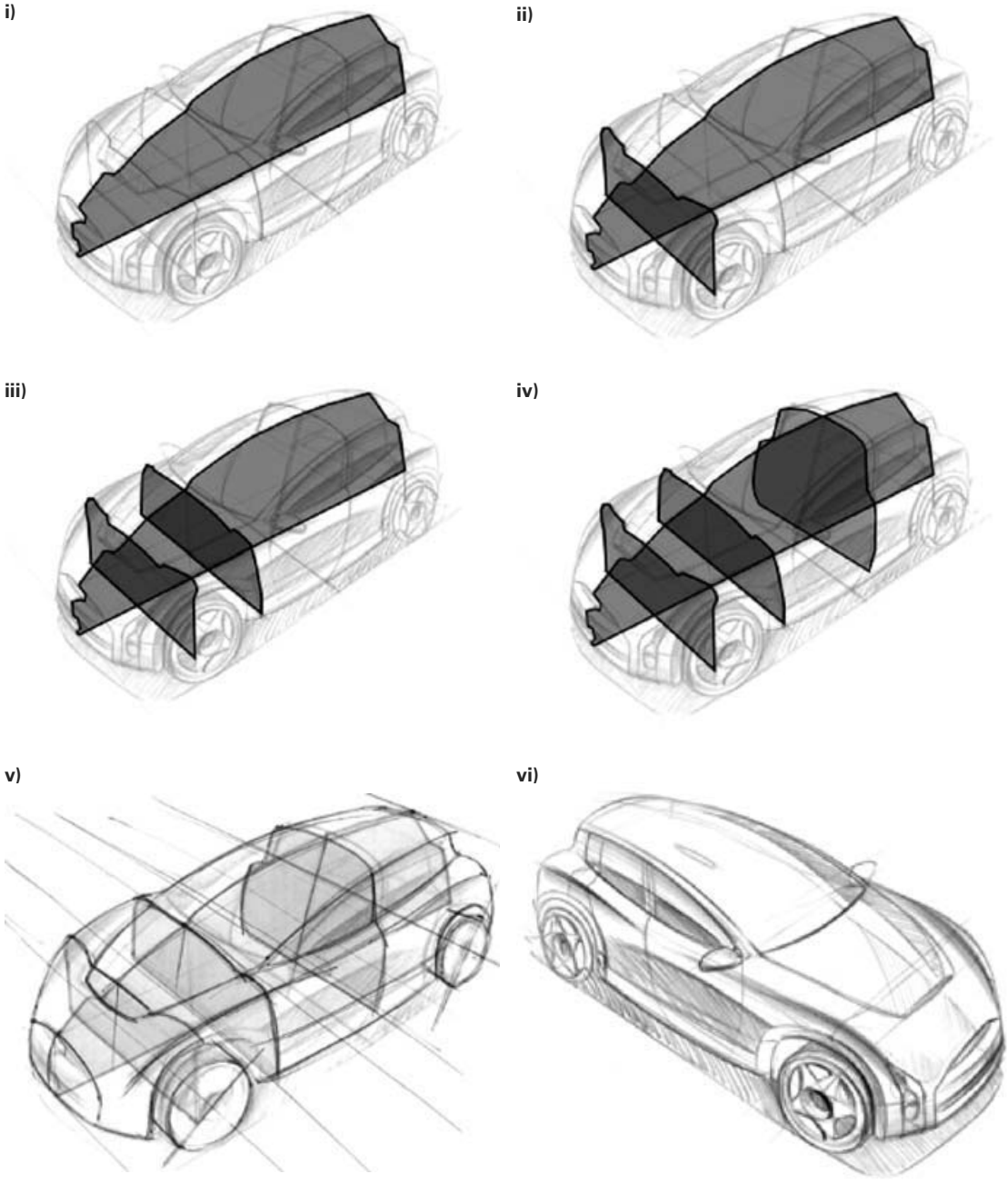
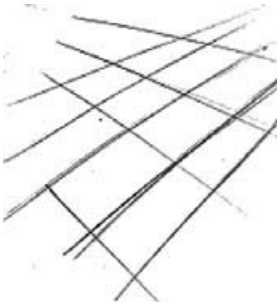
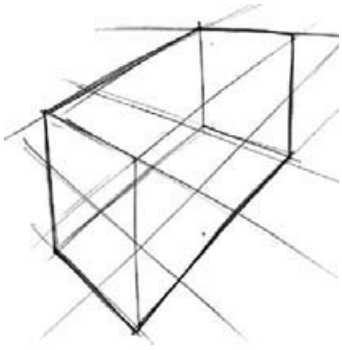


Figure 12. Using sections to sketch a car.

The three techniques were introduced to the students as distinct methods during the author's second year of teaching. Previously they had been shown during sketching demonstrations but not highlighted overtly. Industrial Designers tend to use a mix of the three methods, depending on the product in question.

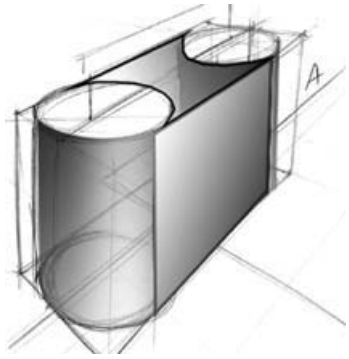


i) Sketch grid.

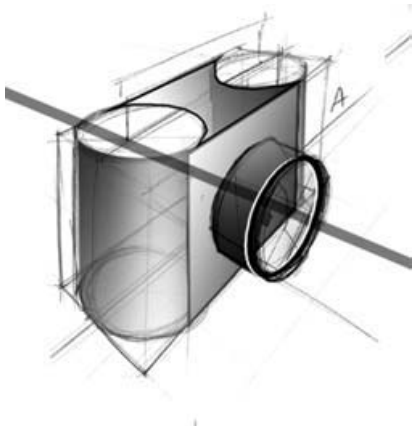


ii) Sketch cate using gridlines.

iii) Add vertical cylinder primitives to approximate the form.



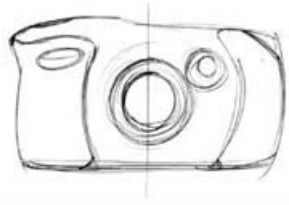
iv) Shading added to aid clarity.



v) Add cylinder to form the lens protusion.

At this stage in the production of the sketch, crating and primitives have been employed to describe the geometry and proportions of the camera.

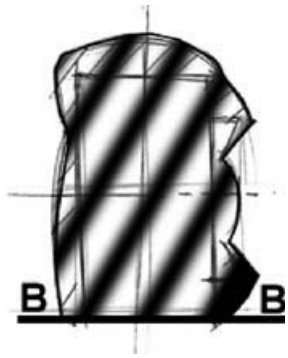
The next stage is to add two sections through the product to describe the complex surface contours.



vi) Sketch front elevation of the camera.

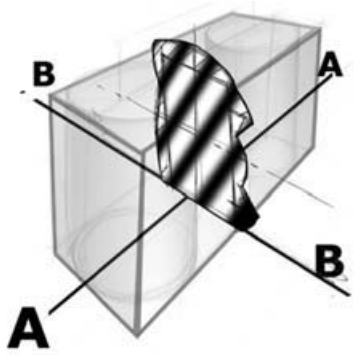
Section on AA derived from front elevation.

vii) Sketch side elevation.

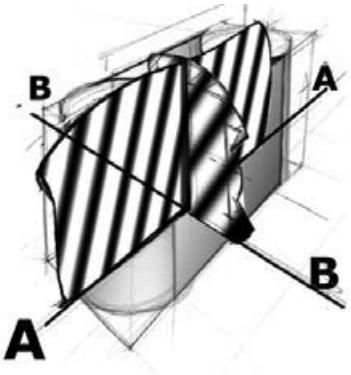


Section on BB derived from side elevation.

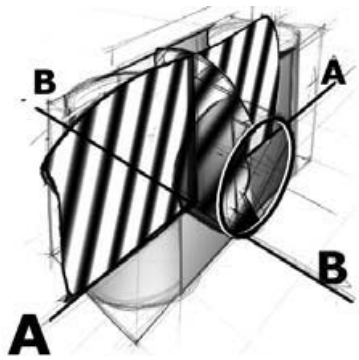
viii) Front elevation/Section AA sketched on the longitudinal centreline of the product



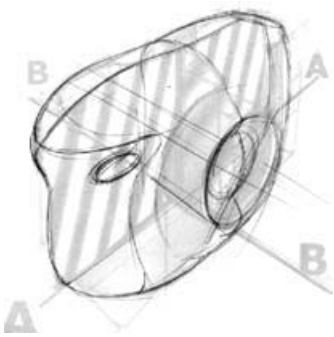
ix) Side elevation/ Section BB sketched on the transverse centreline



x) Both elevations/sections sketched on the respective centrelines.



xi) Add lens primitive.



xii) Sketch over the construction geometry on an overlaid page connecting the sections and primitives.

xiii) Tidy up line work and vary line thickness to describe form and component join lines etc.

Figure 13. Shows a series of steps in sketching a camera using a combination of Crating, Primitives and Sections.

Early observations concerning the implementation of the new strategy

The initial teaching of the revised module and reflection on this process has led to a number of observations:

- Use of the three methods appeared to raise confidence by allowing students to describe a complex object in a series of relatively simple steps. This ensured that the student always knows the next step to take and the mysterious process of sketching and perspective becomes much more transparent.

- The author has previously observed that first year students tended to be very reluctant to develop sketches; they were slow to start and sketches appeared to be very precious. This tends to lower the potential for creativity. By using grid and construction lines students can confidently start making marks immediately. The pristine quality of the paper is removed and this appeared to promote speed and experimentation. The technique also enabled the students to see immediately where errors have occurred.

- The three methods also make the student engage with the three-dimensional form of the objects in question. This encourages them to 'see' how objects are built up in terms of proportions, volume, contour and surface detail rather than simply as outlines. They are starting to relate to three-dimensional form immediately. This improved understanding is essential when analysing products for other considerations such as ergonomics, styling, manufacturing etc. It may also assist when modelling design concepts in digital or traditional formats.

- However, at first, acceptance of the three methods was not universal. Initially, time spent on view and grid construction may have appeared wasted to students who have developed their own techniques during school based study. A number of complicated shapes needed to be sketched with self analysis and tutor feedback on the results, before all students could see the benefit of the methods. A later survey showed that the whole cohort used at least one or combinations of the methods when sketching.

- Various media are demonstrated during the module and the pros and cons of each discussed. However the students are encouraged to sketch with Biro to begin with. Biro as a sketching medium allows a range of line intensities from very faint construction lines to bold outlines which through the prevention of rubbing out allows the student to see the evolution of a drawing, helping personal analysis and reflection.

- Variation in line intensity is used to create depth and distinguish outlines from internal, contour or construction lines. A degree of mechanical skill is required to vary line intensity with just one pen or pencil, which will only be developed through considerable practice.

- Some students take a lot of persuasion to let go of the techniques used possibly very successfully during AS/A2 level study. There is some reluctance to engage with perspective and many prefer the comfort of isometric sketching. The three methods are used so extensively throughout the module that there is little opportunity to stay with isometric techniques.

- Sketching incorporates kinaesthetic actions, i.e. the brain signals and muscular contractions that control the production of the sketch, need to be learned and practiced. An athlete can train to improve performance by repeating a specific exercise; hence it seems logical that a designer may be able to improve efficiency by practising sketching. Particularly at the start of a design career, time spent 'working out' the 'sketching muscles' is time well spent. It follows that as a result of this practice, sketching can become more automatic, thus potentially releasing more of the brain's processing power towards solving the design task.

- The indications are that these combined techniques are encouraging students to see sketching as a modelling technique rather than simply a method of generating 'pictures'. The focus is now clearly of the sketch as a model used to describe and actively develop an idea/form.

Conclusion

Ideally, undergraduate designers who intend to follow a career in the design industry must be expert at sketching by the time of graduation. The degree course is a relatively short time to perfect these abilities.

Ten or fifteen years ago there was little alternative to sketching to present design ideas, and sketching was used at almost all stages of a design project. However, now CAD is increasingly used to present final design concepts, replacing some of the time spent sketching in both schools and universities. The survey shows that students are arriving with very basic sketching skills and little confidence. Although some students may initially consider themselves to be excellent at sketching they soon realise that the quality and speed required at this level is a considerable step above school based work. Confidence appears to be an essential element if students are to use sketches to design and communicate freely. However, confidence can only develop from being taught principles correctly and then practicing over a broad range of examples, carefully chosen to iteratively improve skills. This takes time and careful planning.

CAD drawing techniques are increasing available to present and develop design ideas. There is some concern about CAD replacing sketching, however the author considers that both CAD and sketching can complement each other, offering synergistic benefits to the designer. For example the three methods of sketching can also be found as methods to create geometry in various CAD packages; Crating has similarities with traditional solid modelling systems, Primitives are the basic building blocks of 3D Studio Max and the Sections method is very much like a surface modelling technique such as Alias Wavefront. CAD can be used to generate; grids, primitives, sections and crates in perspective as a starting point for sketches. Efforts are being made to more overtly link the teaching of CAD with the teaching of sketching to give a more cohesive structure to the use of modelling tools in design.

The findings indicate that the author's reflection on his design consultancy experience and skills, in this case specifically sketching, can transform and improve the teaching and learning of these skills. This approach is to be extended to other consultancy based design skills and examined to explore how this might be used to enhance teaching and learning at an undergraduate level. For degree courses that offer some level of vocational skills training it is essential to keep abreast of current Industry practice. The design business moves quickly and teaching methods and subject matter need to be continually reassessed and updated to keep up or even lead. Hence to keep teaching quality at a high level a degree of research activity needs to be directed at investigating current professional.

The final element to ensure success in design sketching rests with the student themselves. Educators only have a finite amount of time available. Methodology can be explained thoroughly, examples and demonstrations can be presented clearly and tutorial material can be made available on intranets. However if students do not engage with the subject and spend time practising the techniques, little progress will be made.

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