A METHODOLOGY FOR TEACHING NOVICE PRODUCT DESIGNERS HOW TO USE REPRESENTATIONS IN THE DESIGN OF SIMPLE MECHANICAL PRODUCTS

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ABSTRACT
The work describes a methodology for teaching broad-based students of product design how to use representations in the process of creating ideas for new products. Simple mechanical products are used as the focus for 'hands-on' product analysis exercises that provide opportunities for students to develop an experiential base in product function. Some examples of students using the experiential base to design and make functional prototypes are described and analysed. A commentary is given on the efficacy of the methodology in providing the conditions under which students can bring together representational automaticity, common sense and experience to produce innovative new products.

Keywords: Design education, creativity, engineering design

1 INTRODUCTION
Product designers use representations in almost every aspect of the process of creating new products. Representations provide designers with efficient mental models of the concepts, rules and systematic methods that underpin the creative process (1). Representations are used in many forms and also provide designers with a means whereby the knowledge and experience gained from creating past designs can be stored mentally and accessed as an intellectual resource for creating new ones (2). Designers who can employ an automaticity in manipulating representations are able to reduce the cognitive demands of sheer memory and are able to apply creative thought processes more freely (3).

The ability to employ an automaticity in forming and manipulating representations is a function of experience and is unique to the individual designer. Experienced designers are able to call upon an extensive base of past experience and it is the experiential base that shapes the initial responses of designers faced with new design problems (4). These initial responses often appear to be spontaneous and intuitive and a function of nothing more than common sense, but it is this form of common sense that enables the experienced designer to make reliable judgements (5).

The field of product design spreads across diverse intellectual areas and the nature of common sense as an intellectual capability is different in each area. In order to identify some of these differences, it is helpful to examine the notion of common sense in general and a helpful definition is offered by Marvin Minsky:

'Common sense is not a simple thing. Instead, it is an immense society of hard-earned practical ideas – of life-learned rules and exceptions, dispositions and tendencies, balances and checks.' (6).

This general definition of common sense provides a useful starting point for understanding the particular notions of common sense that are of interest to designers. The hard-earned practical 'ideas' and 'rules' in the context of industrial design and the ability to form and manipulate representations of these 'ideas' and 'rules' provide the foundations of the experiential base in designers.

In recognising that experience provides the base for common sense and that common sense is not a simple thing, it is also recognised that teaching common sense cannot be a simple thing. It is evident that if novice designers are to become proficient at using common sense, then they need experience of forming and manipulating the representations upon which common sense is based.

This experience is provided by the reported methodology which sets students the task of designing and making a mechanically functional product. In tackling this task, the student is required to apply particular intellectual and practical skills. Taken together, these skills can be regarded as a form of acumen, a sharpness of mind, applied in response to a design task. In the context of design for mechanical function, a particular form of acumen is required and this can be identified as mechanical acumen. Mechanical acumen in this case, constitutes a notion of common sense that enables industrial designers to deal with ideas in mechanical design. With regard to designing and making simple products, mechanical acumen can be defined as:

'The ability to judge well the relevance and value of the mechanical principles inherent in the design of everyday artefacts and the ability to use these principles in the design of new products' (7).

Devising a methodology that teaches students how to form and use the representations that underpin this form of common sense is a more manageable proposition than devising a methodology for teaching students a general form of common sense for use in the broad spectrum of industrial design. In the chosen case, the context in which the learning is to take place can be adequately bounded and the relevant representations of the practical 'ideas' and 'rules' upon which mechanical acumen is founded can be easily identified and properly defined.

2 REPRESENTING THE INNOVATION PROCESS

Students need to understand the ways in which the design process can be represented in order to give proper direction to creative effort and identify the principal areas within which ideas for new products can be generated. The design process can be represented in many ways, but the essential message for students is that the process cannot begin without ideas. A simplified model of the product innovation process is given in Figure 1 which shows how ideas for new products can spring from different sources within a manufacturing enterprise. Three mutually dependent sources are shown - design for technical function, industrial design, and design for manufacture. In each area, particular forms of representation are required and novice designers need to be familiar with these different forms if they are to develop a broad base of design skills.

The problem for those concerned with teaching students how to build an internalised structure of representations is to provide a 'hands-on' methodology that enables students to develop their own mental database in the same way as designers working in professional practice. The reported work addresses this problem by providing a methodology focused on the design of hand-held products. Everyday consumer products have been chosen for the focus since such products have a high degree of familiarity with students and provide product examples where the technical principles are not too complicated to obscure the lessons to be learned.

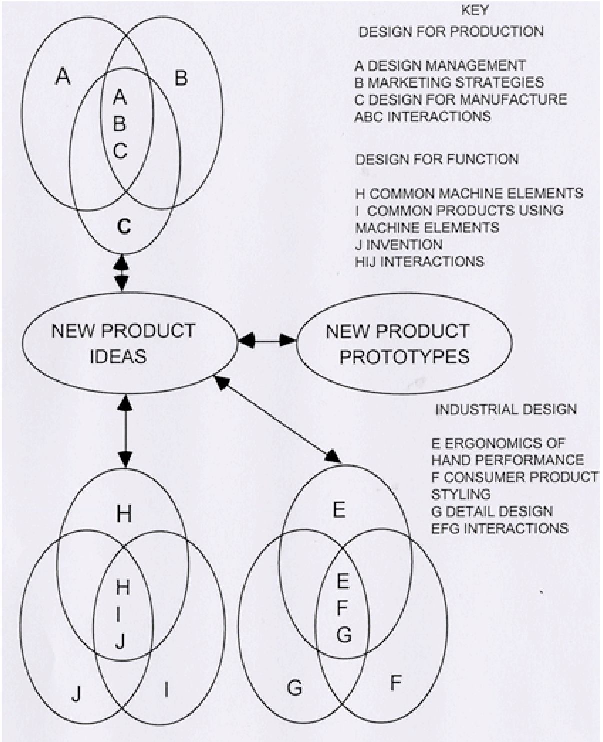

Figure 1. Three fields for representations in the innovation chain

3 REPRESENTATIONS IN IDEA GENERATION

With regard to the design of everyday functional products, a structure that identifies the areas where designers are required to form and use representations is shown in Figure 2. The structure shows how the search for new product ideas can be approached from any one of four different perspectives - mechanisms, styling, ergonomics and manufacturing and shows that a theoretically infinite number of feature permutations, and consequently, prototype designs can be produced to satisfy a single design concept characteristic of each one.

Students may make little sense of such models representing the design process since, in general, they lack the experience necessary to imagine applications of the model without practical examples of its use. Figure 3 gives a practical example showing two successful products from the consumer gift market. In this example the model has been used to conduct a broad-based product analysis exercise. The model shows how the flow of ideas, feature permutations and integrations can be identified and traced within a structured framework. It is by conducting such exercises that students can derive an understanding of (i) how models representing the design process can be used and (ii) how the characteristic forms of representation of ideas can be applied within the model.

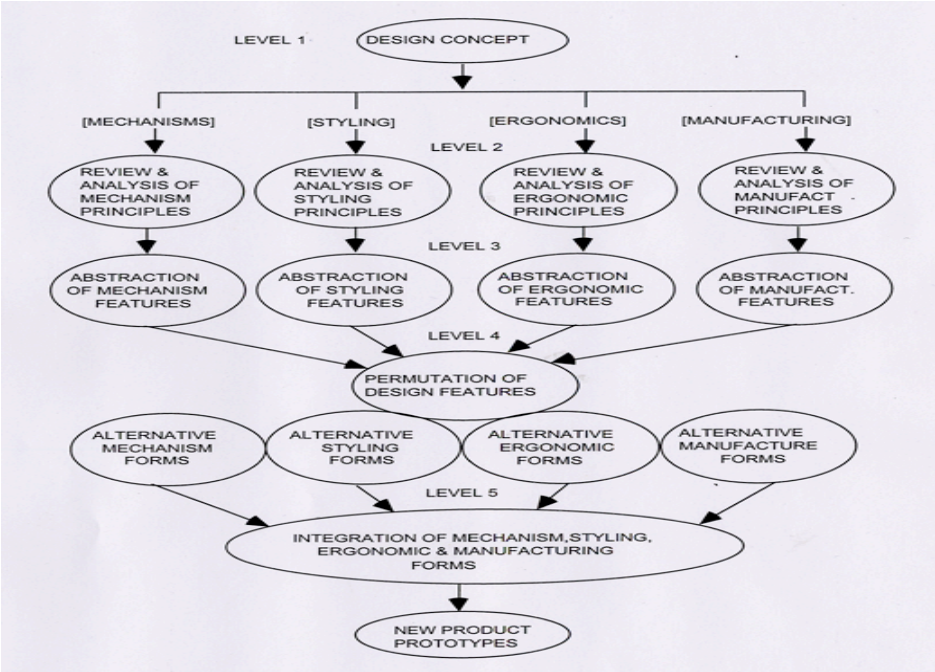

Figure 2. The role of representations in a structured design process

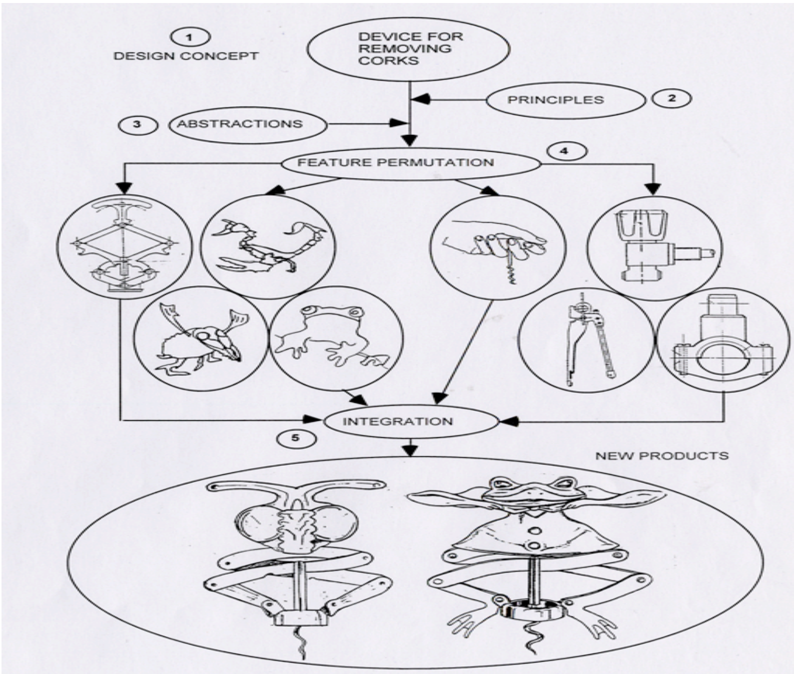

Figure 3. The role of representations in product analysis

4 REPRESENTING IDEAS EMBODIED IN PRODUCTS

The two products shown in Figure 3 have both evolved from one basic mechanical principle, the lazytong mechanism. However, each product bears little resemblance to the basic, utilitarian design from which it has evolved (8). The success of such products is directly attributable to the ability of the designer to extract, represent and manipulate existing ideas, rather than make new inventions in mechanism design. Experienced designers are able to make reliable judgements and students need experience on which to base judgements in the same way as experienced designers (9). Hands-on product analysis exercises based on directed investigations enable students to develop an experiential base as a foundation for their own judgements.

5 LEARNING REPRESENTATIONAL AUTOMATICITY

Designers need to employ representations in the same effortless way that mathematicians are able to employ algorithm automaticity in solving algebraic problems (10). In the simple products shown, the areas of mechanisms, styling, ergonomics and manufacture all require distinctive and characteristic forms of representation to be used in the manipulation of ideas. In the context of mechanism design the automatic representation of concepts is needed in order for the designer to free the mind for the creative manipulation of ideas. In this context, representational automaticity can be regarded as a pre-requisite for intelligent behaviour and the application of common sense. The structured practical investigations embodied in Figure 3 help students to identify and represent the mechanical elements and systems that provide functionality.

Experienced designers are able to choose the most appropriate and expeditious methods of representation from an established repertoire involving drawing and modelling at one extreme and words and numbers at the other (11). Novice designers need such methods in order to engage meaningfully in the process of creating ideas for new products.

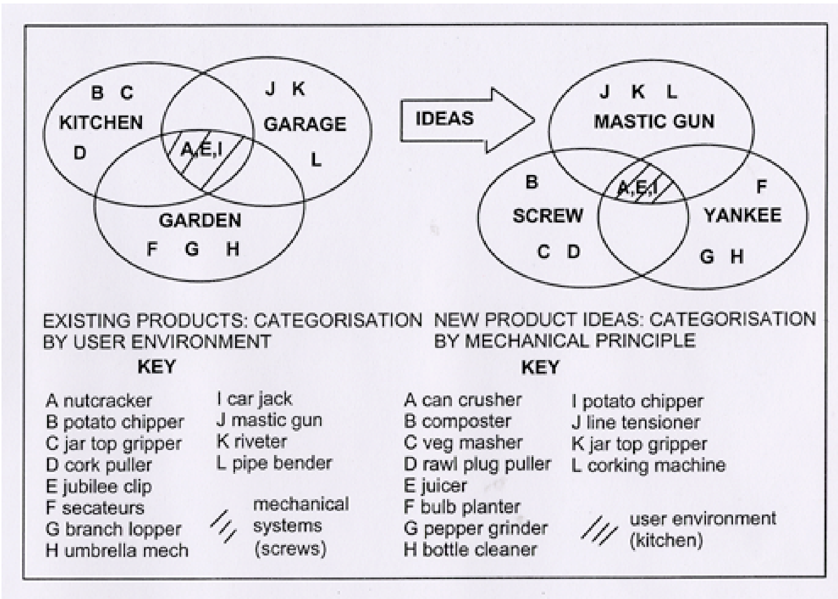

Figure 4. The role of representations in making property analyses

6 USING REPRESENTATIONS IN DESIGN

Student design exercises at the most basic level are best when focused on a product design area that has relevance within the students' own experience of using products. A suitable focus is provided by products that students encounter in their everyday lives, such as, those products found in the home, garage or workshop.

Figure 4 gives an example showing how various concepts concerned with product function have been identified, represented and used to make product categorisations. The products used incorporate a variety of mechanical systems and in the given example the screw thread has been identified as the common concept in products from three different user environments (12). Some ideas for new products generated by students using the conceptual understanding derived from making product categorisations are also shown in Figure 4.

7 AN ANALYSIS OF STUDENTS' PROTOTYPES

Two of the ideas developed by students using the methodology are shown in Figures 5 and 6. In each case, a prototype has been developed to demonstrate the effectiveness of the mechanical system in performing its allotted task. Each of the students has used the mechanical elements embodied in the mastic gun mechanism to generate a new product design. The designs show how the students have brought together a practical understanding of mechanical product function, life experiences and creativity to produce something new (13).

7.1 Corking machine for wine bottles

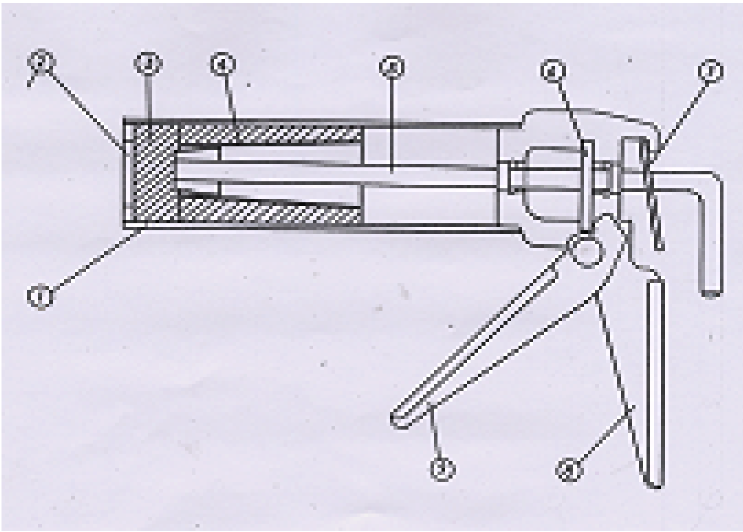

Figure 5. A corking machine for wine bottles

The student's attempt to design a better corking machine arises from his personal interest in home wine making. His integration of mechanical elements from existing corking machines with the mastic gun mechanism forms a unique product The design is a proper use of the performance characteristics of the mastic gun mechanism in that it provides the necessary hand force magnification over the required range of travel and usefully employs the friction lock. The design provides ergonomic advantages over two existing corking devices - for example, (i) the wooden sleeve and mallet and (ii) the sleeve and pivoted lever machine. The new design provides for one-handed operation, improved stability and reduced operator skill.

7.2 Bicycle brake tool

Similarly, the bicycle brake tool arises from the personal interests of the student and his particular experience of performing an essential task in bicycle maintenance. In this case, the design provides an entirely new product function and has been conceived as a direct result of bringing together personal experience and the given techniques. The student has not used the mastic gun mechanism directly, but has adapted it by changing the class of lever, re-positioning the friction lock and using the mechanism to pull instead of push. It properly uses the performance characteristic of the mastic gun mechanism in that it delivers variable force over a suitable range of movement and maintains the locking action. The design provides ergonomic advantages in that it eases the manipulative demands of the cable tightening task and reduces the skill required.

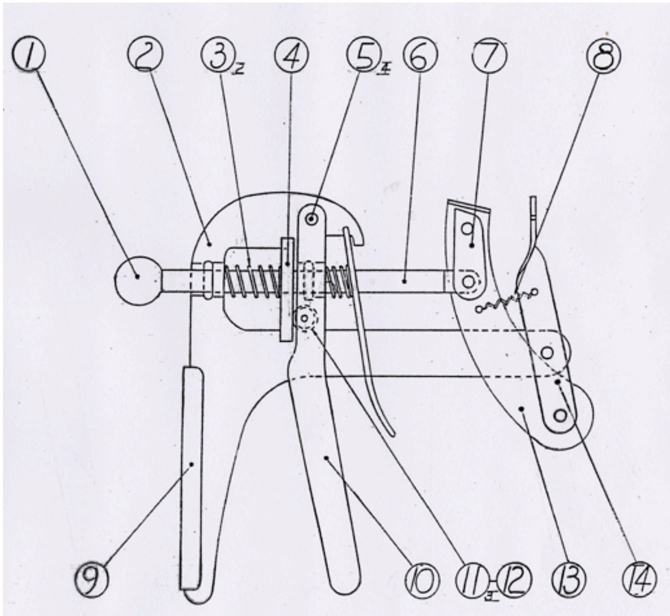

Figure 6. A machine for tightening brake cables

8 CONCLUSIONS

The functional prototypes made by students and analysed in the work constitute innovative proposals for new hand-held consumer products. The nature of innovation in each proposal is different, but each innovation has been shown to spring from a common source - the interaction between ideas represented in common products, ideas represented in existing mechanical devices and ideas represented within the process of invention. The proposals demonstrate that mechanical acumen can be learned and applied by students who have little previous experience of designing and making functional mechanical products. The working prototypes provide evidence that the students have been able to use the practical experience of 'thinking with the hands' to form appropriate representations and to use these representations as a basis for the higher order intellectual pursuit of 'generating and realising' new product ideas.

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