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LEARNING FROM PRACTICAL EXPERIENCE: A STUDY TO EXAMINE LEARNING STYLES WITHIN AN INTEGRATED METHODOLOGY FOR TEACHING ENGINEERING AND INDUSTRIAL DESIGN STUDENTS

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Abstract

The demand for combined Ba/BSc degrees in Product Design has continued to increase at UK universities at the expense of demand for traditional engineering degrees. Students enrolling for combined degrees can achieve university entrance through school courses that include major elements of art and hands-on learning or school courses that include more academic, mathematically-based learning. Both groups of students bring with them particular modes of cognising and learning styles appropriate to their individual school-based experiences. The problem for university teachers is to provide design-based learning experiences in the early stages of undergraduate programmes that can integrate, build upon and develop these different learning styles. The reported work presents the results of an investigation into the characteristic strategies used by the two different groups when presented with a practical problem in mechanical design. The results show how the different strategies are related to the traditional problem solving techniques characteristic of design engineers and the more product-focused techniques characteristic of industrial designers. An integrated teaching methodology has been presented to accommodate the different learning styles and recommendations have been given with regard to structuring learning experiences in the early stages of broad-based undergraduate programmes in design.

Keywords: experiential learning, mechanical design projects

1. Introduction

Increasing numbers of young people are pursuing career ambitions in design by enrolling on combined product design and engineering degree programmes at British universities [1]. The combined programmes offered at prominent universities continue to recruit high calibre school leavers, but applicants are recruited with different academic backgrounds. Some applicants are able to offer 'A' level subjects that qualify them for traditional engineering degree programmes [2], whilst other applicants gain entry by showing design aptitude in art-based subjects [3]. Research indicates that individuals within these two groups bring with them particular modes of cognising and learning styles [4] that are a direct consequence of their academic subject choices in the final years of school.

The different academic backgrounds cause problems for undergraduate course organisers in their endeavours to provide practice-based learning experiences that can accommodate and build upon the learning styles associated with the different backgrounds. Course organisers are required to provide a broad, practice-based education to enable students to integrate the skills of the industrial designer and the design engineer [5]. The requirement to provide an integrated programme raises pedagogic issues with regard to learning styles [6] and these issues must be addressed in order to devise suitable learning experiences in the early stages of degree programmes.

The primary concern in addressing these issues is to determine how the particular modes of cognising and learning styles influence the strategies employed by students with different academic backgrounds when attempting to solve design problems. The reported work uses a simple design exercise concerned with the design of a technically functional product to identify the strategies adopted by some first year students. The technique of reflective design analysis has been applied to the students' work [7] and the results used to examine the influence of the two types of academic background. In particular, the tendency towards polarisation into problem-focused and product-focused strategies within the two groups has been examined [8].

The research findings have been used to develop a structured design methodology that integrates the disparate strategies and identifies the teaching elements required to support the structure. The methodology is intended to overcome the perceived limitations of the school background in order to provide students with an intellectual and experiential base [9] for creativity in functional product design. Conclusions have been presented with regard to the influence of these learning styles on the inherent creativity of students with different academic backgrounds.

2. The design task

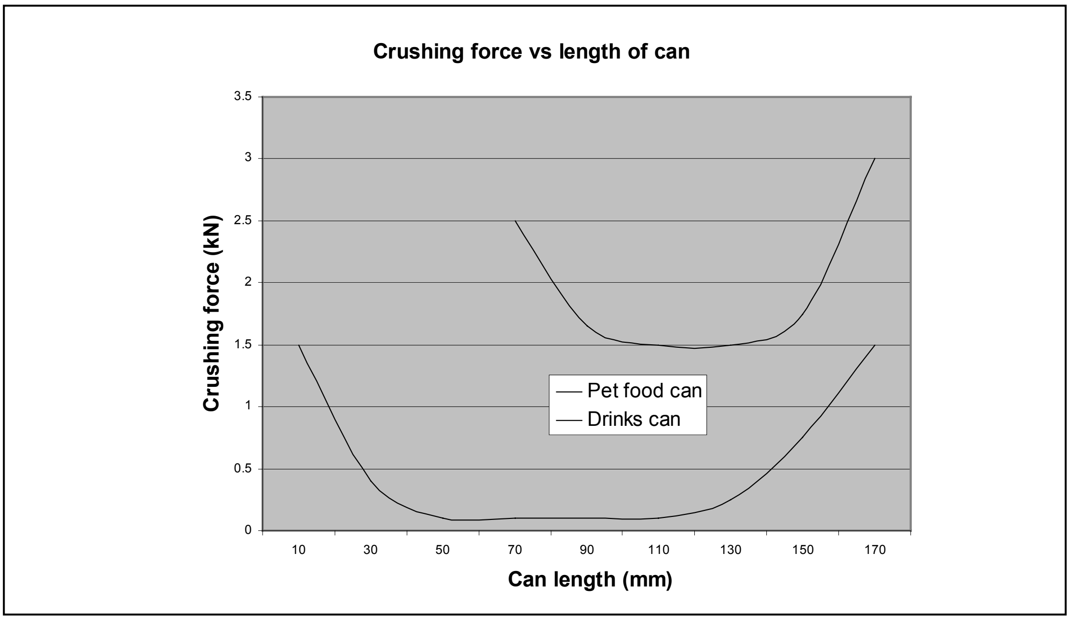

Figure 1. Task characteristic for axial crushing of steel cans

Students were set the task of designing a 'better' can crusher for use in the domestic household. The outline task characteristic shown in Figure 1 was presented to the students with some samples of cans crushed in the proprietary domestic can crusher shown in Figure 2. The task characteristic shows that a peak force of some 3kN is needed to start the crushing action for a steel pet food can and that a peak force is also needed at the end of the cycle for the final stages of compression. For steel drinks cans smaller peak forces are required, but the forces need to be applied over a longer stroke.

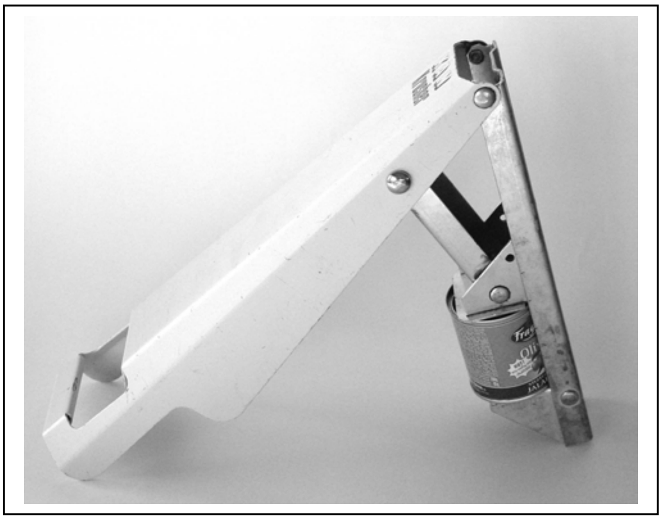

Figure 2. A proprietary can crusher

3. A student engineer's can crusher

The machine shown in Figure 3 was designed by a student with an 'A' level background in mathematics and physics who was enrolled on a course in mechanical engineering. An examination of the device and its performance characteristics provides an insight into the strategies adopted by the student in attempting to design a better can crusher. It is evident that the design is inspired by personal experience of using the popular design of car scissor-jack shown in Figure 4 - all elements of the student's device have been adapted from it.

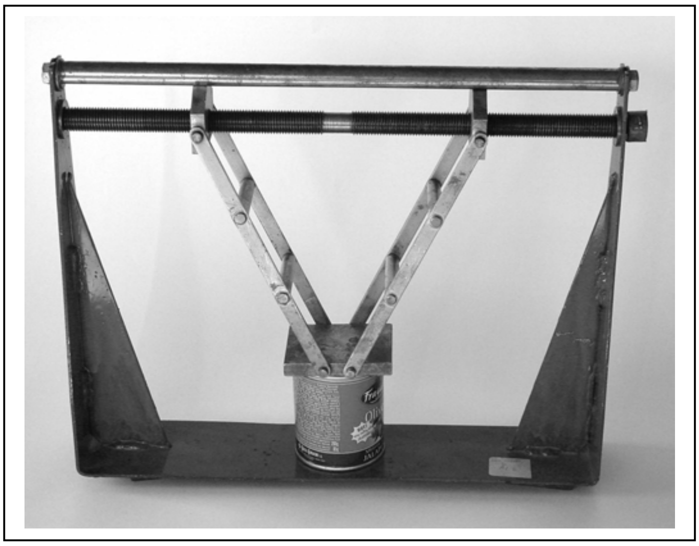

Figure 3. A student engineer's can crusher

A close examination of any scissor jack operating characteristic shows that such devices are ideally matched to their task requirement in lifting a car. The linkage provides an increasing mechanical advantage (MA) towards the top of its travel where it is most needed, but at the start of travel the linkage actually reduces the MA provided by the screw thread. The main benefit of the linkage at the lower end of its travel is to improve the rate of ascent of the jack. The MA provided by the screw thread is not improved by the linkage until the angle between the lower and upper arms of the linkage exceeds ninety degrees.

Figure 4. The proprietary scissor jack used as a source of ideas

In the student's device the mechanical components of the scissor jack have been re-configured to allow a can to be inserted and crushed, but the performance characteristic has not been altered by the re-configuration. The peak force is not delivered until the end of the cycle and the requirement for a high force magnification to provide crushing at the start of the cycle is not met. In addition, the device requires some sixty turns of the operating lever to crush a drinks can, which makes it slow and tedious to use. Screw thread theory suggests that the screw thread alone could generate sufficient force to complete the task.

4. A student engineer's strategies

Engineers typically use problem-focused strategies where solutions are expected to emerge through an expanded understanding of the problem - usually derived from quantification and pointed exploration of the problem parameters. With regard to the can crusher, an expanded understanding of the problem requires an investigation of the technical performance of existing can crushers and potentially useful mechanisms from other machines. The techniques for investigating technical performance in this case, include practical testing, scaled layout drawing and mathematical modelling all of which can provide a better understanding of the problem and a basis of practical experience for the generation of solutions [10].

The student has not conducted tests to expand his understanding of the problem, but has used a problem-focused approach to generate a solution. The student has started the task by translating the given brief into a problem statement that reads ‘design a machine to produce a 3kN force over a distance of 200mm’.

The student’s learning style has pointed him towards a definition of the problem as one that requires a single answer solution. This is an over simplification of the problem which in turn has ‘blinkered’ the thinking used to generate solutions. The learning style has been derived from the school mathematics background where single answer solutions are typical. The particular modes of cognising that constitute the student’s learning style have not been sufficiently extensive for him to form useful mental models of the task and the mechanism performance. The student has been constrained by his inability to compare and manipulate such models in his search for solutions.

5. A student industrial designer’s can crusher

The machine shown in Figure 4 was designed by a first year student of industrial design. The student’s ‘A’ level background consisted of art-based subjects without mathematics or physics. The machine uses a double lever system and a two stage crushing action. The first stage of the action initiates some sideways crushing of the can in order to weaken it and continued rotation of the handle initiates a second stage crushing action whereby the can is compacted along its length

6. A student industrial designer’s strategies

Industrial designers find it easier to generate and communicate ideas for solutions by reacting to and criticising existing product designs. Industrial designers typically use product-focused strategies where the problem is explored and understanding of it developed through an attempt to produce solutions that are demonstrably identifiable as products. The tendency to develop understanding through exploring design features of potential product solutions generates an inseparable relationship in the mind of the designer between the perceived problem and its solution.

Figure 5. A student designer’s can crusher

The student has used a typical product-focused approach, whereby the solution has emerged through the practical testing of existing devices. The understanding of the problem derived from testing has emphasised the advantage to be gained in weakening the can by sideways crushing before applying axial crushing forces. The student has not been constrained by the given problem definition, the problem has been perceived as designing something new to crush cans, rather than designing a device to produce 3kN. The design is successful in that it is ergonomically suitable for crushing drinks cans, but the input forces required to crush steel pet food cans could not be applied by a typical user.

The student's learning style has pointed him towards the requirement to produce a 'product' and typifies the learning styles developed in school-based design courses structured on narrow perceptions of industrial design [11]. The experience derived from such a course has precluded the student from applying mathematical principles as an aid to understanding in the given design situation. The learning style has lead the student to ignore the given task description which in turn has allowed him to be innovative in developing a solution. The particular modes of cognising used by the student have lead to a new product without the student being able to base his ideas on quantified mental models of task and mechanism.

7. Comparing the two designers

Both designers have produced solutions that could be used to crush cans, but in each case, the solutions are inappropriate and deficient in some respects. In the student engineer's case, the conceptual understanding derived from the mathematical background has constrained the student's perception of the problem. The device created represents the antithesis of true design. The student's strategies have been unable to overcome the blinkered effect on thinking that has resulted from his previous experience. Knowledge of existing solutions to the problem of generating a large force has been restrictive in the creative process. In the student designer's case, the lack of mathematical background has produced a design that could not generate adequate force magnification. However, this machine does show some degree of innovation and reflects the application of creative thought within the applied strategy.

8. A structured design strategy

The examples illustrate that previously acquired learning styles can limit the individual's ability to be innovative in design situations where technical performance is important. The learning styles used in both cases have directly influenced the strategies the novice designers have been able to apply. If novice designers are to overcome the perceived limitations of previously acquired learning styles, it is necessary to provide them with opportunities to develop more appropriate learning styles.

A suitably structured methodology for identifying such opportunities within an integrated approach to the design of products for technical performance is given in Figure 6. By treating the product design process as a logical progression from problem statement to problem solution, the individual elements of the process can be identified and the implications for teaching drawn out. Appropriate learning styles can be developed by students when they address the individual elements according to whether those elements are concerned with mathematically-based concepts or art-based concepts. By setting broad-based product design exercises within an appropriate and well-bounded context, purpose and relevance is given to the individual elements and students are better motivated to develop the necessary learning styles.

Figure 6 shows product innovation as a logical progression from design concept to product prototype consisting of four parallel strands of activity at five different levels. The

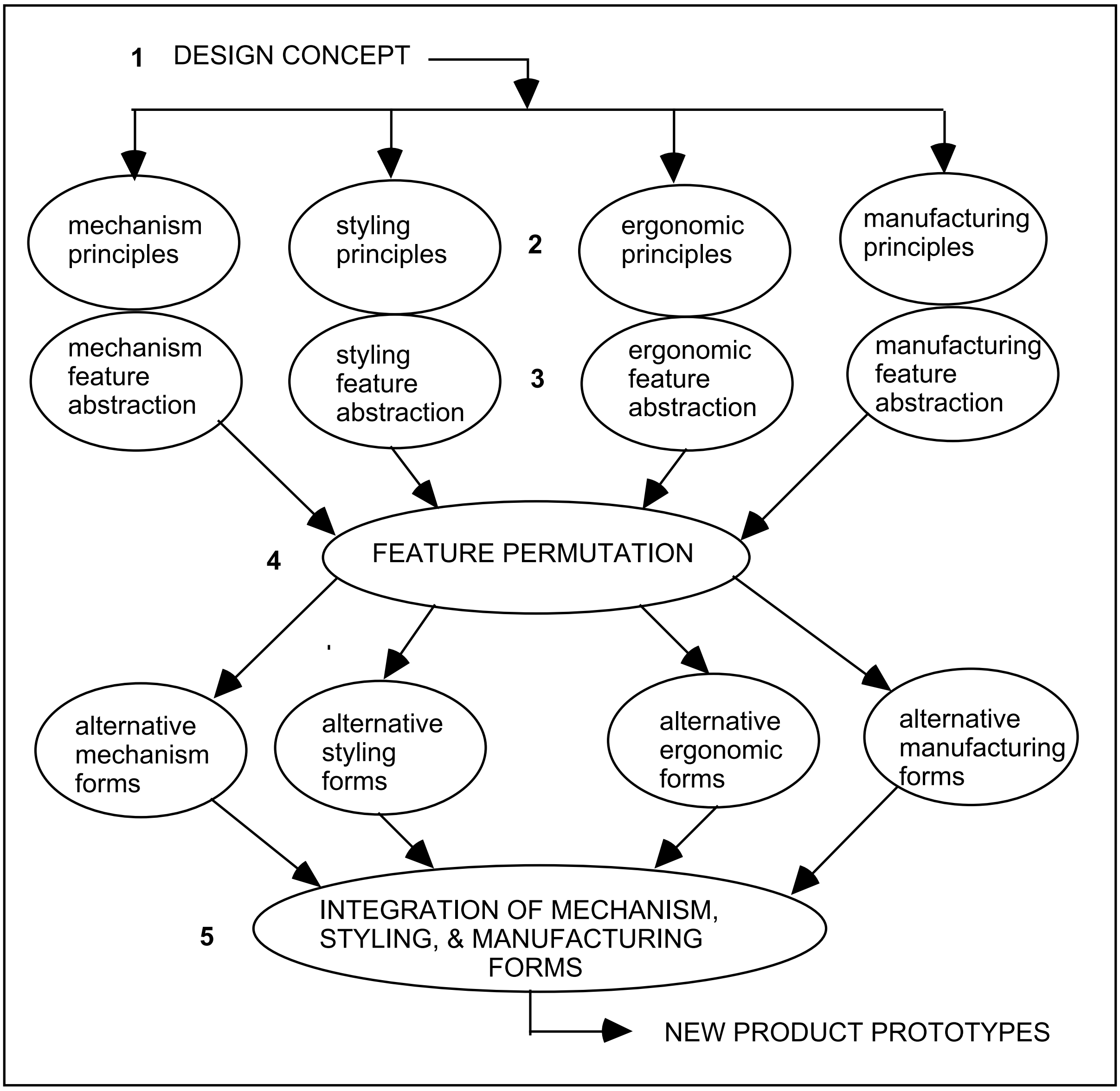

Figure 6. A structured design process

individual areas of design activity are shown as elements covering the necessary spectrum for generating solutions to problems concerned with the design of mechanically functional consumer products. The structure shows how new product development 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.

The number of ideas that can be generated depends on the extent of the knowledge base in each of the four areas. The development of an extensive knowledge base depends in turn on the ability of the student to apply the learning styles characteristic of each area. At one extreme the student is required to apply analytical techniques concerned with understanding and developing mathematical and technical models and at the other extreme the student is required to apply drawing and modelling techniques concerned with developing product aesthetics. The structure also shows the areas where individual creativity [12] can be applied to generate feature permutations and their integration into alternative product forms.

In applying the structure to the problem of designing a better can crusher, it is evident that a better understanding of the problem can be derived through exploring and analysing existing devices. An analysis of the performance characteristics of the proprietary can crusher shown in Figure 2 indicates that the device has an ideal characteristic for crushing drinks cans – it produces a toggle action at the start and finish of the stroke where the maximum forces are most required. However, for the pet food can, which is much shorter than the drinks can, the mechanism produces its least mechanical advantage at the start of the crushing action. This deficiency can easily be remedied by modifying the design so that the fixed anvil can be re-positioned to accommodate different lengths of can. By this means, the optimum crushing force may be brought to bear at both the start and finish of the cycle.

The process of bringing together analytical models of task and technical performance has produced a solution to the problem of designing a better can crusher. Also, in analysing just one device, particular styles of learning and modes of cognising have been practised and can be applied in investigating the potential of other mechanisms. The device investigated uses the toggle principle at the start and finish of the cycle. Many other proprietary products achieve high force magnifications using the toggle principle in various configurations and with a little imagination some of these configurations may also provide ideas for solutions to the problem of designing a better can crusher.

Similarly, product analysis techniques [13] applied in the remaining design perspectives can provide practice in applying the cognitive and practical modelling skills that need to be integrated into the process of designing better products. The styling and ergonomic features are important attributes of products that play a significant part in consumer choice and these features are in turn influenced by manufacturing considerations. The methodology allows a focus to be made on learning objectives in any particular perspective and cultivates appropriate learning styles across the boundaries of different design perspectives.

9. Conclusions

The reported work has examined the learning styles of two groups of students and has used an example of the work of a student from each group to compare the influence of the school background on each student's ability to devise design strategies. The school backgrounds of a typical mechanical engineering student and a typical industrial design student were found to have a direct influence on the strategies employed by the students when confronted with a problem in technical product design. The strategies were found to be polarised towards problem-focused and product-focused methods in each case, although neither strategy produced successful outcomes.

A teaching methodology has been presented that enables novice designers to develop new, more appropriate learning styles. The methodology is structured on a logical series of elements that identify opportunities for teaching students how to develop the knowledge base in the constituent design areas. The methodology provides opportunities for integrating the different thinking skills associated with each area in order for students to develop a cognitive style that can accommodate the analysis of existing products and the synthesis of ideas for developing new ones.

With regard to the inherent creativity of the students, the examples shown and other examples from the two groups not shown in the current work, allow some comparisons to be made. The engineering student's solution was typical of the group, engineering students were limited to a single set of solution types derived from previous experience of mechanical devices. These students tended to rely on an habitual mental set in trying to apply old solutions to new problems. The strategies used are the antithesis of creativity.

The design student has demonstrated a greater concern for creating something new and an inclination to exercise creativity in the context of mechanical design, but in this case, the quantification of the problem has been ignored in the process of generating a solution. Other examples from the design students group not shown in the current work suggest that the tendency to ignore the quantified aspects of the problem was typical. Design students were limited to a set of solution types that consisted of visually interesting, but mechanically inappropriate solutions.

The need to improve already successful products provides a severe test of creative thinking and in this respect, the structural elements of the methodology identify those areas where creative thinking is needed in each of the different design perspectives. The restricted thinking evident in both student groups is the opposite of what is required. Creativity needs to be applied in context and in the context of mechanical design, requires an appropriate intellectual and experiential base. The methodology shows that the nature of the intellectual and experiential base can be identified and teaching of the disparate elements within it made relevant. The methodology has been situated in a mechanical product context, but can be adapted for use where the objective is to provide students with experience of designing consumer products for functionality.

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