Teaching Design by Practice

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The Engineering Design Centre concentrates on teaching Design by way of realistic practice with copious tutorial guidance. At undergraduate level this must be achieved using artificial problems set up for educational purposes only, but at postgraduate level nothing less than wholly commercial design projects are considered acceptable. All the activities of the Centre were briefly reviewed in an earlier issue of *Studies in Design Education & Craft* (Vol. 6 No. 2). This article examines the one-year postgraduate course in more detail, with special reference to the project system.

The Engineering Design Activity

Design is carried out over a range of products from ornaments to power stations, but the complexity of design work bears no resemblance. In the former the designer is concerned mainly with the 'appearance' aspects of a single item. Basically, one material is used and one production process; the timescale is short and little expenditure is involved. By comparison, in the latter case, there are teams of designers concerned with many items of equipment which must satisfy economic, technical and social factors. The management of large resources of money, men and materials are involved over a long period of time. This article is concerned with training at professional level in this latter area of Design.

Undergraduate courses are largely orientated towards an 'engineering science' approach, being analytical in nature. Much of the work covers theoretical approaches to idealised systems. Valuable as this work is, it does not cover many activities which occupy a practising design engineer. There are possibly as many models for the engineering design process as there are designers! This is because, as in any human activity, it is exceedingly complex and personal and depends upon the type of design being carried out. Fig. 1 is intended only to highlight some of the main features of the design activity.

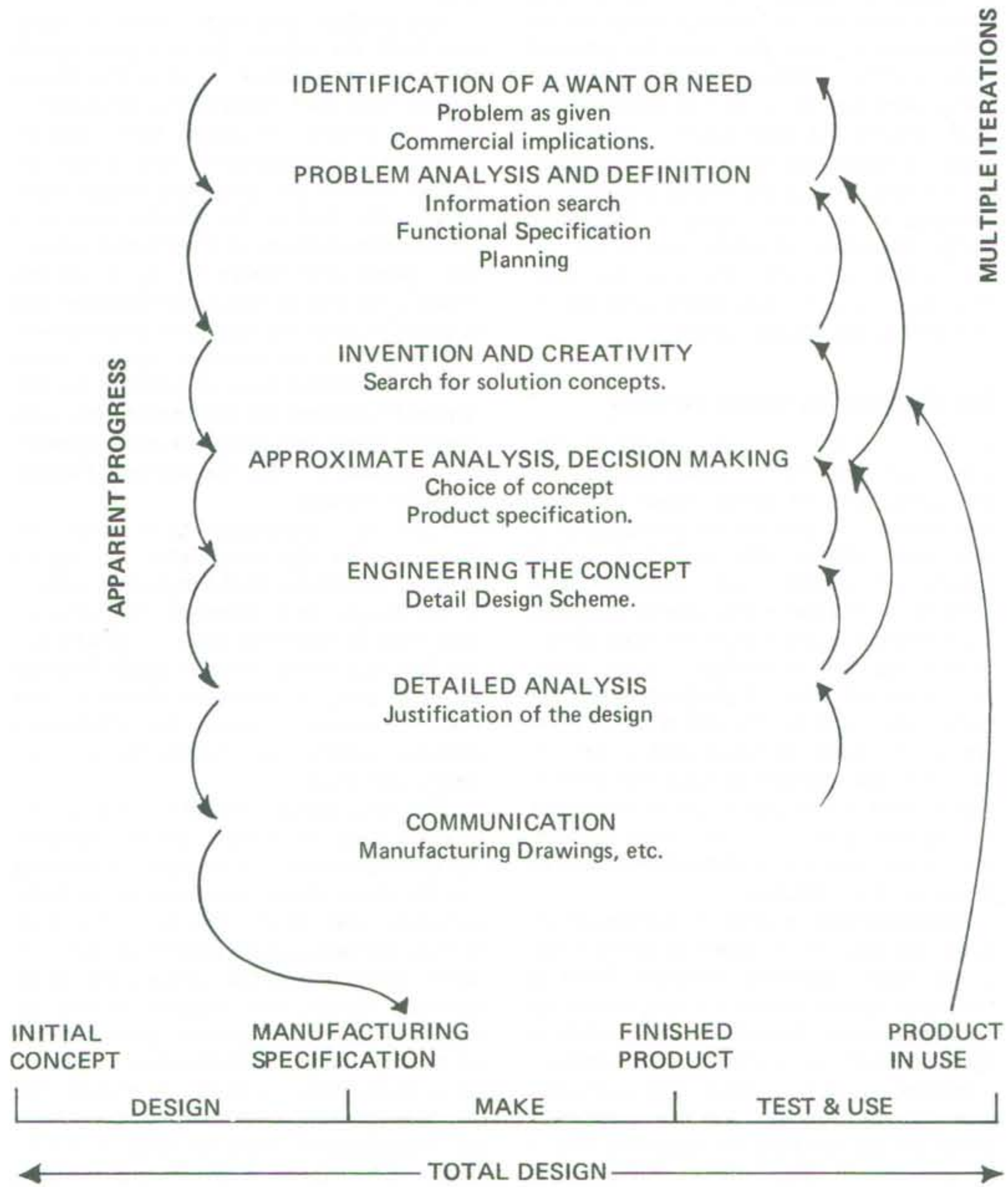
Any product starts with a 'need' or 'want' and must, for success, be at a price which the intended customer can pay. The design process must start, therefore by determining the real problem in overall terms and by formulating a specification stating the objectives which the proposed design must satisfy. This part of the activity involves a considerable amount of information gathering, sifting and evaluating. It is usually towards the end of this phase that planning in terms of time and resources is carried out.

There must be creative periods when various alternative ways of carrying out the required functions are considered. Decisions must be taken on the ways in which a design is to proceed in order that the specification is finally satisfied.

Ideas in conceptual form must be developed to the stage where a 'design scheme', specifying all the important aspects of the design, can be prepared. This information must be communicated to manufacturing functions in the form of detail drawings of each part, material specifications and manufacturing instructions. The information provided enables manufacture followed by testing and service.

This may appear straightforward, but in practice is not so. Firstly, the process does not go step by step. For example, in carrying out the detail design, some unforeseen problem may arise which requires re-consideration of the best concept to develop. Further, some activities will take place many times during a design. For example, it will be necessary to think creatively, both in terms of overall concept and in the detailed aspects of a design. What is more, all through the process, the many objectives incorporated in the specification must be kept in mind. These will include such factors as cost, performance, size, weight, maintenance, safety, ergonomics, aesthetics, engineering science and so on.

FIG. 1 A DESIGN PROCESS



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Implementation at Postgraduate Level

Students arrive at the Centre with varied experience of this complex activity. Some with minimal industrial experience straight from an undergraduate course, others already Chartered Engineers with considerable experience, and some with a College or Polytechnic teaching background. The course, leading to the degree of Master of Technology in Design, treats three broad areas: Firstly, a planned approach to Design tasks, introducing methods for creativity and decision making which complement and develop the individual's essential flair for Design. Secondly, management techniques, including the financial and cost awareness essential to practice at professional level. Lastly, an introduction to modern production methods and a few lectures on engineering science subjects which have not been covered by undergraduate courses in the past; for instance, Control Theory, Materials Science and Corrosion. (In the main reliance is placed on the student's previous studies in engineering science). These areas are discussed in a concentrated series of lectures, tutorials and minor projects, mainly in the first term from October to Christmas. More details of the syllabus can be seen in the earlier article. The main projects are then introduced and form the major part of the students' work until the end of the course in mid-September. There are only four weeks of holiday during the year.

A philosophy of 'Total Design' is promoted. Stated briefly, this means that a professional designer is responsible (to a greater or lesser degree, depending on his project and industry) for all aspects of a job from examining the need and commercial viability, to the time when products are selling in the market.

Finding Suitable Projects

The staff of the Centre are all experienced professional engineers recruited from industry, and it is part of their duties to maintain and expand their contacts. They also practice as consultants, accepting design briefs and other work, either singly or in co-operation with other members of the University staff. Thus, a network of contacts is maintained from which projects are sought in the latter part of each year. Recently, the publicity, arising from the exhibition and sales of products designed in the Centre, has been assisting in the search for projects.

Suitable projects are, nevertheless, difficult to find. It is normal to have perhaps five from which to choose two or three each December. It is essential that a project is needed by the sponsoring company, not some time in the next decade but within the next year. Only in this way can the necessary urgency be assured to meet the tight timescale involved in designing, manufacturing and testing in eight to nine months. Small to medium sized sponsor companies are preferred for this reason.

An ideal project would be demanding in all aspects of the Total Design approach. This is not always possible, most of industry being concerned with the detailed development of established concepts. However, such concepts are always challenged and only pursued when the project team have demonstrated their continued applicability. Projects tend to fall into two categories, either products for sale by the sponsor, such as a dumper truck or a printing machine, or production machines for use in the sponsor's own workshops.

By Christmas of each year suitable projects have been chosen and agreements concluded with the sponsors.

Progress of a Typical Project

The students work in groups of three or four in well equipped syndicate rooms. All the normal drawing office equipment and supplies are available, including materials for

artwork. The Centre has two powerful programmable desk computers with a graph plotter attachment, and the main University computer can be used. Each syndicate operates largely as an extension of the sponsor company's own design function. Travelling and out of pocket expenses are paid.

Each project is tutored by a member of staff, and the tutor's duties can vary depending on the abilities and personalities of the group. He may need to act as an out and out project leader or, on the other hand, he may need only to adopt an advisory and tutorial role.

The Initial Phase

The staff make some evaluation of the projects before and after accepting them, using their experience and judgement to assess difficulties and likely strategies. However, the real work can only start when the syndicate is formed and an initial briefing session is held. After two or three days in which to absorb the initial briefing and to learn something of the industry concerned, the syndicate visits the sponsor company. Here the briefing is completed, the students meet the company personnel with whom they will be working, and they see the production facilities. In the case of the valve project illustrated in the earlier article, the prototype valve was manufactured by a sub-contractor and assembled and tested in the sponsor's works. In such cases these arrangements are discussed in outline right at the start.

Taking the valve project as an example, the students entered into an information gathering stage lasting about four weeks. They needed information about the sponsors, their background, facilities and experience in making valves, their costing system and overhead structure. Information about the valve industry, materials used, standards of performance, leak tightness and life commonly achieved. Firms which would be competing in the production of high pressure and temperature valve gear, their facilities and pricing structure. Information about the proposed use of the valves in a pressurised water reactor system, the range of sizes needed and duty cycles, safety standards and codes of practice, maintenance requirements and operating personnel. This stage ended in early February, 1972 with the production of a specification for a range of valves of various nominal bore sizes, one size of which would be detail designed, made and tested during the project. Also a programme was produced showing how this design make and test exercise could be achieved by September of that year. The specification and programme were then discussed with the sponsor, modified and agreed so that everyone understood the extent and timescale of this not inconsiderable commitment.

Some Points Arising

Several important points began to clarify as more information was collected. Firstly, on examining the cost patterns of the industry it became clear that the sponsors were in an unfavourable competitive position, due mainly to the profit taken by their subcontractors producing basic valve components. Thus, a new design would have to be very economical of production costs.

Secondly, an extensive analysis of the final design would be needed with justification against the ASME III code for nuclear vessels, if the new valve was to be accepted by customers. One member of the team undertook to prepare himself for this irksome task and in the end he carried it through to produce a separate and extensive report.

Thirdly, thermal cycling tests would be needed after initial prototype testing. A rig for this purpose is complicated and expensive, so the syndicate began searching for and negotiating the use of a suitable rig. Seven major organisations were contacted

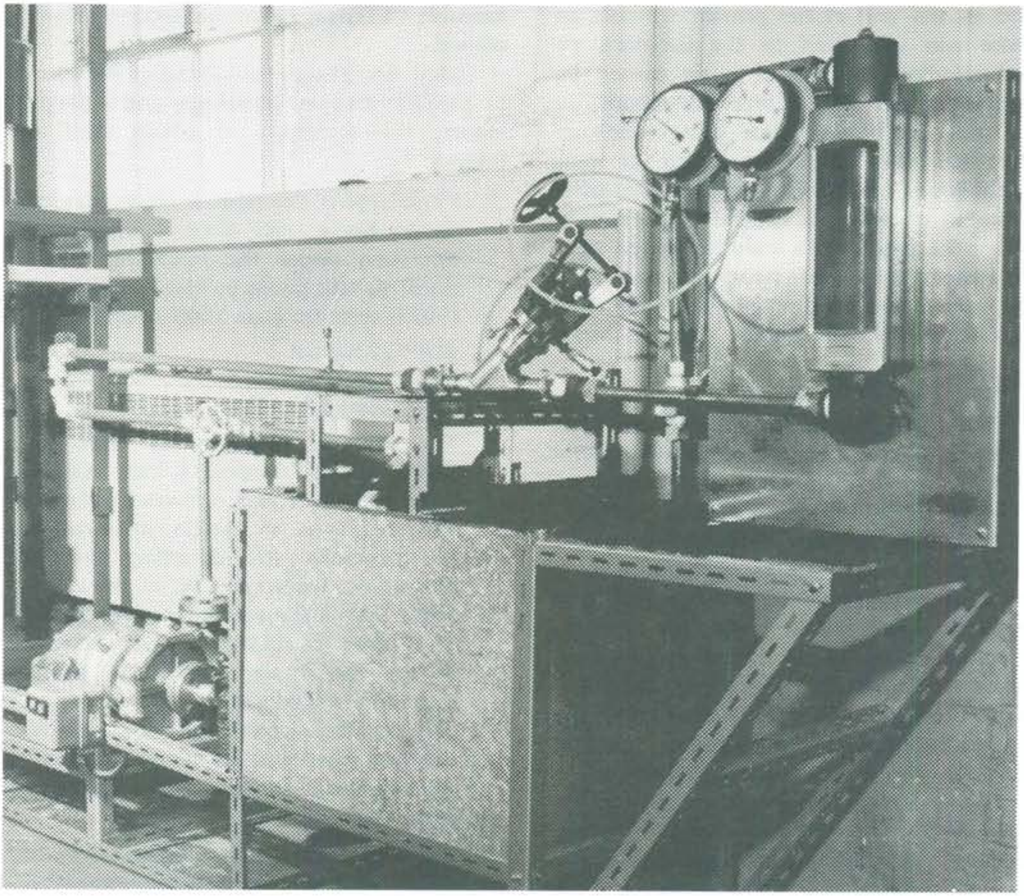

FIG. 2

One of the test rigs in the sponsor's works.

and at the end of the project a report on these was submitted to the sponsors, recommending the use of a rig owned by Foster Wheeler Ltd., at West Hartlepool.

Lastly, it became clear that varients of the basic valve would be needed for some applications, and that the sponsor must offer these to obtain bulk orders for the valves. Thus, the programme included design work on systems for remote powered actuation of the valves, and on the bellows sealing alternatives to the basic spindle gland packings.

The Main Design

Returning now to the main stream of the project, the students were faced with several well known valve concepts, the most common of which is embodied in an ordinary domestic tap. However, they returned to the basic problem of "stopping the flow of a liquid along a pipe" and searched for other concepts. They found several; for instance, freezing a slug of the liquid in the pipe. These were evaluated along with the more conventional ideas. Not surprisingly, the globe valve principle was judged the best and a decision made to proceed on that basis.

Conventional handwheel operation of globe valves requires very large operating torques at the high system pressures specified. This results in operator fatigue and the common resort to hammers or crowbars to assist in closing the valves. Thus, some method of giving the operator more mechanical advantage over the spindle movement was required. Here, conceptual thinking paid off and several methods were proposed. Three combinations of basic valve and actuation system were developed by different members of the syndicate to the outline scheme stage for discussion with the sponsors.

The best features of these three schemes were then combined into what was to become the final scheme, embodying a novel cranked lever method of actuation. Details of this method were prepared to enable the sponsors to obtain patent protection if they wished.

Detail design was completed in the form of a design scheme, (drawings) and a design report, the summary of which read as follows:

> "This report describes a recommended design for a high duty, 1 inch valve operating under the following conditions, as laid down by the A.S.M.E. III (1971) code for class 1500 valves:
>
> 400^oC 2355 psi
> 343^oC 2500 psi
> 38^oC 3600 psi
>
> The valve is intended for water or steam, and although a 1 inch valve is being presented here, a range of valves is also proposed. A design justification gives reasons for adopting specific techniques, materials, etc. in the valve, and a technical justification gives results of detailed calculations. Later sections of the report are devoted to topics including procedures for operation and maintenance, procedures for testing, powered operation and costs. A list of references and information sources completes the report."

This was discussed with the sponsors in late April, 1974 and agreement obtained to proceed with manufacture.

Manufacture and Testing

The detailed manufacturing drawings were prepared by the syndicate; each student's work being checked by a colleague. This is normal practice within the Centre unless a project involves an excessive amount of draughting work, when help can be made available. Final arrangements were made with the chosen sub-contractor and one student assumed responsibility for liaison during manufacture, to ensure that all parts arrived on time in the sponsor's valve assembly shop.

One student assumed primary responsibi-

lity for testing from the outset of the project and two test rigs were designed in parallel with the other activities. These were assembled in the sponsor's works. Assembly instructions were written and also a test procedure so that testing could start as soon as the prototype valve was completed. This was carried out during August and early September when the students spent two or three weeks in the sponsor's works. See Fig. 2.

Finally, at the end of the course in mid-September, all the material generated during the project was presented to the sponsors for their continuing development and utilisation.

Assessment

Student performance is assessed every three months during the course and by an extensive oral examination during the final week. The first assessment includes course work marks from the lecture sessions. Later, assessments are based almost wholly on the project work, when each student is considered against a set of twenty-five criteria covering his performance as a designer, as a manager, and as an engineering scientist. During the oral examination each student meets each of four examiners, two from within the University and two external. A detailed and overall view of each student is thus available for consideration at the final examination panel meeting.

Final Comment

The project based course with continuous assessment, offers scope for students with a wide range of experience and ability on entry. Some, very able at mathematics and engineering science, are not suited to design work. If such a person slips through the acceptance procedure he is detected, probably at the first assessment and definitely by the second, so that he can be advised to seek a more appropriate postgraduate course. The student with little or no design experience can be overawed, quite naturally, by the complexity of project work on the scale described. However, there are plenty of sub-problems for him to tackle under tutorial guidance and by the end of the course he can have developed a good grasp of the overall project. An average man develops his understanding of the design process and its management, whilst for the first class student, there is plenty of scope for practising design and project management, and for studying these activities.

Acknowledgement

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