Case studies of creativity in innovative product development

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Case Studies of Creativity in Innovative Product Development

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1 INTRODUCTION

Case Studies of creative designers and innovators can reveal much useful understanding and insight into:

- the product development process;
- the role of creative thinking in product development, where creative design ideas come from and how they are developed into working products;
- the problems faced by designers and inventors in getting novel products on to the market as commercial innovations.

This paper examines some of these questions through case studies of creative individuals who have invented, designed, developed and introduced innovative products. The individuals and products are:

- James Dyson, an inventor, entrepreneur and product designer, and his innovative designs of wheelbarrow and vacuum cleaner;
- Mark Sanders, a product designer and design consultant, and his novel design of folding bicycle.

In addition brief comparison is made between these cases and similar examples of innovative mechanical products created by other individual inventor/designers.

These are cases of designers and innovators either working alone or in a small consultancy business and the focus is on how creative individuals conceive ideas and develop them. Nevertheless, the insights into the creative process provided by these cases are also relevant to the characteristics and practices of designers and engineers working in large R & D and design teams.

2 RESEARCH METHOD

The case studies were developed using a similar research method. This first involved background research on the products and inventor/designers concerned, using published articles, patents, etc., followed by preliminary interviews with the individuals. Then in-depth interviews with the individuals were conducted. Finally, material gathered at the interviews - including promotional material, archive drawings and notes, photographs, etc. - was consulted and a further search for published information was made.

The case studies were originally prepared as educational material for an undergraduate Open University design course, entitled *Design: Principles and Practice* which was first presented in 1992. Video programmes for this course were made using recordings made during the interviews. These videos and the full interview transcripts provided a valuable source of information for the material in this paper.

3 THE CASE STUDIES

The case studies presented in this section were chosen to help provide an understanding of the motivations of two creative inventor/designers; their sources of ideas; their different approaches to developing those ideas; their use of drawing and modelling at different stages of product development; their need for specific knowledge and expertise and their use of tools such as creative thinking techniques and computer-aided design (CAD). The cases also illustrate some of the difficulties faced by British inventors and designers in commercialising innovative products.

James Dyson - the Ballbarrow and Cyclone

James Dyson is an inventor and designer, trained at the Royal College of Art, who directs a small research, design and development company based near Bath. He is best known for two products; a wheelbarrow with a ball-shaped wheel called the Ballbarrow and a novel type of domestic cleaner based on the cyclone principle, called the Cyclone or 'G-force' vacuum cleaner. The creative and innovative processes behind the development of these products is outlined below.

The Ballbarrow

Many innovative designs arise from a creative individual's dissatisfaction with, and desire to improve, existing products - what has been termed 'constructive discontent'. In this case it was Dyson's experience of using of a conventional barrow whose wheel sunk into soft surfaces, whose body shape was poor for mixing cement and which was difficult to tip, that stimulated him to design the Ballbarrow (Figure 1). Dyson got the key idea for a ball-shaped wheel from his experience as a designer in an engineering company called Rotork, where he learned about balloon tyres produced by rotational moulding for amphibious vehicles. This is a clear case of the *transfer* of an idea and technology from one application to another.

From this basic idea, Dyson developed the Ballbarrow concept, from initial sketches and drawings, to a prototype with a fibre-glass wheel moulded around a football, to patents and the finished design.

Dyson is an entrepeneur as well as an inventor/designer and always designs with manufacturing constraints and market potential in mind. With a relatively low investment in tooling required, he saw an opportunity to set up a business to make and sell the Ballbarrow.

Existing wholesalers and retailers of garden equipment did not think this novel design would sell and so Dyson initially marketed the Ballbarrow by mail order. He discovered that it sold well, even at about three times the price of conventional wheelbarrows. The Ballbarrow was launched in 1975 and after about four years Dyson sold the business to a major manufacturer. The Ballbarrow is still in production over fifteen years after its introduction and is now widely available through retailers.

Figures 1 and 2

The Cylone vacuum cleaner

Dyson's next invention and enterprise arose from a production problem in the Ballbarrow factory. The resin powder used to coat the metal parts of the Ballbarrow kept clogging the fitration system. Dyson was advised to install an industrial cyclone (similar to that used to remove dust from the air in sawmills and other industrial plant) to separate the fine powder from the air. While installing the cyclone James Dyson got the idea for a domestic cleaner that used the cyclone principle to separate the dust from dirty air (see Figure 3). Although it may be argued that the cyclone cleaner idea arose by chance, it is significant that Dyson is always on the lookout for such ideas and 'chance favours the prepared mind'. As with the Ballbarrow, Dyson's cyclone cleaner involved a mental *transfer* of technology from one application to another - 'We're never original' he observed, 'there are always connections somewhere'.

Dyson established the basic technical feasibility of his idea by testing a simple cardboard model cylone fitted to a conventional vacuum cleaner. Dyson then considered the commercial potential of his invention before attempting to develop it. In this case tooling costs were likely to be high and it would therefore be necessary to license production to a major manufacturer. However, since vacuum cleaner technology had been static for years, he considered that the price of a radically new cleaner could be set sufficiently high for it to be a viable proposition.

Conceiving the basic idea behind the cyclone cleaner was, however, only the beginning of a lengthy research, design and development process. Determining the precise shapes of the cyclones needed to efficiently separate coarse particles and fine dust entailed Dyson in making and testing many thousands of brass, aluminium and perspex models in his workshop (Figure 4). He argues that this empirical 'cut and try' approach was necessary because none of the theories about how cyclones worked could provide the answers he wanted. Nevertheless, other individuals might have attempted to model the cyclone mathematically before proceeding to empirical experimenation.

The first protoype, with two cyclones, one for particles and one for dust, placed side-by-side was built in 1981 (Figure 4 - centre). This innovative design was an upright cleaner that did not clog or lose power as it filled with dust, was easy to empty and had a built-in retractable hose to provide the functions of a cylinder vacuum cleaner. Its design involved Dyson's combination of skills as inventor, engineer and industrial designer.

Figures 3, 4 and 5

Dyson showed his prototype cyclone cleaner to the two major UK manufacturers of vacuum cleaners. Although keen to see his invention, these manufacturers were not willing to license it for production. Dyson believes that this rejection was partly due to the 'not invented here' syndrome and partly because such a radically new product represented too great a risk and challenge to the established technology. Undeterred, Dyson conducted further design and development work and produced a completely new design with concentric cyclones plus other improved features (the 'G-force vacuum cleaner' - see Figure 3 and Figure 4 -left). He deliberately designed the product to be coloured pink to emphasis its innovativeness and made the cylone enclosure transparent so that customers would be be to observe the swirling dust particles. 'From a market standpoint', Dyson argues, 'if the product contains any new ideas then it is absolutely essential that the product be visually different'. [1]

This design was successfully licensed in 1986 to a Japanese manufacturer after an abortive contract involving a British, an Italian and a US firm. The US firm subsequently copied the cyclone cleaner, which forced Dyson into very costly patent litigation. In the early 1990s the pink vacuum cleaner continued in production in Japan in limited numbers for design-conscious customers willing to pay £1100 for the machine. However, by then Dyson had licenced another US firm to produce a cyclone cleaner called the 'Fantom' which was coloured black and sold at a more realistic price of about $300. In 1993 Dyson's company launched in the UK another new design of cyclone cleaner, the Dyson Dual Cyclone (Figure 5). This was priced at £199, comparable to that of top-of the-range conventional vacuum cleaners from the major manufacturers which had earlier rejected the cyclone concept.

Dyson's company has developed or is designing several other products using the cyclone principle, including a dry powder carpet cleaner, a wet-and-dry tank cleaner, a stick-shaped compact cleaner, a back-pack industrial cleaner and a device for removing soot from diesel exhaust. Dyson is therefore using his invention as the basis for a whole family of designs.

Dyson's creative approach

Dyson combines the ability to conceive and develop technical inventions with the design skills to translate those inventions into attractive products. His particular approach to invention and creative design depends on getting ideas and solving problems when working with and observing physical objects (what Thring and Laithwaite [2] call 'thinking with the hands') rather than by drawing or theorising. Dyson says he almost never solves problems by getting 'brainwaves in the bath' - on the classic psychological model of creativity [3] - for him solutions come when 'welding or hammering something in the workshop'.

Dyson also believes that at the initial concept stage of an invention or new design it is best not to be *too* expert because the innovator has to question established ideas. However, in order to develop an idea into something that works and can be economically manufactured it is usually necessary to become highly expert technically. He observed: 'The more you get involved and study something in depth, the more creative ideas arise. You can't create marketable innovations as a amateur.' Fortunately, acquiring the necessary in-depth expertise is not very difficult when focussed on a finite problem and specific area of knowledge.

Dyson's company makes extensive use of CAD running on personal computers for a variety of purposes, especially producing engineering and presentation drawings and analysing test results. Dyson does not regard CAD technology to be directly relevant to creative design, but it can liberate time formerly required for routine drawing and other tasks for creative work.

Thus, for Dyson, innovation is a matter of having good ideas based on experience and careful observation of the real world followed by hard work involving practical skills and technical expertise to convert that idea into a marketable product.

Mark Sanders - the Strida

The Strida is an innovative design of folding bicycle intended for short distance use and to link with other modes of transport. Mark Sanders designed the Strida while he was a mature postgraduate student on the joint Royal College of Art/Imperial College Industrial Design Engineering course (although he had been thinking about folding bicycles while working as a mechanical engineer before joining the course). As with the Ballbarrow the Strida arose from personal need, Sanders was commuting from Windsor to London and felt that a folding bicycle would both meet his transport needs and provide a suitable college project.

Specification

Having decided on a folding bike, the starting point - as in most well-managed design projects - was a specification. The main points of the specification drawn up by Sanders, after reviewing the current state of the art in folding bicycle design, are shown in the box below.

PROPOSED FOLDING BICYCLE [4]

A folding bicycle for short journeys with emphasis on low cost, simplicity and ease of use.

Draft Specification

1 *Cost* - low pricing essential i.e retail about £100 [...]

2 *Foldability* - must be very simple and obvious, ideally taking less than 10 seconds.

3 *Appearance* - must look simple (most folding bicycles look complex - a mass of tubes, spokes and cables); must look 'modern' and fashionable.

4 *Original* - ideally a new configuration rather than a folding version of an existing configuration - patentable.

5 *Ease of handling when folded* - must be easy to handle on public transport, without any sharp bits sticking out, and must fit in most car boots.

6 *Weight* - must be light enough to be carried i.e less than 25 pounds.

7 *Cleanliness* - must be clean and require minimum maintenance.

8 *Additional features* - to appeal to both non-cyclists and cyclists for short suburban journeys, possibly in conjunction with other forms of transport i.e commuting.

Basic concept

What general form of folding bicycle would satisfy the specification Sanders had set himself? Often an idea for solving a problem will arise from an individual mentally 'immersing themselves in the problem'. Sanders did this by spending a long time thinking about folding bicycles and jotting down ideas as they occurred. Realising that none of the existing types of folding bike were satisfactory, he turned for inspiration to other folding devices. The Maclaren baby buggy (a very successful design of folding childs' pushchair) led Sanders to the basic concept behind the Strida. This was a bike that would fold up, not into the smallest size possible, but like the buggy, into 'a stick with wheels at one end' (Figure 6). Like the buggy, such a bicycle could be carried in car boots, in buses and on trains. Here is a clear case of an *analogy* (in this case an object with a similar function) providing the basic concept for an innovative design.

Figure 6

Conceptual design

The next step was to find a configuration that would fold into the desired form. For this conceptual design stage Sanders again 'immersed himself in the problem' by making sketches of as many designs of folding bicycle as he could find in the literature and elsewhere and sketching new ideas as they occurred (Figure 7). Two basic configurations - an X-shaped and a triangular frame - emerged after two months researching, thinking and sketching. Alternative forms of these basic configurations with different folding and drive mechanisms were systematically checked against the specification on a matrix and the choice verified with the aid of simple wire models (Figure 8). Sanders chose the triangular frame configuration because it was novel and therefore could be patented. This choice was further checked by simple calculations of the loads and stresses in the frame members and by building an adjustable test rig from available cycle components to test basic ergonomics and steering characteristics.

Figures 7 and 8

Detail design

Having established the basic configuration, more detailed aspects of the design had to be tackled. These also required considerable creativity.

For example, on the wire model the triangular frame folded using a slider crank mechanism (the front end of the bottom tube sliding up the front tube). But for the wheels to fold together, this concept was abandoned in favour of the simpler solution of a joint between the bottom and front tubes.

Sanders conceived the design of the bottom and top joints by different approaches. The bottom joint design arose from thinking of other objects that easily disconnect. A car seat belt clasp provided the concept (Figure 9) - another clear example of *analogical* thinking in creative design. For the top joint Sanders was having difficulties with the mechanical design. So he turned to an approach of thinking visually - 'what would look good at the top of the triangle' - from the viewpoint of the rider. This provided the inspiration which lead to the design of a ball and socket top joint. As before Sanders used sketching extensively to 'clarify and develop the ideas I was having in my head'.

After a lot of further detailed design work, including decisions on materials, calculations to check dimensions of components, etc., Sanders was able to patent his invention (Figure 10) and build the first working prototype.

Figures 9, 10 and 11

Manufacture and marketing

Sanders attempted, unsucessfully, to interest several manufacturers in making and marketing his patented folding bicycle. It was only after the first prototype was exhibited at the Royal College of Art degree show and featured in *The Sunday Times* in 1985 that manufacturers began to show interest. This led to an agreement with an entrepreneur who established a company to put the design into production.

The production version of the Strida has larger tube diameters than the prototype for extra stiffness and several prototype components were redesigned so as to be more economical to manufacture. The Strida has several unique features including a triangular frame constructed from bonded aluminium, a toothed belt drive and several plastics components (Figure 11).

The Strida was launched in 1987 at £189 and sold well in Japan, Italy, Germany and Scandinavia, but less well in the conservative UK market. The company marketing the (then Portugese-manufactured) Strida ceased trading in 1992, after some 25,000 machines had been sold. The patents reverted back to Sanders, who then assigned them to the British Technology Group to license to manufacturers around the world. Future production is most likely to be in Japan or the USA.

Computer-Aided Design

Since the Strida project Sanders has made considerable use of computer-aided design running on his personal computer. Although the original Strida was not designed using CAD, Sanders used his computer to produce the drawings for a steel-frame version, and the system Sanders uses could have been used to display animated 3D models of alternative frame configurations. This latter technique Sanders uses very effectively for other projects in his work as an independent design consultant. He views CAD as a tool that helps him rapidly explore, refine and present design ideas. It is most useful *after* the conceptual stage because the computer system is not as fast as sketching for exploring ideas.

Sanders' creative approach

Sanders, like Dyson, combines engineering and industrial design skills, but has a different approach to creative design. Key points of this approach include:

• 'Immersing yourself in the problem' at each stage in order to see if ideas from other areas or from nature (biological analogies) might offer a solution.

• Gathering information from any likely source, including both specialist publications on the problem in question and general design or engineering reference books for ideas and information on related products, mechanisms, etc.

• Sketching 'as a dialogue with yourself' or 'visual brainstorming' to get as many ideas as possible down on paper in order to 'clarify vague ideas in the head' and to move forward. The standard of drawing can be quite rough as the sketches are for personal use.

4 COMPARISONS

From these case studies of innovative product development it is possible to identify many similarities in and differences between: the product development process; the sources of creative ideas; the personal qualities of the individuals who produced the innovations; and the way in which the products were introduced to the market.

The product development process

The product development process followed a broadly similar pattern in the three cases, but with differences in the details depending on the nature of the innovation and the approach of the individual concerned.

Two projects arose from the personal need of the designer (Ballbarrow, Strida) and one from the chance occurrence of an inventive idea (Cyclone).

In all three cases the inventor/designers considered that their idea had commercial potential. However, in none of the cases was any formal market research conducted to assess the potential demand or to identify the requirements of potential customers. Indeed Dyson argues that conventional market research, 'meaning asking people what they want is absolutely no use at all...it cannot predict how successful a radically new product is going to be.' He contrasts conventional market research with his approach of creatively researching the market: 'seeing what other people are doing and why, getting market figures, analysing costings, shopping...travelling, study, by observing what is there and what isn't, new ideas are born'. [1]

In only one case (Strida) was a written specification for the proposed product drawn up. This is despite all the evidence about the importance of drawing up detailed market and technical specifications at the beginning of any product development project [5]. The lack of formal specifications is probably due to the fact that these were projects conducted by individuals working alone or in small organisations who may not have felt the need to write down a specification for communication to other people.

In all cases there was a '*primary generator*' [6], or essential generating idea, behind the invention or new design - a ball-shaped wheel, the cylone principle, a 'wheels on a stick' folded form. This arose at the beginning, or at an early stage, in the project and provided the guiding concept for all the design and development work that followed.

Conceptual design involved testing the technical feasibility of this basic idea, using a mockup (Cyclone) and/or developing a configuration that could practically embody the concept, by sketching, or physical modelling (Ball-barrow, Strida).

As the projects moved from concept to development the processes diverged due to the different nature of the problems to be solved. Extensive empirical experimentation to verify and optimise the performance of an inventive technical idea was required in the case of the Cyclone before a working prototype could be constructed. Producing this prototype involved creating an overall design configuration to embody the technology plus detail design of components. In the other cases (Ball-barrow, Strida), no new technical principle was involved and so detail design of the components of a production prototype through sketching, engineering analysis, physical models and mockups could proceed once the overall design configuration had been established.

In one case (Ballbarrow) the design was relatively simple and could be established in sufficient detail at the prototype stage for materials to be specified, tools to be ordered and manufacture to commence. However, the Cyclone and Strida were more complex products and considerable further design and development work was required to covert the prototype to a product suitable for manufacture and sale.

Sources of creative ideas

As these cases clearly show, creative ideas are needed not only to provide the basic concept for an innovative product but also to solve the many development and detail design problems involved in converting the basic concept into a commercial innovation. These creative ideas can come from many sources. The basic concept for both of Dyson's innovations arose from a mental *transfer* of technology from one application to another. Sanders, on the other hand, tended to seek *analogies* between the problem he was trying to solve and products or components with similar functions.

Although Sanders occasionally uses 'brainstorming with other people he knows well' when stuck for ideas, in general such inventor/designers rarely employ formal creativity techniques. This may be because of their inate ability to generate new ideas, but Eugene Ferguson [7] has suggested a more important reason:

> 'More important to a designer than a set of techniques (empty of content) to induce creativity are a knowledge of current practice and products and a growing stock of first hand knowledge and insights gained through critical field observation of engineering projects and industrial plants.'

It is not surprising therefore that in searching for ideas both individuals draw upon their prior knowledge and accumulated experience. However, both also recognise that it is almost always necessary to obtain further information from any accessible source. Where they may differ is in the timing and in their preferred method of thinking. For Dyson it is often better to be relatively uninformed at the early concept stage so as not to be hampered by prior solutions, but at the development stage to become a 'leading expert' in the particular area of the invention, whereas Sanders 'immerses himself in the problem' and existing solutions from the start. Dyson moves forward by working with physical models, mockups and prototypes and relatively little drawing, whereas Sanders uses sketching as his main means of problem exploration. What is clear from these cases is that innovative design is never an easy matter; it requires knowledge and expertise plus sustained and dedicated effort over a long period.

Personal qualities of innovators

It follows from the above that a high level of commitment to completing a given project, against all the obstacles that are bound to occur, is one very important quality of innovators. Both Dyson and Sanders combine skills in the technical aspects of design with the visual and human aspects, enabling them to develop products which appeal to customers as well as operating efficiently. Their concern for the commercial potential of an invention or new design, including the manufacturing constraints, is a safeguard against proceeding with ideas that have no hope of reaching the market. However, it is relatively rare to find such a combination of technical, visual and commercial skills in one individual and so in most cases more of a team effort is required to innovate.

Commercial innovation

Before reaching the market all three innovative products met with strong resistance from established UK manufacturers or retailers - they said the Ballbarrow would not sell; felt the Cylone was too risky or radical; and expressed no interest in the Strida. Dyson had initially to set up a business to make the Ballbarrow himself and for the Cyclone was forced to find overseas manufacturers willing to license the invention. Sanders was fortunate to be approached by a British entrepreneur willing to invest in his bicycle. However, when that business failed he decided to assign the patents to the British Technology Group with manufacture in the Far East the most likely outcome.

To date probably the most commercially successful of the innovations is the Ballbarrow, which has been in production in various versions for many years. The other innovations have both been more successful in overseas markets than in the UK, especially in Japan where consumers appear more willing to adopt novel products.

Comparison with other innovations

How typical are these cases of innovative products created by individual inventor/designers? The author has studied several similar cases [8], including the small-wheel bicycles designed by Alex Moulton [9] and the Workmate® workbench invented by Ron Hickman [10].

In these other examples too it is possible to observe:

- a ‘primary generator’ for the basic concept underlying the innovation (Moulton’s belief in the advantages of small wheels for bicycles; Hickman’s idea of making the work surfaces of a workbench function as a vice);
- the development of the design through physical models and prototypes;
- high levels of creativity in designing key components (e.g the suspension system of the Moulton bicycle, the vice mechanism of the Workmate);
- the initial resistance of existing manufacturers to the innovative product;

• commercialisation first achieved by means of the inventor/designer setting up a business to make the product.

5 CONCLUSIONS

Although it would be unwise to draw firm general conclusions based on these relatively few cases (mainly of mechanical innovations created by individual inventor/designers), a general pattern may nevertheless be observed.

Innovative products typically arise from personal need or direct experience of the individual inventor/designer, often as a result of using existing products and finding them unsatisfactory. A desire to improve upon existing artefacts is an aspect of the 'constructive discontent' displayed by creative individuals. Such individuals tend not to employ market research to identify customer needs in advance of the product development process, typically due to the view that a demand for radical new products cannot be properly assessed by conventional market research.

Inventors and designers tend to adopt a 'solution-focussed' strategy [11] with an initial idea or 'primary generator' created early on which guides the product development process. This primary generator is often derived from the accumulated technical or design 'repertoire' of the individual, comprising knowledge of particular production processes or materials, admired or favourite products, and so on. This repertoire of knowledge and experience is far more useful than the numerous formal techniques that have been developed to foster creativity.

Individual inventors and designers typically employ a mix of 2D sketching and 3D physical modelling to conceive and then develop their inventions and designs. The mix will depend partly on the nature of the problem to be solved and partly upon the preferred working method of the individual. Whereas some individuals may rely heavily on what Eugene Ferguson [7] has called 'thinking sketches' to clarify and develop the visual ideas held in the mind's eye, others rely much more on observing and working with physical models. Mathematical analysis and CAD systems tend to be employed to mainly to check and refine ideas and decisions. Indeed, there is a general tendency among such creative individuals to move quickly from ideas, calculations, sketches and drawings to physical models and prototypes. The eminent engineering designer, Alex Moulton, has commented;

> 'Ideas and calculations must be translated into drawings and sketches [...] drawings must be made into hardware as soon as possible, so that reality can be tested and analysed. This is the most important part of the development cycle.' [12]

Translating an innovative idea into a product ready for manufacture, is a difficult process involving long periods of dedicated work, the solution of many sub-problems in component design, and often several setbacks. Creativity is required throughout product development, not just at the early concept stage. Although specialist knowledge may not be required to conceive the basic idea behind an innovation, domain-specific knowledge and technical and design expertise are almost always required to go beyond the idea to develop a workable product. Moulton has observed;

> 'What differentiates the designer, who successfully innovates, from the crackpot inventor is the depth of study. Certainly I have made [...] dozens of "inventions" leading to patents; but they all arise from a revelation emanating from observing and studying in a particular field; never from a random idea occurring in a random field.' [13]

Attempts by an individual inventor/designer to interest established UK manufacturers in producing a highly innovative product seem likely to be unsuccessful; probably due to the 'not invented here' sydrome, the unwillingness of such manufacturers to take risks, or other organisational factors. Successful innovators therefore require the entrepreneurial skills to find alternative sources of support and investment - often from overseas - and/or to establish a business to manufacture the product themselves. Established UK manufacturers may subsequently wish to adopt the innovation, but usually only after it has proved to be a commercial success in the market. These cases therefore seem to lend weight to the argument that creative British inventors and designers are more likely to have their ideas commercialised by overseas manufacturers. Attitudes to innovation and risk need to change if UK (and European) industry is to benefit from the undoubted creative talent of British inventors and designers.

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FIGURE CAPTIONS

Figure 1 James Dyson with the Ballbarrow. (Photo: Mike Levers, Open University)

Figure 2 Details of the bearing to the ball-shaped wheel from the Ballbarrow patent. (Source: British Patent No 151011, 1975)

Figure 3 How the Cyclone vacuum cleaner works. A clean fan sucks in air through the head - or through the hose nozzle - (small arrows). Dirty air (black) enters the first stage cyclone at the top of the cylinder and swirls downward at increasing speed throwing dirt to the side, from where it falls to the bottom. Stripped of large dirt particles and most dust, less dirty air (grey) enters the second stage cyclone where fine dust is thrown to the sides and also falls to the bottom. Clean air (white) is expelled through the fan. (Source: Illustration by David Penny in Design magazine No 416 August 1983 p50 and Engineering Design Education, Spring 1985 p47)

Figure 4 The Cyclone or 'G-force' vacuum cleaner (left) with concentric cyclones made in Japan by Alco International; Dyson's first prototype (centre) in which the cyclones were placed side-by-side and some of the several thousand models (right) used to develop the best shape of cyclone. (Photo: Robin Roy)

Figure 5 Dyson Dual Cylone cleaner launched on the UK market in 1993. As with previous models the machine is brightly coloured and the user is able to see the dust and dirt particles swirling in the cylone chamber. (Photo: Dyson Appliances Ltd)

Figure 6 Page from Mark Sanders' first Bicycle Project Book showing the basic concept of a bike which folds into a stick with wheels at one end.
(Source: Mark Sanders. Photo: Robin Roy)

Figure 7 Page from one of Sanders' sketchbooks showing some initial design concepts. (Source: Mark Sanders, Photo: Robin Roy)

Figure 8 Wire frame models used to present and check the choice of X-shaped and triangular frame configurations.
(Source: Mark Sanders, Photo: Robin Roy)

Figure 9 Page from one of Sanders' sketchbooks showing an exploration of ideas based on a car seat belt mechanism for the bicycle bottom joint.
(Source: Mark Sanders, Photo Robin Roy)

Figure 10 Patent drawings of Sanders' folding bicycle. (Source: Patent GB 2171656, 1986)

Figure 11 Production version of the Strida folding bicycle. (Photo: Mike Levers, Open University)

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BIOGRAPHY

Dr Robin Roy

Robin Roy is a Senior Lecturer in Design in the Faculty of Technology at the Open University with a background in mechanical engineering, design and planning. Since joining the Open University in 1971 he has chaired and contributed to many distance teaching courses, including *Design: Principles and Practice*, *Design and Innovation* and *Managing Design*. In 1979 he founded the Design Innovation Group to act as a focus for research on the management of product design and technological innovation. He has held several major research grants and published many books and papers in this field. Apart from the research on creativity reported in this article, he has several other research interests including environmentally-friendly product design and the design evolution of bicycles and railways. He has been a visiting fellow at the Royal Melbourne Institute of Technology, the University of Technology, Sydney and Sydney University.